

# Pybricks

## Pybricks Modules and Examples

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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.

Click on any device below to see its documentation. Use the menu on the left to find documentation for additional modules. You may need to click the icon above to reveal this menu.

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Note: You are viewing the stand-alone version of the documentation. To learn more about Pybricks and to start coding, visit the [Pybricks website](#)

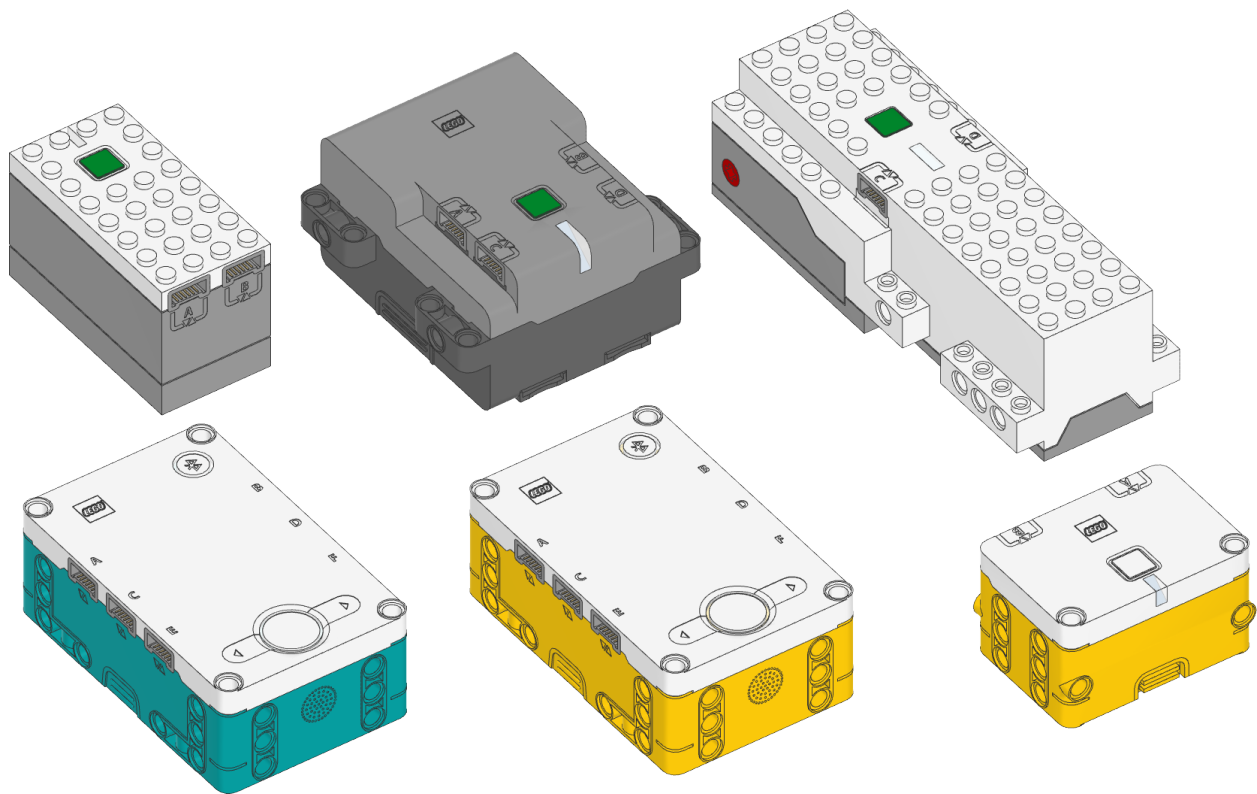
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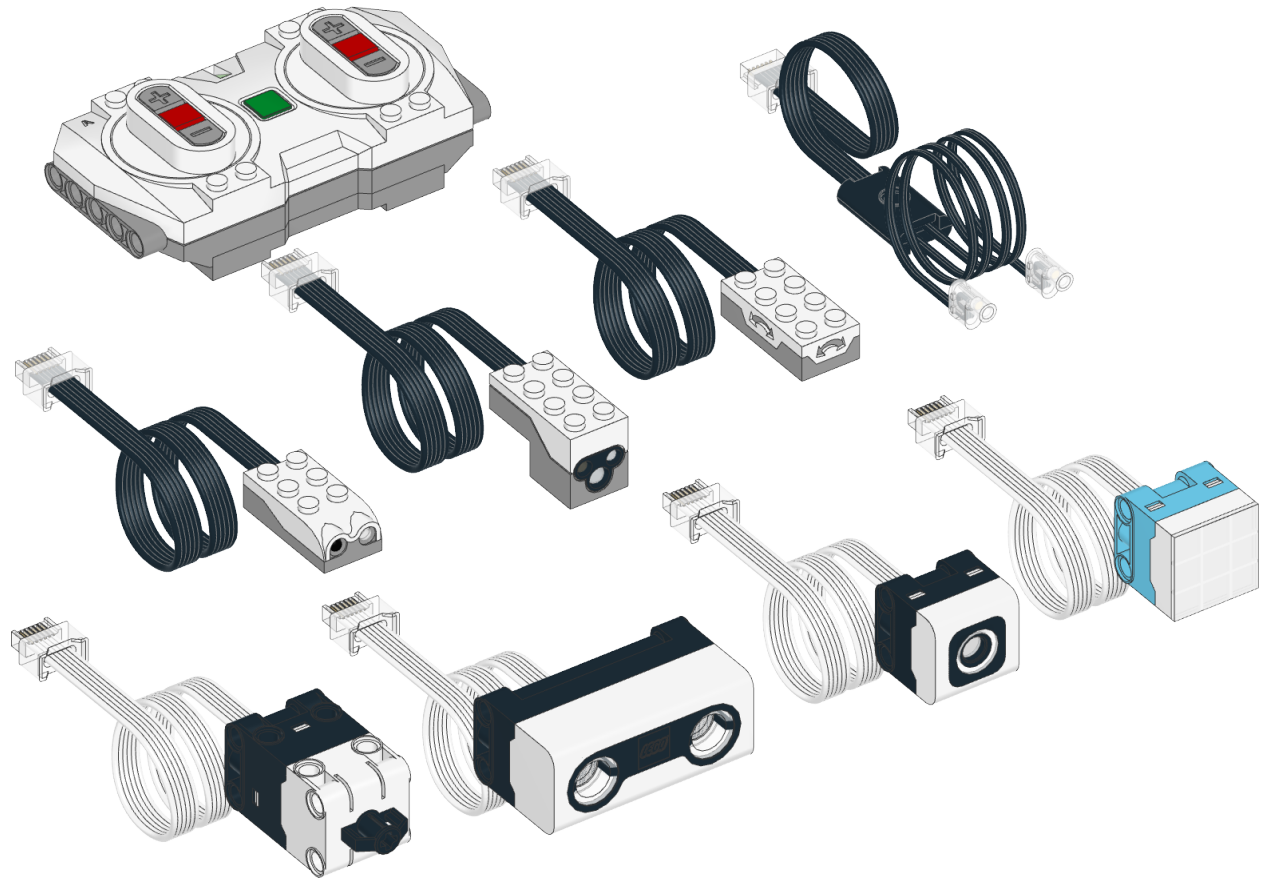
Note: Are you using LEGO MINDSTORMS EV3? Check out the [EV3 documentation](#) instead.

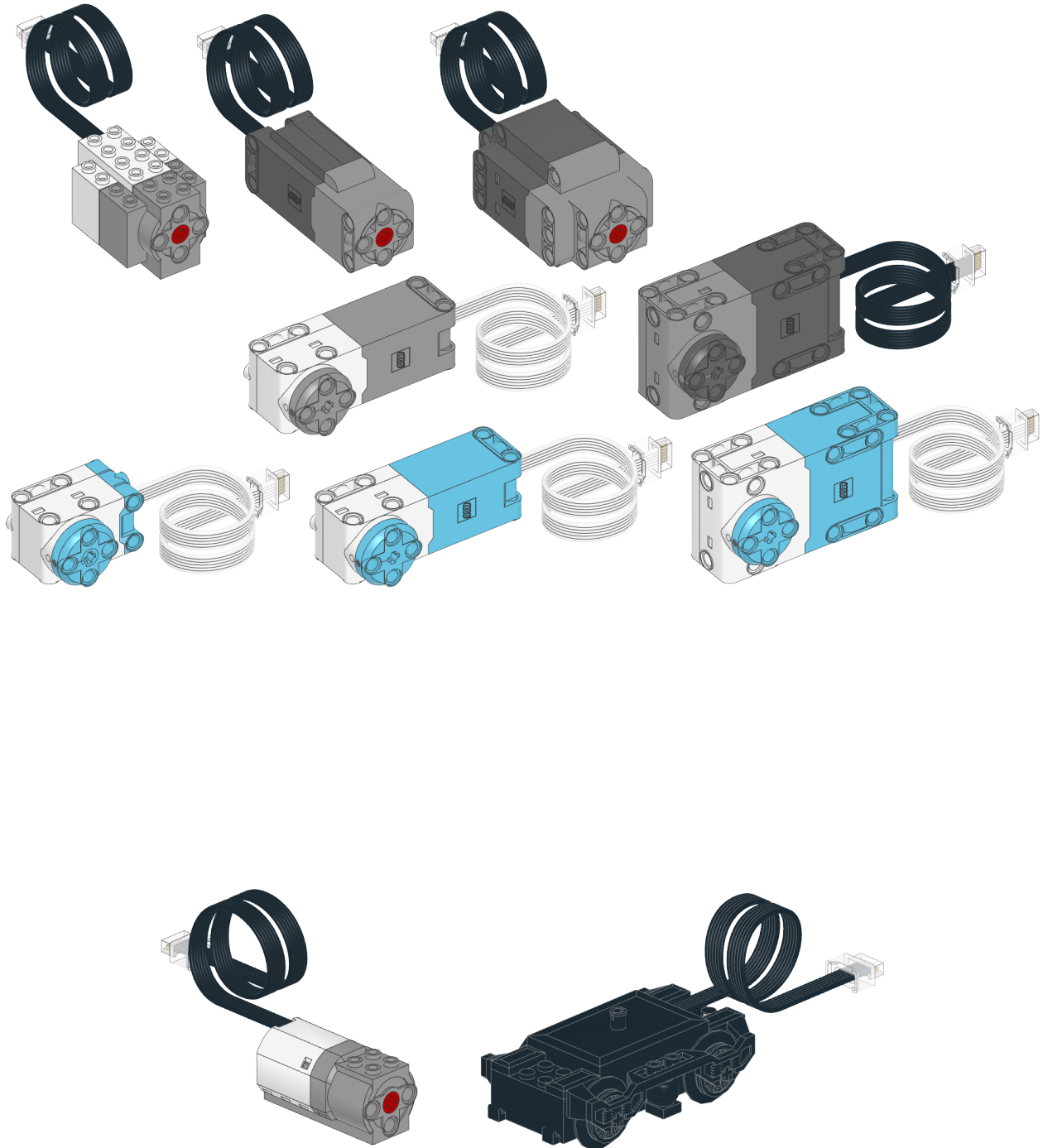
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### Programmable hubs



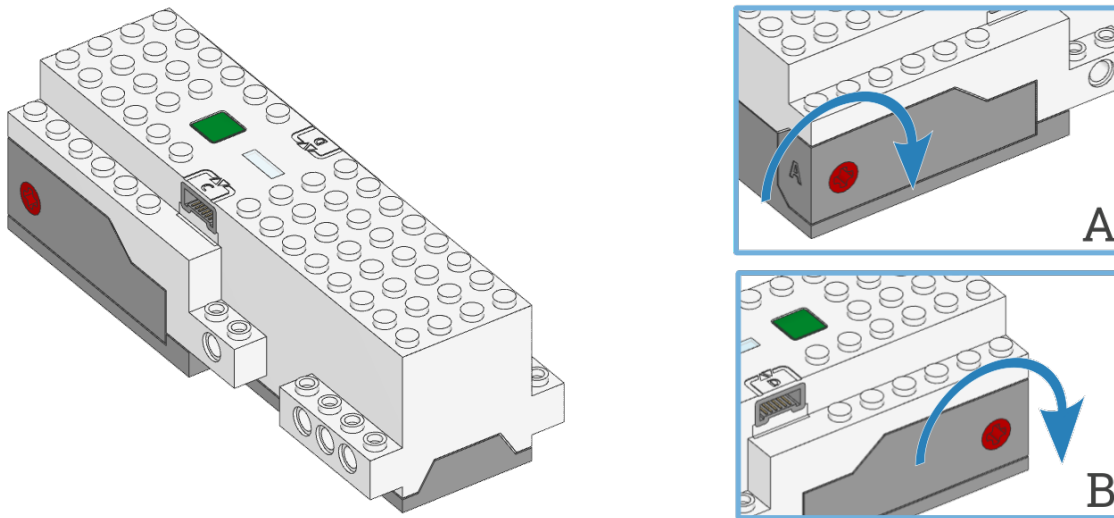
## Powered Up motors and sensors





## HUBS – BUILT-IN HUB FUNCTIONS

### 1.1 Move Hub



```
class MoveHub(top_side=Axis.Z, front_side=Axis.X, broadcast_channel=0, observe_channels=[])
```

LEGO® BOOST Move Hub.

#### 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.
- **broadcast\_channel** – A value from 0 to 255 indicating which channel `hub.ble.broadcast()` will use. Default is channel 0.
- **observe\_channels** – A list of channels to listen to when `hub.ble.observe()` is called. Listening to more channels requires more memory. Default is an empty list (no channels).

Changed in version 3.3: Added `broadcast_channel` and `observe_channels` arguments.

## 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)` – Sequence of time values of the form `[on_1, off_1, on_2, off_2, ...]`.

`light.animate(colors, interval)`

Animates the light with a sequence of colors, shown one by one for 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)` – Sequence of `Color` values.
- `interval (Number, ms)` – Time between color updates.

## Using the IMU

`imu.up()` → `Side`

Checks which side of the hub currently faces upward.

Returns

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

`imu.tilt()` → `Tuple[int, int]`

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**

Tuple of pitch and roll angles in degrees.

`imu.acceleration()` → `Tuple[int, int, int]: mm/s2`

Gets the acceleration of the device.

**Returns**

Acceleration along all three axes.

Changed in version 3.2: Changed acceleration units from  $\text{m/s}^2$  to  $\text{mm/s}^2$ .

## Using connectionless Bluetooth messaging

`PrimeHub.ble.broadcast(data)`

Starts broadcasting the given data on the `broadcast_channel` you selected when initializing the hub.

Data may be of type `int`, `float`, `str`, `bytes`, `True`, or `False`, or a list thereof.

Choose `None` to stop broadcasting. This helps improve performance when you don't need the broadcast feature, especially when observing at the same time.

The total data size is quite limited (26 bytes). `True` and `False` take 1 byte each. `float` takes 5 bytes. `int` takes 2 to 5 bytes depending on how big the number is. `str` and `bytes` take the number of bytes in the object plus one extra byte.

When multitasking, only one task can broadcast at a time. To broadcast information from multiple tasks (or block stacks), you could use a dedicated separate task that broadcast new values when one or more variables change.

**Parameters**

`data` – The value or values to be broadcast.

New in version 3.3.

`PrimeHub.ble.observe(channel)` → `bool | int | float | str | bytes | tuple | None`

Retrieves the last observed data for a given channel.

Receiving data is more reliable when the hub is not connected to a computer or other devices at the same time.

**Parameters**

`channel` (`int`) – The channel to observe (0 to 255).

**Returns**

The received data in the same format as it was sent, or `None` if no recent data is available.

New in version 3.3.

`ble.signal_strength(channel)` → `int: dBm`

Gets the average signal strength in dBm for the given channel.

This indicates how near the broadcasting device is. Nearby devices may have a signal strength around -40 dBm, while far away devices might have a signal strength around -70 dBm.

**Parameters**

`channel` (`int`) – The channel number (0 to 255).



**Returns**

The signal strength or -128 if there is no recent observed data.

New in version 3.3.

`ble.version()` → `str`

Gets the firmware version from the Bluetooth chip.

New in version 3.3.

## Using the battery

`battery.voltage()` → `int: mV`

Gets the voltage of the battery.

**Returns**

Battery voltage.

`battery.current()` → `int: mA`

Gets the current supplied by the battery.

**Returns**

Battery current.

## Button and system control

`buttons.pressed()` → `Set[Button]`

Checks which buttons are currently pressed.

**Returns**

Set of pressed buttons.

`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 (Button)` – A button such as `Button.CENTER`, or a tuple of multiple buttons. Choose `None` to disable the stop button altogether. If you do, you can still turn the hub off by holding the center button for three seconds.

`system.name()` → `str`

Gets the hub name. This is the name you see when connecting via Bluetooth.

**Returns**

The hub name.

`system.storage(offset, write=)`

`system.storage(offset, read=) → bytes`

Reads or writes binary data to persistent storage.

This lets you store data that can be used the next time you run the program.

The data will be saved to flash memory when you turn the hub off normally. It will not be saved if the batteries are removed while the hub is still running.

Once saved, the data will remain available even after you remove the batteries.

Parameters

- `offset (int)` – The offset from the start of the user storage memory, in bytes.
- `read (int)` – The number of bytes to read. Omit this argument when writing.
- `write (bytes)` – The bytes to write. Omit this argument when reading.

Returns

The bytes read if reading, otherwise None.

Raises

`ValueError` – If you try to read or write data outside of the allowed range.

You can store up to 128 bytes of data on this hub. The data is cleared when you update the Pybricks firmware or if you restore the original firmware.

`system.shutdown()`

Stops your program and shuts the hub down.

`system.reset_reason() → int`

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

Returns

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

### 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)
```

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```
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)

# 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()
```

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```
# 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())

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 Bluetooth examples

### Broadcasting data to other hubs

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

# Initialize the hub.
hub = MoveHub(broadcast_channel=1)

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Read the motor angles to be sent to the other hub.
    left_angle = left_motor.angle()
    right_angle = right_motor.angle()

    # Set the broadcast data and start broadcasting if not already doing so.
```

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```
data = (left_angle, right_angle)
hub.ble.broadcast(data)

# Broadcasts are only sent every 100 milliseconds, so there is no reason
# to call the broadcast() method more often than that.
wait(100)
```

## Observing data from other hubs

```
from pybricks.hubs import MoveHub
from pybricks.pupdevices import Motor
from pybricks.parameters import Color, Port
from pybricks.tools import wait

# Initialize the hub.
hub = MoveHub(observe_channels=[1])

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Receive broadcast from the other hub.

    data = hub.ble.observe(1)

    if data is None:
        # No data has been received in the last 1 second.
        hub.light.on(Color.RED)
    else:
        # Data was received and is less than one second old.
        hub.light.on(Color.GREEN)

        # *data* contains the same values in the same order
        # that were passed to hub.ble.broadcast() on the
        # other hub.
        left_angle, right_angle = data

        # Make the motors on this hub mirror the position of the
        # motors on the other hub.
        left_motor.track_target(left_angle)
        right_motor.track_target(right_angle)

    # Broadcasts are only sent every 100 milliseconds, so there is
    # no reason to call the observe() method more often than that.
    wait(100)
```

### 1.1.4 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.buttons.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!")
wait(100)

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

## Making random numbers

The Move Hub does not include the `urandom` module. If you need random numbers in your application, you can try a variation of the following example.

To make it work better, change the initial value of `_rand` to something that is truly random in your application. You could use the IMU acceleration or a sensor value, for example.

```
from pybricks.hubs import MoveHub

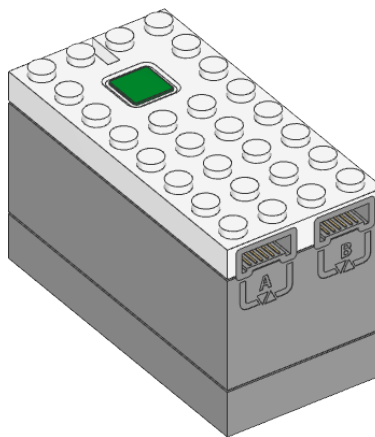
# Initialize the hub.
hub = MoveHub()

# Initialize "random" seed.
_rand = hub.battery.voltage() + hub.battery.current()

# 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

# Generate a few example numbers.
for i in range(5):
    print(randint(0, 1000))
```

## 1.2 City Hub



```
class CityHub(broadcast_channel=0, observe_channels=[])
```

LEGO® City Hub.

Parameters

- `broadcast_channel` – A value from 0 to 255 indicating which channel `hub.ble.broadcast()` will use. Default is channel 0.
- `observe_channels` – A list of channels to listen to when `hub.ble.observe()` is called. Listening to more channels requires more memory. Default is an empty list (no channels).

Changed in version 3.3: Added `broadcast_channel` and `observe_channels` arguments.

### 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`) – Sequence of time values of the form `[on_1, off_1, on_2, off_2, ...]`.

#### `light.animate(colors, interval)`

Animates the light with a sequence of colors, shown one by one for 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`) – Sequence of `Color` values.
- `interval` (`Number`, `ms`) – Time between color updates.

### Using connectionless Bluetooth messaging

#### `ble.broadcast(data)`

Starts broadcasting the given data on the `broadcast_channel` you selected when initializing the hub.

Data may be of type `int`, `float`, `str`, `bytes`, `True`, or `False`, or a list thereof.

Choose `None` to stop broadcasting. This helps improve performance when you don't need the broadcast feature, especially when observing at the same time.



The total data size is quite limited (26 bytes). `True` and `False` take 1 byte each. `float` takes 5 bytes. `int` takes 2 to 5 bytes depending on how big the number is. `str` and `bytes` take the number of bytes in the object plus one extra byte.

When multitasking, only one task can broadcast at a time. To broadcast information from multiple tasks (or block stacks), you could use a dedicated separate task that broadcast new values when one or more variables change.

#### Parameters

`data` – The value or values to be broadcast.

New in version 3.3.

`ble.observe(channel) → bool | int | float | str | bytes | tuple | None`

Retrieves the last observed data for a given channel.

Receiving data is more reliable when the hub is not connected to a computer or other devices at the same time.

#### Parameters

`channel (int)` – The channel to observe (0 to 255).

#### Returns

The received data in the same format as it was sent, or `None` if no recent data is available.

New in version 3.3.

`ble.signal_strength(channel) → int: dBm`

Gets the average signal strength in dBm for the given channel.

This indicates how near the broadcasting device is. Nearby devices may have a signal strength around -40 dBm, while far away devices might have a signal strength around -70 dBm.

#### Parameters

`channel (int)` – The channel number (0 to 255).

#### Returns

The signal strength or -128 if there is no recent observed data.

New in version 3.3.

`ble.version() → str`

Gets the firmware version from the Bluetooth chip.

New in version 3.3.

## Using the battery

`battery.voltage() → int: mV`

Gets the voltage of the battery.

#### Returns

Battery voltage.

`battery.current()` → int: mA

Gets the current supplied by the battery.

Returns

Battery current.

## Button and system control

`buttons.pressed()` → Set[Button]

Checks which buttons are currently pressed.

Returns

Set of pressed buttons.

`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` (Button) – A button such as `Button.CENTER`, or a tuple of multiple buttons. Choose `None` to disable the stop button altogether. If you do, you can still turn the hub off by holding the center button for three seconds.

`system.name()` → str

Gets the hub name. This is the name you see when connecting via Bluetooth.

Returns

The hub name.

`system.storage(offset, write=)`

`system.storage(offset, read=)` → bytes

Reads or writes binary data to persistent storage.

This lets you store data that can be used the next time you run the program.

The data will be saved to flash memory when you turn the hub off normally. It will not be saved if the batteries are removed while the hub is still running.

Once saved, the data will remain available even after you remove the batteries.

Parameters

- `offset` (int) – The offset from the start of the user storage memory, in bytes.
- `read` (int) – The number of bytes to read. Omit this argument when writing.
- `write` (bytes) – The bytes to write. Omit this argument when reading.

Returns

The bytes read if reading, otherwise `None`.

Raises

`ValueError` – If you try to read or write data outside of the allowed range.

You can store up to 128 bytes of data on this hub. The data is cleared when you update the Pybricks firmware or if you restore the original firmware.

`system.shutdown()`

Stops your program and shuts the hub down.

`system.reset_reason()` → `int`

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

Returns

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

### 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)
```

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```
# 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)
```

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```
# 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 Bluetooth examples

### Broadcasting data to other hubs

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

# Initialize the hub.
hub = CityHub(broadcast_channel=1)

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Read the motor angles to be sent to the other hub.
    left_angle = left_motor.angle()
    right_angle = right_motor.angle()

    # Set the broadcast data and start broadcasting if not already doing so.
    data = (left_angle, right_angle)
    hub.ble.broadcast(data)

    # Broadcasts are only sent every 100 milliseconds, so there is no reason
    # to call the broadcast() method more often than that.
    wait(100)
```

### Observing data from other hubs

```
from pybricks.hubs import CityHub
from pybricks.pupdevices import Motor
from pybricks.parameters import Color, Port
from pybricks.tools import wait

# Initialize the hub.
hub = CityHub(observe_channels=[1])

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)
```

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```
while True:
    # Receive broadcast from the other hub.

    data = hub.ble.observe(1)

    if data is None:
        # No data has been received in the last 1 second.
        hub.light.on(Color.RED)
    else:
        # Data was received and is less than one second old.
        hub.light.on(Color.GREEN)

        # *data* contains the same values in the same order
        # that were passed to hub.ble.broadcast() on the
        # other hub.
        left_angle, right_angle = data

        # Make the motors on this hub mirror the position of the
        # motors on the other hub.
        left_motor.track_target(left_angle)
        right_motor.track_target(right_angle)

    # Broadcasts are only sent every 100 milliseconds, so there is
    # no reason to call the observe() method more often than that.
    wait(100)
```

## 1.2.3 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.buttons.pressed():
        hub.light.on(Color.GREEN)
    else:
        hub.light.on(Color.RED)
```

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```
# 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

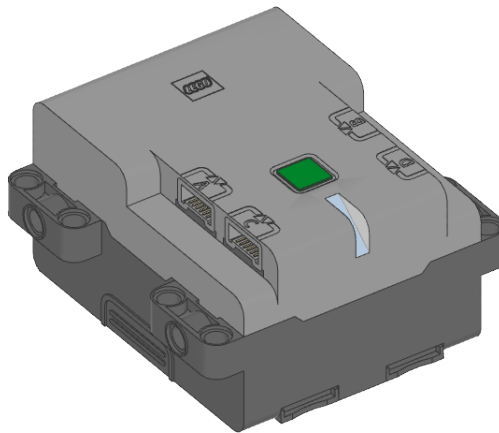
```
from pybricks.hubs import CityHub
from pybricks.tools import wait

# 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, broadcast_channel=0, observe_channels=[])
```

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.
- `broadcast_channel` – A value from 0 to 255 indicating which channel `hub.ble.broadcast()` will use. Default is channel 0.
- `observe_channels` – A list of channels to listen to when `hub.ble.observe()` is called. Listening to more channels requires more memory. Default is an empty list (no channels).

Changed in version 3.3: Added `broadcast_channel` and `observe_channels` arguments.

### 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`) – Sequence of time values of the form `[on_1, off_1, on_2, off_2, ...]`.

#### `light.animate(colors, interval)`

Animates the light with a sequence of colors, shown one by one for 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`) – Sequence of `Color` values.
- `interval` (`Number`, `ms`) – Time between color updates.



## Using the IMU

`imu.ready()` → `bool`

Checks if the device is calibrated and ready for use.

This becomes `True` when the robot has been sitting stationary for a few seconds, which allows the device to re-calibrate. It is `False` if the hub has just been started, or if it hasn't had a chance to calibrate for more than 10 minutes.

Returns

`True` if it is ready for use, `False` if not.

`imu.stationary()` → `bool`

Checks if the device is currently stationary (not moving).

Returns

`True` if stationary for at least a second, `False` if it is moving.

`imu.up()` → `Side`

Checks which side of the hub currently faces upward.

Returns

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

`imu.tilt()` → `Tuple[int, int]`

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

Tuple of pitch and roll angles in degrees.

`imu.acceleration(axis)` → float:  $\text{mm/s}^2$

`imu.acceleration()` → vector:  $\text{mm/s}^2$

Gets the acceleration of the device along a given axis in the [robot reference frame](#).

Parameters

`axis` ([Axis](#)) – Axis along which the acceleration should be measured.

Returns

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

`imu.angular_velocity(axis)` → float:  $\text{deg/s}$

`imu.angular_velocity()` → vector: deg/s

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 should be measured.

Returns

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

`imu.heading()` → float: deg

Gets the heading angle of your robot. A positive value means a clockwise turn.

The heading is 0 when your program starts. The value continues to grow even as the robot turns more than 180 degrees. It does not wrap around to -180 like it does in some apps.

---

Note: For now, this method only keeps track of the heading while the robot is on a flat surface.

This means that the value is no longer correct if you lift it from the table. To solve this, you can call `reset_heading` to reset the heading to a known value after you put it back down. For example, you could align your robot with the side of the competition table and reset the heading 90 degrees as the new starting point.

---

Returns

Heading angle relative to starting orientation.

`imu.reset_heading(angle)`

Resets the accumulated heading angle of the robot.

Parameters

`angle` ([Number](#), deg) – Value to which the heading should be reset.

`imu.rotation(axis)` → float: deg

Gets the rotation of the device along a given axis in the [robot reference frame](#).

This value is useful if your robot only rotates along the requested axis. For general three-dimensional motion, use the `orientation()` method instead.

The value starts counting from 0 when you initialize this class.

Parameters

`axis` ([Axis](#)) – Axis along which the rotation should be measured.

Returns

The rotation angle.

`imu.orientation()` → [Matrix](#)

Gets the three-dimensional orientation of the robot in the [robot reference frame](#).

It returns a rotation matrix whose columns represent the X, Y, and Z axis of the robot.

---

Note: This method is not yet implemented.

---

**Returns**

The rotation matrix.

```
imu.settings(angular_velocity_threshold, acceleration_threshold)
```

```
imu.settings() → Tuple[float, float]
```

Configures the IMU settings. If no arguments are given, this returns the current values.

The `angular_velocity_threshold` and `acceleration_threshold` define when the hub is considered stationary. If all measurements stay below these thresholds for one second, the IMU will recalibrate itself.

In a noisy room with high ambient vibrations (such as a competition hall), it is recommended to increase the thresholds slightly to give your robot the chance to calibrate. To verify that your settings are working as expected, test that the `stationary()` method gives `False` if your robot is moving, and `True` if it is sitting still for at least a second.

**Parameters**

- `angular_velocity_threshold` (**Number**, deg/s) – The threshold for angular velocity. The default value is 1.5 deg/s.
- `acceleration_threshold` (**Number**, mm/s<sup>2</sup>) – The threshold for angular velocity. The default value is 250 mm/s<sup>2</sup>.

**Using connectionless Bluetooth messaging**

```
ble.broadcast(data)
```

Starts broadcasting the given data on the `broadcast_channel` you selected when initializing the hub.

Data may be of type `int`, `float`, `str`, `bytes`, `True`, or `False`, or a list thereof.

Choose `None` to stop broadcasting. This helps improve performance when you don't need the broadcast feature, especially when observing at the same time.

The total data size is quite limited (26 bytes). `True` and `False` take 1 byte each. `float` takes 5 bytes. `int` takes 2 to 5 bytes depending on how big the number is. `str` and `bytes` take the number of bytes in the object plus one extra byte.

When multitasking, only one task can broadcast at a time. To broadcast information from multiple tasks (or block stacks), you could use a dedicated separate task that broadcast new values when one or more variables change.

**Parameters**

`data` – The value or values to be broadcast.

New in version 3.3.

```
ble.observe(channel) → bool | int | float | str | bytes | tuple | None
```

Retrieves the last observed data for a given channel.

Receiving data is more reliable when the hub is not connected to a computer or other devices at the same time.

**Parameters**

`channel` (**int**) – The channel to observe (0 to 255).

**Returns**

The received data in the same format as it was sent, or `None` if no recent data is available.

New in version 3.3.

`ble.signal_strength(channel) → int: dBm`

Gets the average signal strength in dBm for the given channel.

This indicates how near the broadcasting device is. Nearby devices may have a signal strength around -40 dBm, while far away devices might have a signal strength around -70 dBm.

Parameters

`channel` (`int`) – The channel number (0 to 255).

Returns

The signal strength or -128 if there is no recent observed data.

New in version 3.3.

`ble.version() → str`

Gets the firmware version from the Bluetooth chip.

New in version 3.3.

## Using the battery

`battery.voltage() → int: mV`

Gets the voltage of the battery.

Returns

Battery voltage.

`battery.current() → int: mA`

Gets the current supplied by the battery.

Returns

Battery current.

## Button and system control

`buttons.pressed() → Set[Button]`

Checks which buttons are currently pressed.

Returns

Set of pressed buttons.

`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 (Button)` – A button such as `Button.CENTER`, or a tuple of multiple buttons. Choose `None` to disable the stop button altogether. If you do, you can still turn the hub off by holding the center button for three seconds.

`system.name()` → `str`

Gets the hub name. This is the name you see when connecting via Bluetooth.

#### Returns

The hub name.

`system.storage(offset, write=)`

`system.storage(offset, read=)` → `bytes`

Reads or writes binary data to persistent storage.

This lets you store data that can be used the next time you run the program.

The data will be saved to flash memory when you turn the hub off normally. It will not be saved if the batteries are removed while the hub is still running.

Once saved, the data will remain available even after you remove the batteries.

#### Parameters

- `offset (int)` – The offset from the start of the user storage memory, in bytes.
- `read (int)` – The number of bytes to read. Omit this argument when writing.
- `write (bytes)` – The bytes to write. Omit this argument when reading.

#### Returns

The bytes read if reading, otherwise `None`.

#### Raises

`ValueError` – If you try to read or write data outside of the allowed range.

You can store up to 128 bytes of data on this hub. The data is cleared when you update the Pybricks firmware or if you restore the original firmware.

`system.shutdown()`

Stops your program and shuts the hub down.

`system.reset_reason()` → `int`

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

#### Returns

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

### 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.parameters 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 in g's.
print(hub.imu.acceleration() / 9810)

# 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.parameters 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 Bluetooth examples

#### Broadcasting data to other hubs

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

# Initialize the hub.
hub = TechnicHub(broadcast_channel=1)

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Read the motor angles to be sent to the other hub.
    left_angle = left_motor.angle()
    right_angle = right_motor.angle()

    # Set the broadcast data and start broadcasting if not already doing so.
    data = (left_angle, right_angle)
    hub.ble.broadcast(data)

    # Broadcasts are only sent every 100 milliseconds, so there is no reason
    # to call the broadcast() method more often than that.
    wait(100)
```

#### Observing data from other hubs

```
from pybricks.hubs import TechnicHub
from pybricks.pupdevices import Motor
from pybricks.parameters import Color, Port
from pybricks.tools import wait

# Initialize the hub.
hub = TechnicHub(observe_channels=[1])
```

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```
# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Receive broadcast from the other hub.

    data = hub.ble.observe(1)

    if data is None:
        # No data has been received in the last 1 second.
        hub.light.on(Color.RED)
    else:
        # Data was received and is less than one second old.
        hub.light.on(Color.GREEN)

        # *data* contains the same values in the same order
        # that were passed to hub.ble.broadcast() on the
        # other hub.
        left_angle, right_angle = data

        # Make the motors on this hub mirror the position of the
        # motors on the other hub.
        left_motor.track_target(left_angle)
        right_motor.track_target(right_angle)

    # Broadcasts are only sent every 100 milliseconds, so there is
    # no reason to call the observe() method more often than that.
    wait(100)
```

### 1.3.4 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.buttons.pressed():
```

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```
        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

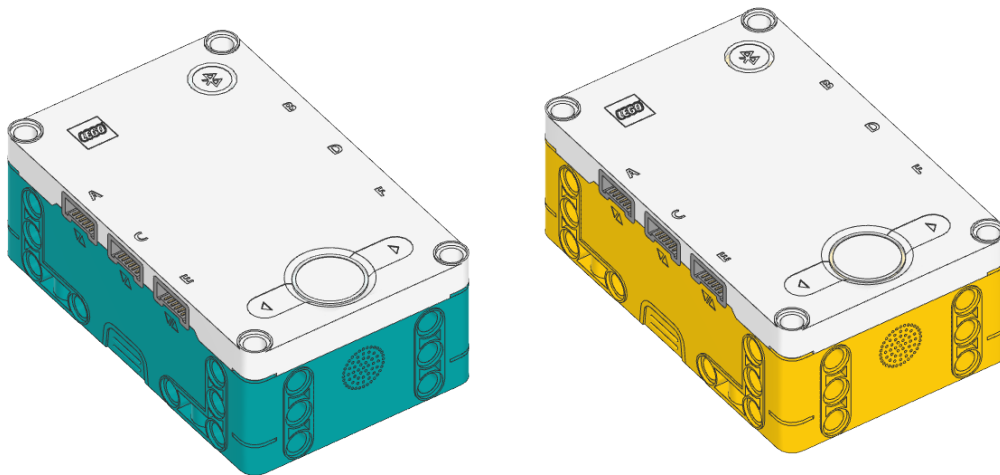
```
from pybricks.hubs import TechnicHub
from pybricks.tools import wait

# 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, broadcast_channel=0, observe_channels=[])
```

LEGO® SPIKE Prime Hub.

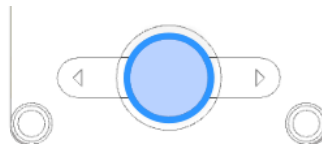
Initializes the hub. Optionally, specify how the hub is [placed in your design](#) by saying in which direction the top side (with the buttons) and front side (with the USB port) are pointing.

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.
- `broadcast_channel` – A value from 0 to 255 indicating which channel `hub.ble.broadcast()` will use. Default is channel 0.
- `observe_channels` – A list of channels to listen to when `hub.ble.observe()` is called. Listening to more channels requires more memory. Default is an empty list (no channels).

Changed in version 3.3: Added `broadcast_channel` and `observe_channels` arguments.

[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](#)) – Sequence of time values of the form `[on_1, off_1, on_2, off_2, ...]`.

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

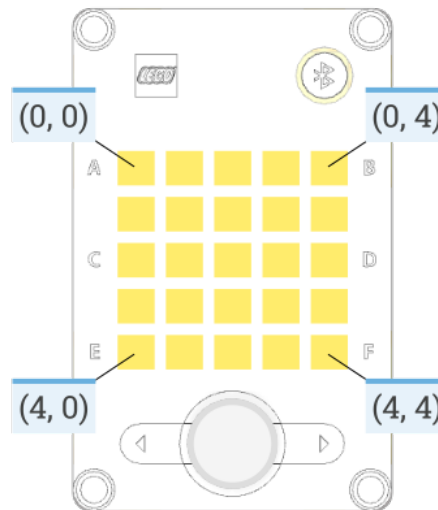
Animates the light with a sequence of colors, shown one by one for the given interval.

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

Parameters

- `colors` (`list`) – Sequence of `Color` values.
- `interval` (`Number`, `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` (`Number`) – Vertical grid index, starting at 0 from the top.
- `column` (`Number`) – Horizontal grid index, starting at 0 from the left.
- `brightness` (`Number` `brightness: %`) – Brightness of the pixel.

`display.icon(icon)`

Displays an icon, represented by a matrix of `brightness: %` values.

Parameters

`icon (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

- `matrices (iter)` – Sequence of `Matrix` of intensities.
- `interval (Number, 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 (Number, ms)` – For how long a character is shown.
- `off (Number, ms)` – For how long the display is off between characters.

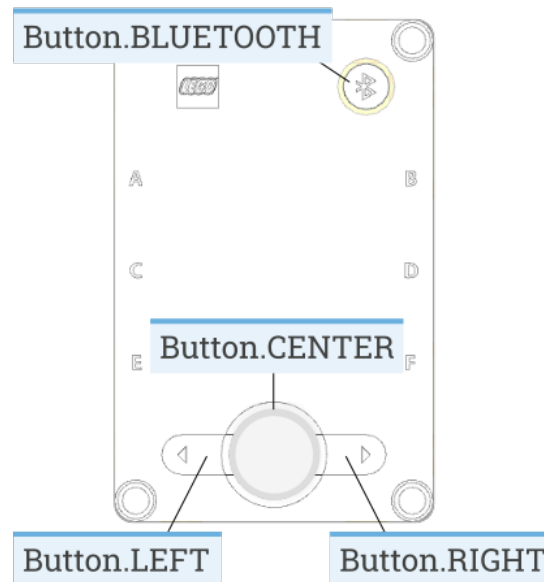
## Using the buttons

`buttons.pressed()` → Set[`Button`]

Checks which buttons are currently pressed.

Returns

Set of pressed buttons.



```
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` (`Button`) – A button such as `Button.CENTER`, or a tuple of multiple buttons. Choose `None` to disable the stop button altogether. If you do, you can still turn the hub off by holding the center button for three seconds.

## Using the IMU

```
imu.ready() → bool
```

Checks if the device is calibrated and ready for use.

This becomes `True` when the robot has been sitting stationary for a few seconds, which allows the device to re-calibrate. It is `False` if the hub has just been started, or if it hasn't had a chance to calibrate for more than 10 minutes.

Returns

`True` if it is ready for use, `False` if not.

```
imu.stationary() → bool
```

Checks if the device is currently stationary (not moving).

Returns

`True` if stationary for at least a second, `False` if it is moving.

```
imu.up() → Side
```

Checks which side of the hub currently faces upward.



**Returns**

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

`imu.tilt()` → Tuple[int, int]

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**

Tuple of pitch and roll angles in degrees.

`imu.acceleration(axis)` → float: mm/s<sup>2</sup>

`imu.acceleration()` → vector: mm/s<sup>2</sup>

Gets the acceleration of the device along a given axis in the [robot reference frame](#).

**Parameters**

**axis** ([Axis](#)) – Axis along which the acceleration should be measured.

**Returns**

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

`imu.angular_velocity(axis)` → float: deg/s

`imu.angular_velocity()` → vector: deg/s

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 should be measured.

**Returns**

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

`imu.heading()` → float: deg

Gets the heading angle of your robot. A positive value means a clockwise turn.

The heading is 0 when your program starts. The value continues to grow even as the robot turns more than 180 degrees. It does not wrap around to -180 like it does in some apps.

---

Note: For now, this method only keeps track of the heading while the robot is on a flat surface.

This means that the value is no longer correct if you lift it from the table. To solve this, you can call `reset_heading` to reset the heading to a known value after you put it back down. For example, you could align your robot with the side of the competition table and reset the heading 90 degrees as the new starting point.

---

**Returns**

Heading angle relative to starting orientation.

`imu.reset_heading(angle)`

Resets the accumulated heading angle of the robot.

Parameters

`angle` (**Number**, deg) – Value to which the heading should be reset.

`imu.rotation(axis) → float: deg`

Gets the rotation of the device along a given axis in the [robot reference frame](#).

This value is useful if your robot only rotates along the requested axis. For general three-dimensional motion, use the `orientation()` method instead.

The value starts counting from 0 when you initialize this class.

Parameters

`axis` (**Axis**) – Axis along which the rotation should be measured.

Returns

The rotation angle.

`imu.orientation() → Matrix`

Gets the three-dimensional orientation of the robot in the [robot reference frame](#).

It returns a rotation matrix whose columns represent the X, Y, and Z axis of the robot.

---

Note: This method is not yet implemented.

---

Returns

The rotation matrix.

`imu.settings(angular_velocity_threshold, acceleration_threshold)`

`imu.settings() → Tuple[float, float]`

Configures the IMU settings. If no arguments are given, this returns the current values.

The `angular_velocity_threshold` and `acceleration_threshold` define when the hub is considered stationary. If all measurements stay below these thresholds for one second, the IMU will recalibrate itself.

In a noisy room with high ambient vibrations (such as a competition hall), it is recommended to increase the thresholds slightly to give your robot the chance to calibrate. To verify that your settings are working as expected, test that the `stationary()` method gives `False` if your robot is moving, and `True` if it is sitting still for at least a second.

Parameters

- `angular_velocity_threshold` (**Number**, deg/s) – The threshold for angular velocity. The default value is 1.5 deg/s.
- `acceleration_threshold` (**Number**, mm/s<sup>2</sup>) – The threshold for angular velocity. The default value is 250 mm/s<sup>2</sup>.

## Using the speaker

`speaker.volume(volume)`

`speaker.volume()` → int: %

Gets or sets the speaker volume.

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

Parameters

`volume (Number, %)` – Volume of the speaker in the 0-100 range.

`await speaker.beep(frequency=500, duration=100)`

Play a beep/tone.

Parameters

- `frequency (Number, Hz)` – Frequency of the beep in the 64-24000 Hz range.
- `duration (Number, 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.

`await 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 connectionless Bluetooth messaging

`ble.broadcast(data)`

Starts broadcasting the given data on the `broadcast_channel` you selected when initializing the hub.

Data may be of type `int`, `float`, `str`, `bytes`, `True`, or `False`, or a list thereof.

Choose `None` to stop broadcasting. This helps improve performance when you don't need the broadcast feature, especially when observing at the same time.

The total data size is quite limited (26 bytes). `True` and `False` take 1 byte each. `float` takes 5 bytes. `int` takes 2 to 5 bytes depending on how big the number is. `str` and `bytes` take the number of bytes in the object plus one extra byte.

When multitasking, only one task can broadcast at a time. To broadcast information from multiple tasks (or block stacks), you could use a dedicated separate task that broadcast new values when one or more variables change.

#### Parameters

`data` – The value or values to be broadcast.

New in version 3.3.

`ble.observe(channel) → bool | int | float | str | bytes | tuple | None`

Retrieves the last observed data for a given channel.

Receiving data is more reliable when the hub is not connected to a computer or other devices at the same time.

#### Parameters

`channel (int)` – The channel to observe (0 to 255).

#### Returns

The received data in the same format as it was sent, or `None` if no recent data is available.

New in version 3.3.

`ble.signal_strength(channel) → int: dBm`

Gets the average signal strength in dBm for the given channel.

This indicates how near the broadcasting device is. Nearby devices may have a signal strength around -40 dBm, while far away devices might have a signal strength around -70 dBm.

#### Parameters

`channel (int)` – The channel number (0 to 255).

#### Returns

The signal strength or -128 if there is no recent observed data.

New in version 3.3.

`ble.version() → str`

Gets the firmware version from the Bluetooth chip.

New in version 3.3.

## Using the battery

`battery.voltage() → int: mV`

Gets the voltage of the battery.

#### Returns

Battery voltage.

`battery.current()` → int: mA

Gets the current supplied by the battery.

Returns

Battery current.

### Getting the charger status

`charger.connected()` → bool

Checks whether a charger is connected via USB.

Returns

True if a charger is connected, False if not.

`charger.current()` → int: mA

Gets the charging current.

Returns

Charging current.

`charger.status()` → int

Gets the status of the battery charger, represented by one of the following values. This corresponds to the battery light indicator right next to the USB port.

0. Not charging (light is off).
1. Charging (light is red).
2. Charging is complete (light is green).
3. There is a problem with the charger (light is yellow).

Returns

Status value.

### System control

`system.name()` → str

Gets the hub name. This is the name you see when connecting via Bluetooth.

Returns

The hub name.

`system.storage(offset, write=)`

`system.storage(offset, read=)` → bytes

Reads or writes binary data to persistent storage.

This lets you store data that can be used the next time you run the program.

The data will be saved to flash memory when you turn the hub off normally. It will not be saved if the batteries are removed while the hub is still running.

Once saved, the data will remain available even after you remove the batteries.

Parameters

- `offset` (int) – The offset from the start of the user storage memory, in bytes.
- `read` (int) – The number of bytes to read. Omit this argument when writing.

- `write(bytes)` – The bytes to write. Omit this argument when reading.

Returns

The bytes read if reading, otherwise `None`.

Raises

`ValueError` – If you try to read or write data outside of the allowed range.

You can store up to 512 bytes of data on this hub.

`system.shutdown()`

Stops your program and shuts the hub down.

`system.reset_reason()` → `int`

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

Returns

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

---

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.icon(Icon.UP)

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

# Display a heart at half brightness.
hub.display.icon(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.
    hub.display.orientation(up_side)

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

    wait(10)
```

## Making your own images

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

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```

        [100, 50, 0, 50, 100],
        [100, 50, 50, 50, 100],
        [100, 100, 100, 100, 100],
    ]
)

# Display the square.
hub.display.icon(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.icon(GRADIENT)
wait(3000)

```

### Combining icons 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)

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.icon(Icon.EYE_LEFT + Icon.EYE_RIGHT + brows)
        wait(2000)

```

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```
# Display eyes blinked plus the random brows.
hub.display.icon(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.icon(Icon.CIRCLE)

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

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

    # 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 in g's.
print(hub.imu.acceleration() / 9810)

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

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```
# 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.parameters 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 Bluetooth examples

### Broadcasting data to other hubs

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

# Initialize the hub.
hub = PrimeHub(broadcast_channel=1)

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Read the motor angles to be sent to the other hub.
    left_angle = left_motor.angle()
    right_angle = right_motor.angle()

    # Set the broadcast data and start broadcasting if not already doing so.
    data = (left_angle, right_angle)
```

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```
hub.ble.broadcast(data)

# Broadcasts are only sent every 100 milliseconds, so there is no reason
# to call the broadcast() method more often than that.
wait(100)
```

### Observing data from other hubs

```
from pybricks.hubs import PrimeHub
from pybricks.pupdevices import Motor
from pybricks.parameters import Color, Port
from pybricks.tools import wait

# Initialize the hub.
hub = PrimeHub(observe_channels=[1])

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Receive broadcast from the other hub.

    data = hub.ble.observe(1)

    if data is None:
        # No data has been received in the last 1 second.
        hub.light.on(Color.RED)
    else:
        # Data was received and is less than one second old.
        hub.light.on(Color.GREEN)

        # *data* contains the same values in the same order
        # that were passed to hub.ble.broadcast() on the
        # other hub.
        left_angle, right_angle = data

        # Make the motors on this hub mirror the position of the
        # motors on the other hub.
        left_motor.track_target(left_angle)
        right_motor.track_target(right_angle)

    # Broadcasts are only sent every 100 milliseconds, so there is
    # no reason to call the observe() method more often than that.
    wait(100)
```



## 1.4.6 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

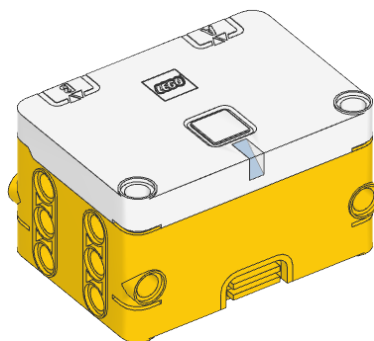
```
from pybricks.hubs import PrimeHub
from pybricks.tools import wait

# 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()
```

## 1.5 Essential Hub



```
class EssentialHub(top_side=Axis.Z, front_side=Axis.X, broadcast_channel=0, observe_channels=[])
```

LEGO® SPIKE Essential 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 the front side (with the USB port, and I/O ports A and B) 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.
- `broadcast_channel` – A value from 0 to 255 indicating which channel `hub.ble.broadcast()` will use. Default is channel 0.
- `observe_channels` – A list of channels to listen to when `hub.ble.observe()` is called. Listening to more channels requires more memory. Default is an empty list (no channels).

Changed in version 3.3: Added `broadcast_channel` and `observe_channels` arguments.

### 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](#)) – Sequence of time values of the form `[on_1, off_1, on_2, off_2, ...]`.

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

Animates the light with a sequence of colors, shown one by one for 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](#)) – Sequence of [Color](#) values.

- `interval (Number, ms)` – Time between color updates.

## Using the button

`buttons.pressed()` → `Set[Button]`

Checks which buttons are currently pressed.

Returns

Set of pressed buttons.

`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 (Button)` – A button such as `Button.CENTER`, or a tuple of multiple buttons. Choose `None` to disable the stop button altogether. If you do, you can still turn the hub off by holding the center button for three seconds.

## Using the IMU

`imu.ready()` → `bool`

Checks if the device is calibrated and ready for use.

This becomes `True` when the robot has been sitting stationary for a few seconds, which allows the device to re-calibrate. It is `False` if the hub has just been started, or if it hasn't had a chance to calibrate for more than 10 minutes.

Returns

`True` if it is ready for use, `False` if not.

`imu.stationary()` → `bool`

Checks if the device is currently stationary (not moving).

Returns

`True` if stationary for at least a second, `False` if it is moving.

`imu.up()` → `Side`

Checks which side of the hub currently faces upward.

Returns

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

`imu.tilt()` → Tuple[int, int]

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

Tuple of pitch and roll angles in degrees.

`imu.acceleration(axis)` → float: mm/s<sup>2</sup>

`imu.acceleration()` → vector: mm/s<sup>2</sup>

Gets the acceleration of the device along a given axis in the [robot reference frame](#).

Parameters

**axis** ([Axis](#)) – Axis along which the acceleration should be measured.

Returns

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

`imu.angular_velocity(axis)` → float: deg/s

`imu.angular_velocity()` → vector: deg/s

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 should be measured.

Returns

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

`imu.heading()` → float: deg

Gets the heading angle of your robot. A positive value means a clockwise turn.

The heading is 0 when your program starts. The value continues to grow even as the robot turns more than 180 degrees. It does not wrap around to -180 like it does in some apps.

---

Note: For now, this method only keeps track of the heading while the robot is on a flat surface.

This means that the value is no longer correct if you lift it from the table. To solve this, you can call `reset_heading` to reset the heading to a known value after you put it back down. For example, you could align your robot with the side of the competition table and reset the heading 90 degrees as the new starting point.

---

Returns

Heading angle relative to starting orientation.

`imu.reset_heading(angle)`

Resets the accumulated heading angle of the robot.

## Parameters

**angle** (**Number**, **deg**) – Value to which the heading should be reset.

`imu.rotation(axis) → float: deg`

Gets the rotation of the device along a given axis in the [robot reference frame](#).

This value is useful if your robot only rotates along the requested axis. For general three-dimensional motion, use the `orientation()` method instead.

The value starts counting from 0 when you initialize this class.

## Parameters

**axis** (**Axis**) – Axis along which the rotation should be measured.

## Returns

The rotation angle.

`imu.orientation() → Matrix`

Gets the three-dimensional orientation of the robot in the [robot reference frame](#).

It returns a rotation matrix whose columns represent the X, Y, and Z axis of the robot.

---

Note: This method is not yet implemented.

---

## Returns

The rotation matrix.

`imu.settings(angular_velocity_threshold, acceleration_threshold)`

`imu.settings() → Tuple[float, float]`

Configures the IMU settings. If no arguments are given, this returns the current values.

The `angular_velocity_threshold` and `acceleration_threshold` define when the hub is considered stationary. If all measurements stay below these thresholds for one second, the IMU will recalibrate itself.

In a noisy room with high ambient vibrations (such as a competition hall), it is recommended to increase the thresholds slightly to give your robot the chance to calibrate. To verify that your settings are working as expected, test that the `stationary()` method gives `False` if your robot is moving, and `True` if it is sitting still for at least a second.

## Parameters

- **angular\_velocity\_threshold** (**Number**, **deg/s**) – The threshold for angular velocity. The default value is 1.5 deg/s.
- **acceleration\_threshold** (**Number**, **mm/s<sup>2</sup>**) – The threshold for angular velocity. The default value is 250 mm/s<sup>2</sup>.

## Using connectionless Bluetooth messaging

### `ble.broadcast(data)`

Starts broadcasting the given data on the `broadcast_channel` you selected when initializing the hub.

Data may be of type `int`, `float`, `str`, `bytes`, `True`, or `False`, or a list thereof.

Choose `None` to stop broadcasting. This helps improve performance when you don't need the broadcast feature, especially when observing at the same time.

The total data size is quite limited (26 bytes). `True` and `False` take 1 byte each. `float` takes 5 bytes. `int` takes 2 to 5 bytes depending on how big the number is. `str` and `bytes` take the number of bytes in the object plus one extra byte.

When multitasking, only one task can broadcast at a time. To broadcast information from multiple tasks (or block stacks), you could use a dedicated separate task that broadcast new values when one or more variables change.

#### Parameters

`data` – The value or values to be broadcast.

New in version 3.3.

### `ble.observe(channel) → bool | int | float | str | bytes | tuple | None`

Retrieves the last observed data for a given channel.

Receiving data is more reliable when the hub is not connected to a computer or other devices at the same time.

#### Parameters

`channel (int)` – The channel to observe (0 to 255).

#### Returns

The received data in the same format as it was sent, or `None` if no recent data is available.

New in version 3.3.

### `ble.signal_strength(channel) → int: dBm`

Gets the average signal strength in dBm for the given channel.

This indicates how near the broadcasting device is. Nearby devices may have a signal strength around -40 dBm, while far away devices might have a signal strength around -70 dBm.

#### Parameters

`channel (int)` – The channel number (0 to 255).

#### Returns

The signal strength or -128 if there is no recent observed data.

New in version 3.3.

### `ble.version() → str`

Gets the firmware version from the Bluetooth chip.

New in version 3.3.

## Using the battery

`battery.voltage()` → int: mV

Gets the voltage of the battery.

Returns

Battery voltage.

`battery.current()` → int: mA

Gets the current supplied by the battery.

Returns

Battery current.

## Getting the charger status

`charger.connected()` → bool

Checks whether a charger is connected via USB.

Returns

True if a charger is connected, False if not.

`charger.current()` → int: mA

Gets the charging current.

Returns

Charging current.

`charger.status()` → int

Gets the status of the battery charger, represented by one of the following values. This corresponds to the battery light indicator right next to the USB port.

0. Not charging (light is off).
1. Charging (light is red).
2. Charging is complete (light is green).
3. There is a problem with the charger (light is yellow).

Returns

Status value.

## System control

`system.name()` → str

Gets the hub name. This is the name you see when connecting via Bluetooth.

Returns

The hub name.

`system.storage(offset, write=)`

`system.storage(offset, read=) → bytes`

Reads or writes binary data to persistent storage.

This lets you store data that can be used the next time you run the program.

The data will be saved to flash memory when you turn the hub off normally. It will not be saved if the batteries are removed while the hub is still running.

Once saved, the data will remain available even after you remove the batteries.

Parameters

- `offset (int)` – The offset from the start of the user storage memory, in bytes.
- `read (int)` – The number of bytes to read. Omit this argument when writing.
- `write (bytes)` – The bytes to write. Omit this argument when reading.

Returns

The bytes read if reading, otherwise None.

Raises

`ValueError` – If you try to read or write data outside of the allowed range.

You can store up to 512 bytes of data on this hub.

`system.shutdown()`

Stops your program and shuts the hub down.

`system.reset_reason() → int`

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

Returns

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

## 1.5.1 Status light examples

Turning the light on and off

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

# Initialize the hub.
hub = EssentialHub()

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

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

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

### Changing brightness and using custom colors

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

# Initialize the hub.
hub = EssentialHub()

# 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 EssentialHub
from pybricks.parameters import Color
from pybricks.tools import wait

# Initialize the hub
hub = EssentialHub()

# 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 EssentialHub
from pybricks.parameters import Color
from pybricks.tools import wait
from umath import sin, pi

# Initialize the hub.
hub = EssentialHub()

# 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)
```

## 1.5.2 IMU examples

### Testing which way is up

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

# Initialize the hub.
hub = EssentialHub()

# 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()
```

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```
# 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 EssentialHub
from pybricks.tools import wait

# Initialize the hub.
hub = EssentialHub()

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 EssentialHub
from pybricks.tools import wait
from pybricks.parameters 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 = EssentialHub(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 EssentialHub
from pybricks.tools import wait

# Initialize the hub.
hub = EssentialHub()

# Get the acceleration vector in g's.
print(hub.imu.acceleration() / 9810)

# 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 EssentialHub
from pybricks.tools import wait
from pybricks.parameters import Axis

# Initialize the hub.
hub = EssentialHub()

# 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)
```

## 1.5.3 Bluetooth examples

## Broadcasting data to other hubs

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

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```
# Initialize the hub.
hub = EssentialHub(broadcast_channel=1)

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Read the motor angles to be sent to the other hub.
    left_angle = left_motor.angle()
    right_angle = right_motor.angle()

    # Set the broadcast data and start broadcasting if not already doing so.
    data = (left_angle, right_angle)
    hub.ble.broadcast(data)

    # Broadcasts are only sent every 100 milliseconds, so there is no reason
    # to call the broadcast() method more often than that.
    wait(100)
```

### Observing data from other hubs

```
from pybricks.hubs import EssentialHub
from pybricks.pupdevices import Motor
from pybricks.parameters import Color, Port
from pybricks.tools import wait

# Initialize the hub.
hub = EssentialHub(observe_channels=[1])

# Initialize the motors.
left_motor = Motor(Port.A)
right_motor = Motor(Port.B)

while True:
    # Receive broadcast from the other hub.

    data = hub.ble.observe(1)

    if data is None:
        # No data has been received in the last 1 second.
        hub.light.on(Color.RED)
    else:
        # Data was received and is less than one second old.
        hub.light.on(Color.GREEN)

        # *data* contains the same values in the same order
        # that were passed to hub.ble.broadcast() on the
        # other hub.
        left_angle, right_angle = data
```

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```
# Make the motors on this hub mirror the position of the
# motors on the other hub.
left_motor.track_target(left_angle)
right_motor.track_target(right_angle)

# Broadcasts are only sent every 100 milliseconds, so there is
# no reason to call the observe() method more often than that.
wait(100)
```

## 1.5.4 System examples

Using the stop button during your program

```
from pybricks.hubs import EssentialHub
from pybricks.parameters import Color, Button
from pybricks.tools import wait, Stopwatch

# Initialize the hub.
hub = EssentialHub()

# 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.buttons.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)
```

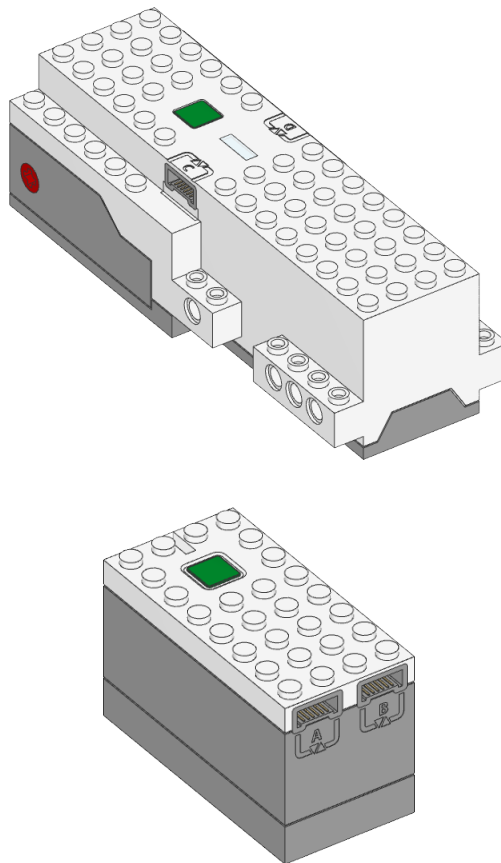
## Turning the hub off

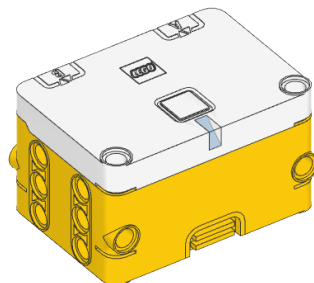
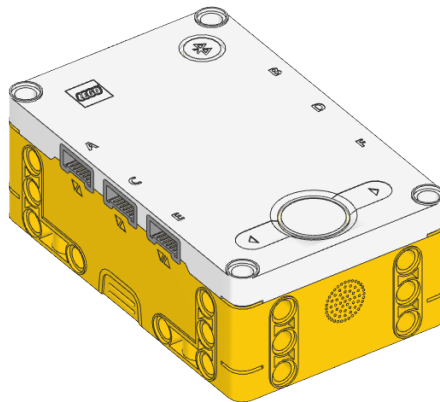
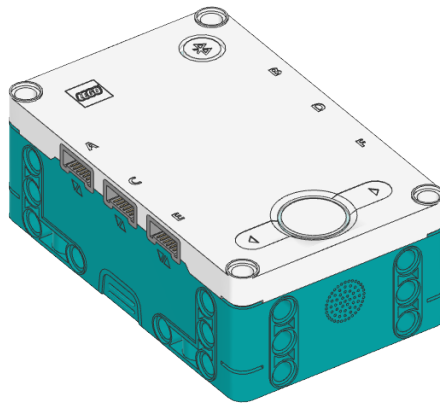
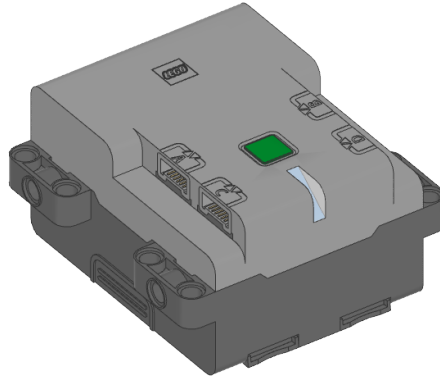
```
from pybricks.hubs import EssentialHub
from pybricks.tools import wait

# Initialize the hub.
hub = EssentialHub()

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

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







## PUPDEVICES – MOTORS, SENSORS, LIGHTS

LEGO® Powered Up motor, sensors, and lights.

### 2.1 Motors without rotation sensors

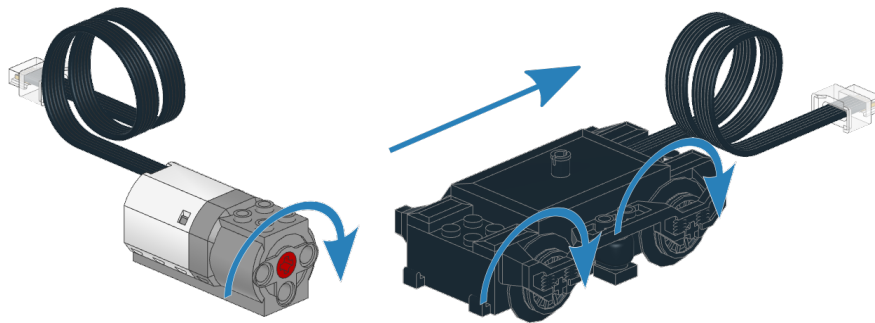


Figure 2.1: Powered Up motors without rotation sensors. The arrows indicate the default positive direction.

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

LEGO® Powered Up motor without 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 duty cycle value.

**dc(duty)**

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

Parameters

**duty** ([Number](#), %) – 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)`

`settings()` → `Tuple[int]`

Configures motor settings. If no arguments are given, this returns the current values.

Parameters

`max_voltage` (`Number`, `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)
```

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```
# 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

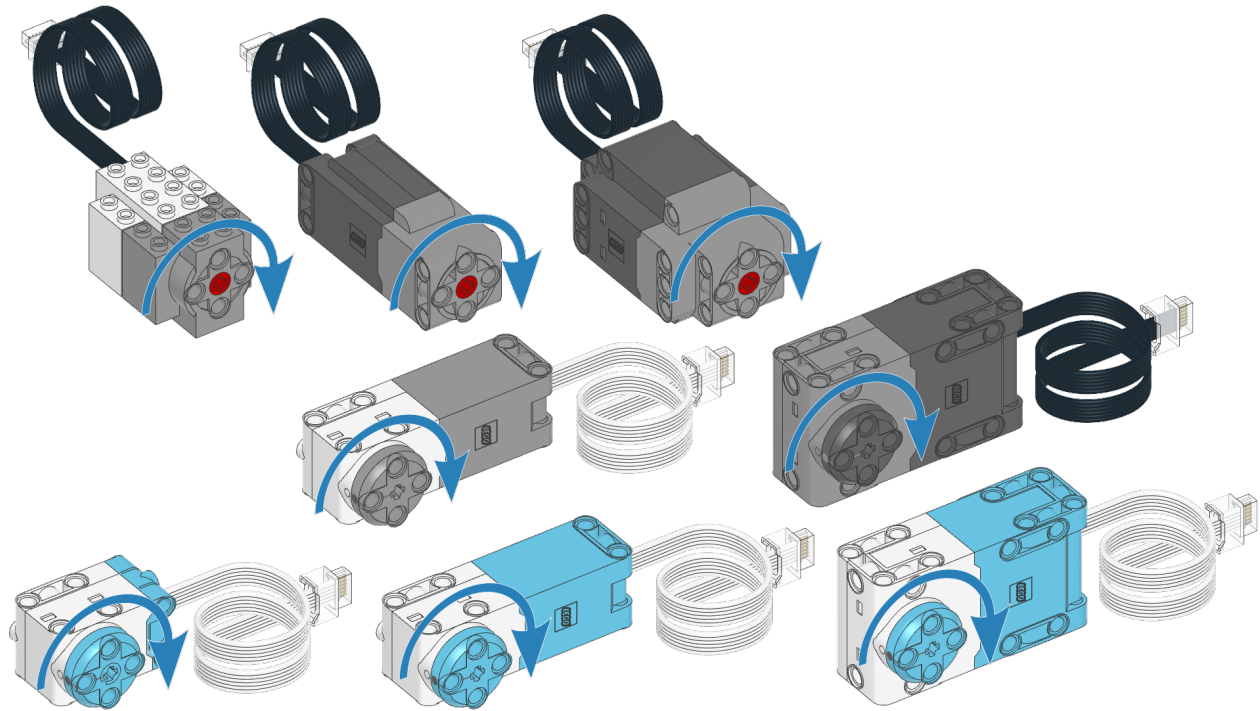


Figure 2.2: Powered Up motors with rotation sensors. The arrows indicate the default positive direction. See the [hubs](#) module for default directions of built-in motors.

```
class Motor(port, positive_direction=Direction.CLOCKWISE, gears=None, reset_angle=True, profile=None)
    LEGO® Powered Up motor with 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. The gear connected to the motor comes first and the gear connected to the output comes last.

For example: `[12, 36]` represents a gear train with a 12-tooth gear connected to the motor and a 36-tooth gear connected to the output. 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.
- **profile** ([Number](#), [deg](#)) – Precision profile. This is the approximate position tolerance in degrees that is acceptable in your application. A lower value gives more precise but more erratic movement; a higher value gives less precise but smoother movement. If no value is given, a suitable profile for this motor type will be selected automatically (about 11 degrees).

## Measuring

`angle()` → int: deg

Gets the rotation angle of the motor.

Returns

Motor angle.

`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` (Number, deg) – Value to which the angle should be reset.

`speed(window=100)` → int: deg/s

Gets the speed of the motor.

The speed is measured as the change in the motor angle during the given time window. A short window makes the speed value more responsive to motor movement, but less steady. A long window makes the speed value less responsive, but more steady.

Parameters

`window` (Number, ms) – The time window used to determine the speed.

Returns

Motor speed.

`load()` → int: mNm

Estimates the load that holds back the motor when it tries to move.

Returns

The load torque.

`stalled()` → bool

Checks if the motor is currently stalled.

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

Returns

True if the motor is stalled, False if not.

## 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.

## Running forever

### `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` (**Number**, deg/s) – Speed of the motor.

### `dc(duty)`

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

Parameters

`duty` (**Number**, %) – The duty cycle (-100.0 to 100).

## Running by a fixed amount

### `await 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` (**Number**, deg/s) – Speed of the motor.
- `time` (**Number**, 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.

`awaitrun_angle(speed, rotation_angle, then=Stop.HOLD, wait=True)`

Runs the motor at a constant speed by a given angle.

Parameters

- `speed` (`Number`, `deg/s`) – Speed of the motor.
- `rotation_angle` (`Number`, `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.

`awaitrun_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` (`Number`, `deg/s`) – Speed of the motor.
- `target_angle` (`Number`, `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.

`awaitrun_until_stalled(speed, then=Stop.COAST, duty_limit=None) → int: deg`

Runs the motor at a constant speed until it stalls.

Parameters

- `speed` (`Number`, `deg/s`) – Speed of the motor.
- `then` (`Stop`) – What to do after coming to a standstill.
- `duty_limit` (`Number`, `%`) – Duty cycle limit during this command. This is useful to avoid applying the full motor torque to a geared or lever mechanism. If it is `None`, the duty limit won't be changed during this command.

Returns

Angle at which the motor becomes stalled.

`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` (`Number`, `deg`) – Target angle that the motor should rotate to.

`done() → bool`

Checks if an ongoing command or maneuver is done.

**Returns**

True if the command is done, False if not.

**Motor settings**

`settings(max_voltage)`

`settings() → Tuple[int]`

Configures motor settings. If no arguments are given, this returns the current values.

**Parameters**

`max_voltage` (**Number**, mV) – Maximum voltage applied to the motor during all motor commands.

`close()`

Closes the motor object so you can call `Motor` again to initialize a new object.

This allows advanced users to change properties such as gearing in the middle of the program, which can be useful for removeable attachments.

**Control settings**

`control.limits(speed, acceleration, torque)`

`control.limits() → Tuple[int, int, int]`

Configures the maximum speed, acceleration, and torque.

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

The new acceleration and speed limit will become effective when you give a new motor command. Ongoing maneuvers are not affected.

**Parameters**

- `speed` (**Number**, deg/s or **Number**, mm/s) – Maximum speed. All speed commands will be capped to this value.
- `acceleration` (**Number**, deg/s<sup>2</sup> or **Number**, mm/s<sup>2</sup>) – Slope of the speed curve when accelerating or decelerating. Use a tuple to set acceleration and deceleration separately. If one value is given, it is used for both.
- `torque` (**torque**: mNm) – Maximum feedback torque during control.

`control.pid(kp, ki, kd, integral_deadzone, integral_rate)`

`control.pid() → Tuple[int, int, int, int, int]`

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:  $\mu\text{Nm/deg}$ .



- `ki` (`int`) – Integral position control constant. It is the feedback torque per accumulated degree of error:  $\mu\text{Nm}/(\text{deg s})$ .
- `kd` (`int`) – Derivative position (or proportional speed) control constant. It is the feedback torque per unit of speed:  $\mu\text{Nm}/(\text{deg/s})$ .
- `integral_deadzone` (`Number`, `deg` or `Number`, `mm`) – Zone around the target where the error integral does not accumulate errors.
- `integral_rate` (`Number`, `deg/s` or `Number`, `mm/s`) – Maximum rate at which the error integral is allowed to grow.

`control.target_tolerances(speed, position)`

`control.target_tolerances()` → `Tuple[int, int]`

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

`control.stall_tolerances(speed, time)`

`control.stall_tolerances()` → `Tuple[int, int]`

Gets or sets stalling tolerances.

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

Parameters

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

`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.

Changed in version 3.2: The `done()`, `stalled()` and `load()` methods have been moved.

`model.state()` → `Tuple[float, float, float, bool]`

Gets the estimated angle, speed, current, and stall state of the motor, using a simulation model that mimics the real motor. These estimates are updated faster than the real measurements, which can be useful when building your own PID controllers.

For most applications it is better to use the measured `angle`, `speed`, `load`, and `stall` state instead.

Returns

Tuple with the estimated angle (deg), speed (deg/s), current (mA), and stall state (True or False).

`model.settings(values)`

`model.settings()` → Tuple

Gets or sets model settings as a tuple of integers. If no arguments are given, this will return the current values. This method is mainly used to debug the motor model class. Changing these settings should not be needed in user programs.

Parameters

values (Tuple) – Tuple with `model settings`.

## 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()
```

### Getting the absolute angle

```
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)

while True:

    # Get the default angle value.
    angle = example_motor.angle()
```

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```
# Get the angle between 0 and 360.
absolute_angle = example_motor.angle() % 360

# Get the angle between -180 and 179.
wrapped_angle = (example_motor.angle() + 180) % 360 - 180

# Print the results.
print(angle, absolute_angle, wrapped_angle)
wait(100)
```

## 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)
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)
```

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```
# 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()
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.
```

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```
# 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
from pybricks.tools import wait

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

# Please have a look at the previous example first. This example
# finds two endpoints and then makes the middle the zero point.

# The run_until_stalled gives us the angle at which it stalled.
# We want to know this value for both endpoints.
left_end = example_motor.run_until_stalled(-200, duty_limit=30)
right_end = example_motor.run_until_stalled(200, duty_limit=30)

# We have just moved to the rightmost endstop. So, we can reset
# this angle to be half the distance between the two endpoints.
# That way, the middle corresponds to 0 degrees.
example_motor.reset_angle((right_end - left_end) / 2)

# From now on we can simply run towards zero to reach the middle.
example_motor.run_target(200, 0)

wait(1000)
```

## 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)
```

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```
# 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

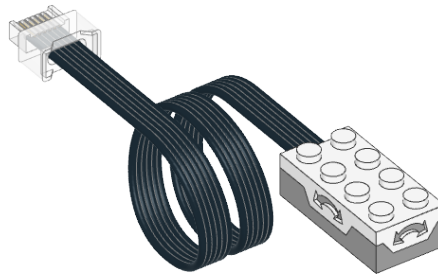
# Initialize motors on port A and B.
track_motor = Motor(Port.A)
gripper_motor = Motor(Port.B)

# 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.done() or not gripper_motor.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.
```

```
awaittilt() → Tuple[int, int]: deg
    Measures the tilt relative to the horizontal plane.
```

Returns

Tuple of pitch and roll angles.

## 2.3.1 Examples

### Measuring pitch and roll

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

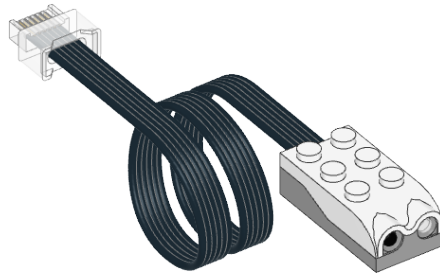
# Initialize the sensor.
accel = TiltSensor(Port.A)

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.

[await](#)distance() → int: %

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

Returns

Distance ranging from 0% (closest) to 100% (farthest).

`await reflection() → int: %`

Measures the reflection of a surface using an infrared light.

Returns

Measured reflection, ranging from 0% (no reflection) to 100% (high reflection).

`await count() → int`

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

Returns

Number of objects counted.

## 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)

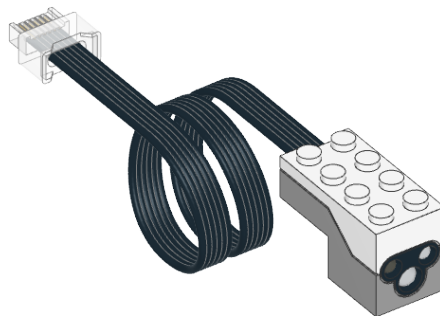
while True:
    # Read all the information we can get from this sensor.
    dist = ir.distance()
    count = ir.count()
    ref = ir.reflection()

    # 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.

```
awaitcolor() → 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.

```
awaitreflection() → int: %
```

Measures how much a surface reflects the light emitted by the sensor.

Returns

Measured reflection, ranging from 0% (no reflection) to 100% (high reflection).

```
awaitambient() → int: %
```

Measures the ambient light intensity.

Returns

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

```
awaitdistance() → int: %
```

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

Returns

Distance ranging from 0% (closest) to 100% (farthest).

```
awaithsv() → Color
```

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).

```
detectable_colors(colors)
```

```
detectable_colors() → Collection[Color]
```

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.

When coding with blocks, this is configured in the sensor setup block.

#### Parameters

`colors` (`list` or `tuple`) – List 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.

#### `awaitlight.on(color)`

Turns on the light at the specified color.

#### Parameters

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

#### `awaitlight.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.

    # 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:

        # 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)
```

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```
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)

# 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)
```

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```

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.

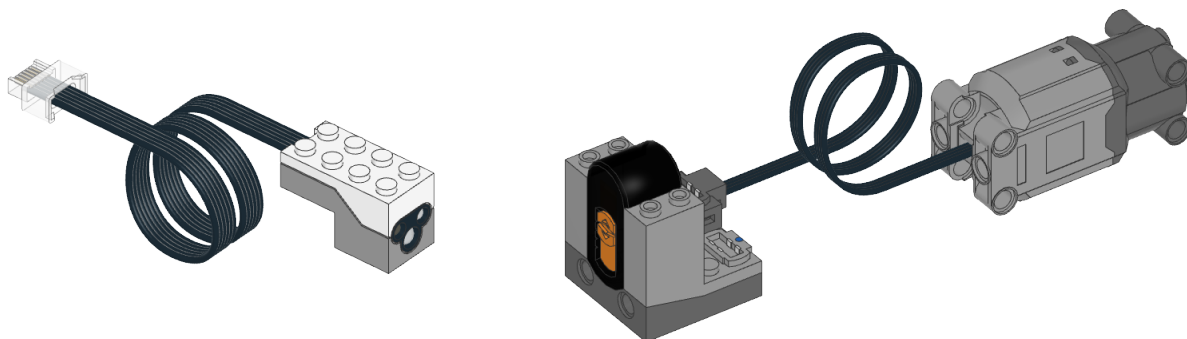


Figure 2.3: Powered Up `ColorDistanceSensor` (left), Power Functions infrared receiver (middle), and a Power Functions motor (right). Here, the receiver uses channel 1 with a motor on the red port.

```

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.

`awaitdc(duty)`

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

Parameters

`duty` (`Number`, `%`) – The duty cycle (-100.0 to 100).

`awaitstop()`

Stops the motor and lets it spin freely.

The motor gradually stops due to friction.

`awaitbrake()`

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)

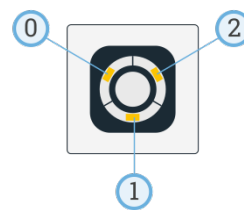
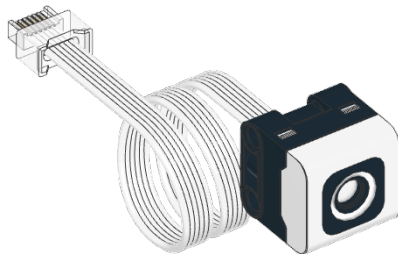
# Accelerate both motors. Only these values are available.
# Other values will be rounded down to the nearest match.
for duty in [15, 30, 45, 60, 75, 90, 100]:
    arm.dc(duty)
    wheel.dc(duty)
    wait(1000)

# 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.

[await](#)color(surface=True) → [Color](#)

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.

`awaitreflection()` → int: %

Measures how much a surface reflects the light emitted by the sensor.

#### Returns

Measured reflection, ranging from 0% (no reflection) to 100% (high reflection).

`awaitambient()` → int: %

Measures the ambient light intensity.

#### Returns

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

## Advanced color sensing

`awaithsv(surface=True)` → `Color`

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).

`detectable_colors(colors)`

`detectable_colors()` → Collection[`Color`]

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.

When coding with blocks, this is configured in the sensor setup block.

#### Parameters

`colors` (**list** or **tuple**) – List 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.

`awaitlights.on(brightness)`

Turns on the lights at the specified brightness.

Parameters

**brightness** (Number or tuple, %) – Use a single value to set the brightness of all lights at the same time. Use a tuple of three values to set the brightness of each light individually.

`awaitlights.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.

    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)
```

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```
# 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)  
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)
```

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

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

Turning off the lights when the program ends

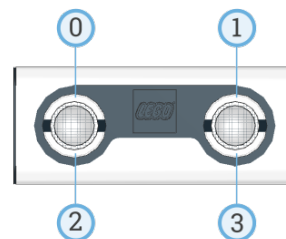
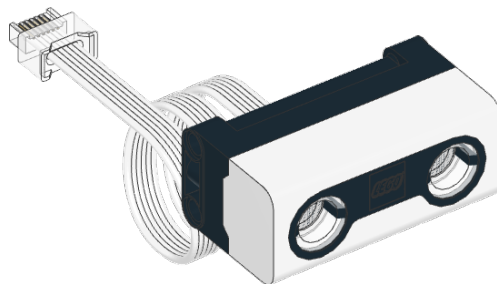
```
from pybricks.parameters import Port
from pybricks.pupdevices import ColorSensor
from pybricks.tools import wait

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

def main():
    # Run the main code.
    while True:
        print(sensor.color())
        wait(500)

# Wrap the main code in try/finally so that the cleanup code always runs
# when the program ends, even if an exception was raised.
try:
    main()
finally:
    # The cleanup code goes here.
    print("Cleaning up.")
    sensor.lights.off()
```

## 2.8 Ultrasonic Sensor



```
class UltrasonicSensor(port)
    LEGO® SPIKE Color Sensor.
```



#### Parameters

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

`awaitdistance()` → int: mm

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.

`awaitpresence()` → bool

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

#### Returns

True if ultrasonic sounds are detected, False if not.

### Built-in lights

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

`awaitlights.on(brightness)`

Turns on the lights at the specified brightness.

#### Parameters

`brightness` (`Number` or `tuple`, %) – Use a single value to set the brightness of all lights at the same time. Use a tuple of four values to set the brightness of each light individually. The order of the lights is shown in the image above.

`awaitlights.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.
```

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```
    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)]

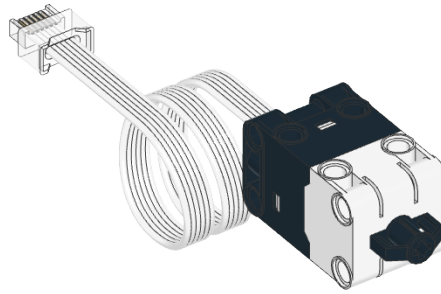
    # Set the brightness values for all lights.
    eyes.lights.on(brightness)

    # 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.
```



`awaitforce()` → float: N

Measures the force exerted on the sensor.

Returns

Measured force (up to approximately 10.00 N).

`awaitdistance()` → float: mm

Measures by how much the sensor button has moved.

Returns

Movement up to approximately 8.00 mm.

`awaitpressed(force=3)` → bool

Checks if the sensor button is pressed.

Parameters

`force` (Number, N) – Minimum force to be considered pressed.

Returns

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

`awaittouched()` → bool

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.

## 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:
```

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```

# 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.

```

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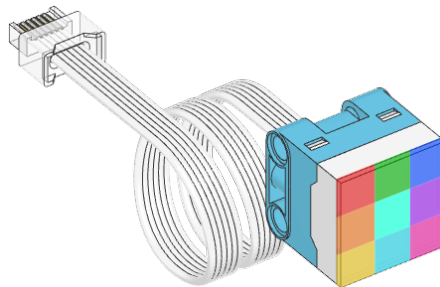
(continued from previous page)

```
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.

```
awaiton(colors)
```

Turns the lights on.

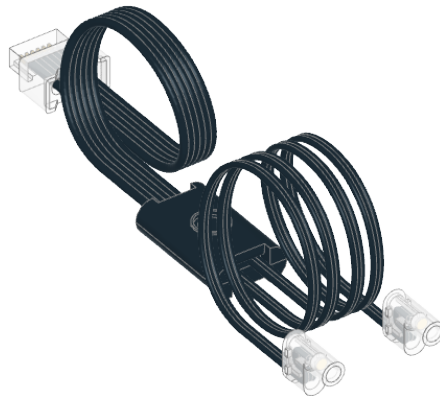
Parameters

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.

```
awaitoff()
```

Turns all 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 ([Number](#), %) – 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)
```

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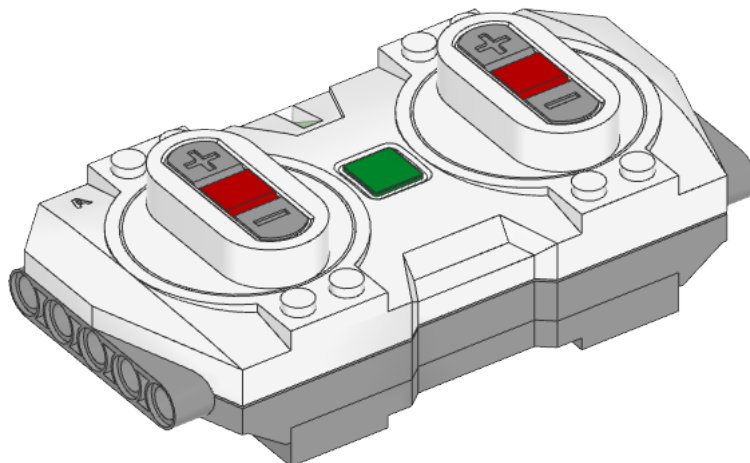
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```
# Turn the light off.  
light.off()  
wait(500)
```

### 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` (`Number`, `ms`) – How long to search for the remote.

```
name(name)
```

```
name() → str
```

Sets or gets the Bluetooth name of the remote.

Parameters

`name` (`str`) – New Bluetooth name of the remote. If no name is given, this method returns the current name.

```
awaitlight.on(color)
```

Turns on the light at the specified color.

Parameters

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

```
awaitlight.off()
```

Turns off the light.

```
buttons.pressed() → Set[Button]
```

Checks which buttons are currently pressed.

Returns

Set of pressed buttons.

```
awaitdisconnect()
```

Disconnects the remote from the hub.

## 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.
```

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```
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
```

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```
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.
```

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```
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!")
```

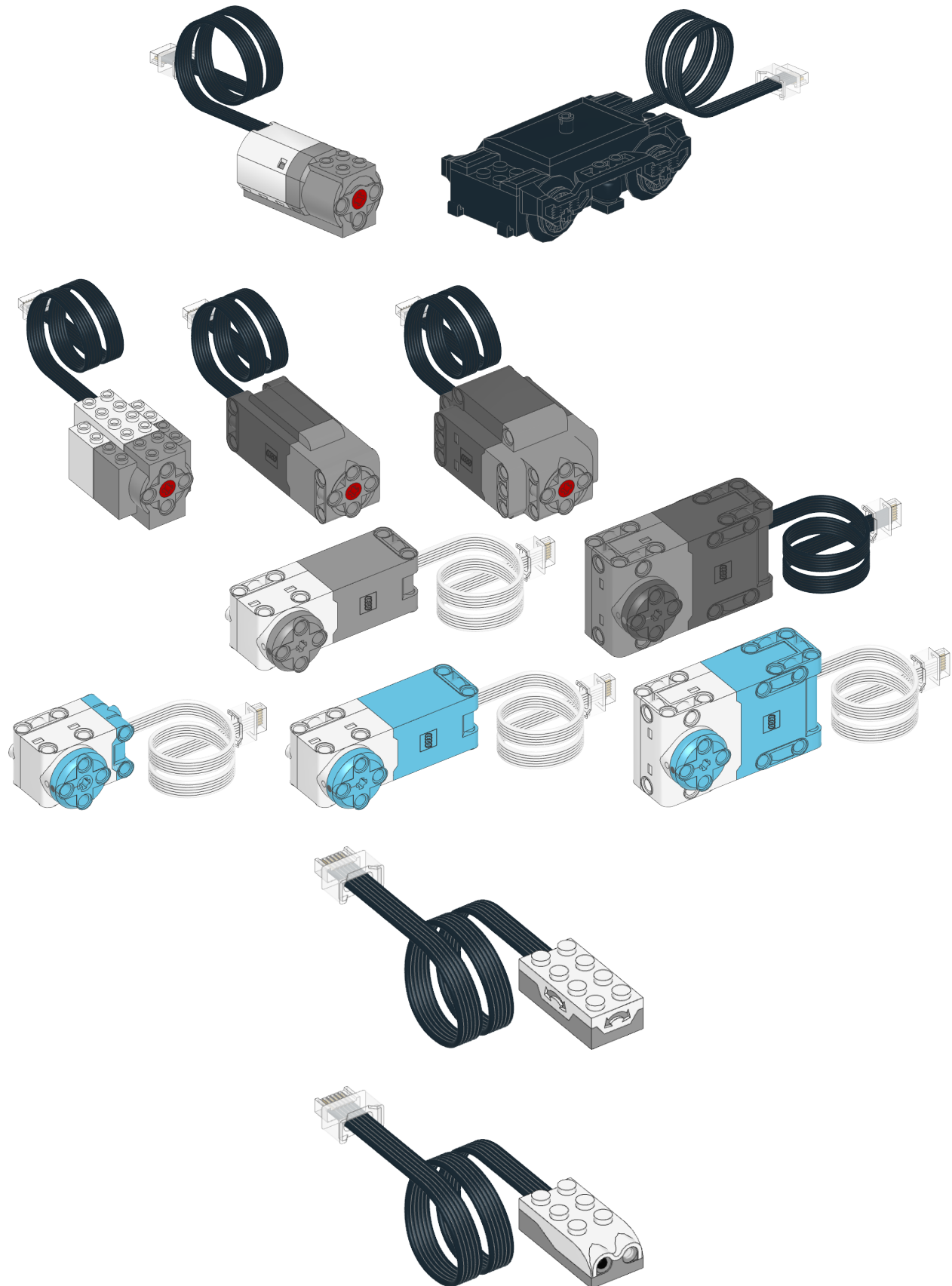
You can specify this name when connecting to the remote. This lets you pick the right one if multiple remotes are nearby.

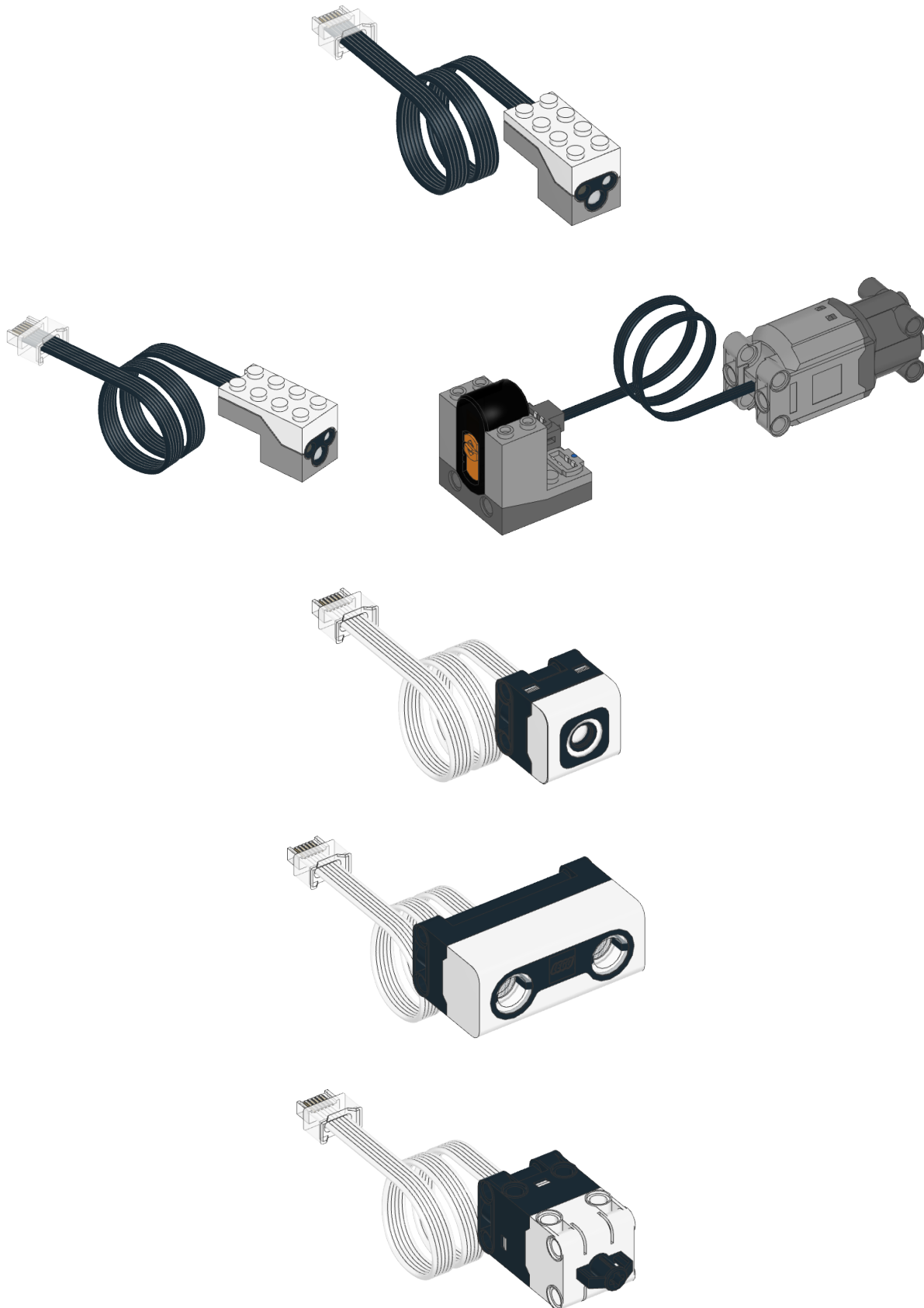
```
from pybricks.pupdevices import Remote
from pybricks.tools import wait

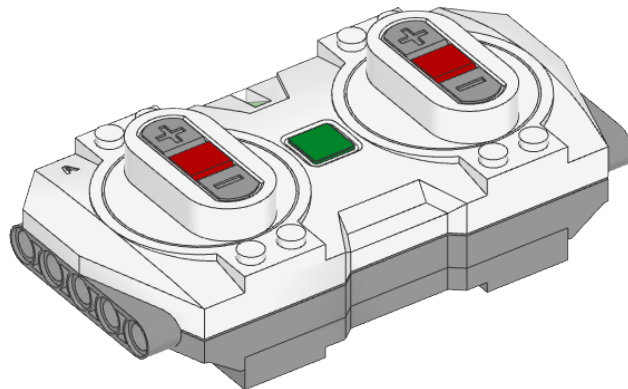
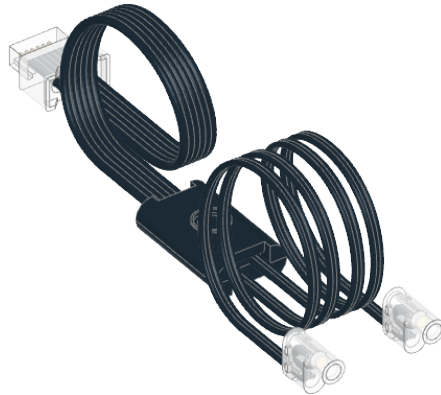
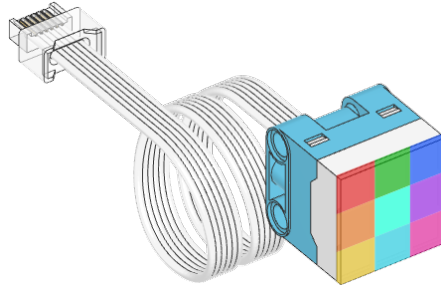
# Connect to a remote called truck2.
truck_remote = Remote("truck2", timeout=None)

print("Connected!")

wait(2000)
```

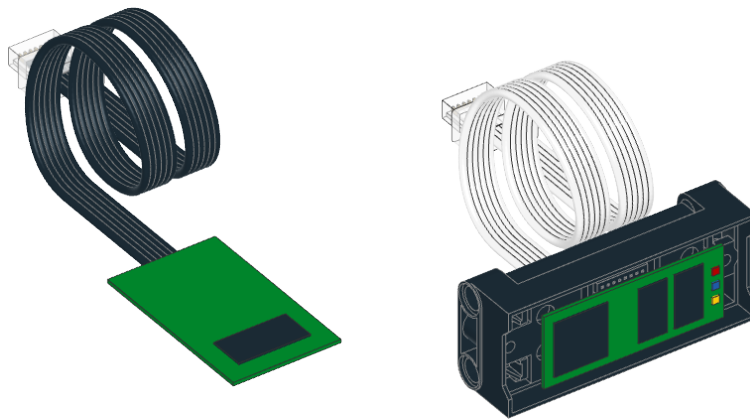






## IODEVICES – CUSTOM DEVICES

### 3.1 Powered Up Device



```
class PUPDevice(port)
    Powered Up motor or sensor.

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

    info() → Dict
        Gets information about the device.

    Returns
        Dictionary with information, such as the device id.

    awaitread(mode) → Tuple
        Reads values from a given mode.

    Parameters
        mode (int) – Device mode.

    Returns
        Values read from the sensor.

    awaitwrite(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 = {
    # pybricks.pupdevices.DCMotor
    1: "Wedo 2.0 Medium Motor",
    2: "Powered Up Train Motor",
    # pybricks.pupdevices.Light
    8: "Powered Up Light",
    # pybricks.pupdevices.Motor
    38: "BOOST Interactive Motor",
    46: "Technic Large Motor",
    47: "Technic Extra Large Motor",
    48: "SPIKE Medium Angular Motor",
    49: "SPIKE Large Angular Motor",
    65: "SPIKE Small Angular Motor",
    75: "Technic Medium Angular Motor",
    76: "Technic Large Angular Motor",
    # pybricks.pupdevices.TiltSensor
    34: "Wedo 2.0 Tilt Sensor",
    # pybricks.pupdevices.InfraredSensor
    35: "Wedo 2.0 Infrared Motion Sensor",
    # pybricks.pupdevices.ColorDistanceSensor
    37: "BOOST Color Distance Sensor",
    # pybricks.pupdevices.ColorSensor
    61: "SPIKE Color Sensor",
    # pybricks.pupdevices.UltrasonicSensor
    62: "SPIKE Ultrasonic Sensor",
    # pybricks.pupdevices.ForceSensor
    63: "SPIKE Force Sensor",
    # pybricks.pupdevices.ColorLightMatrix
    64: "SPIKE 3x3 Color Light Matrix",
}

# 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
```

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```

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

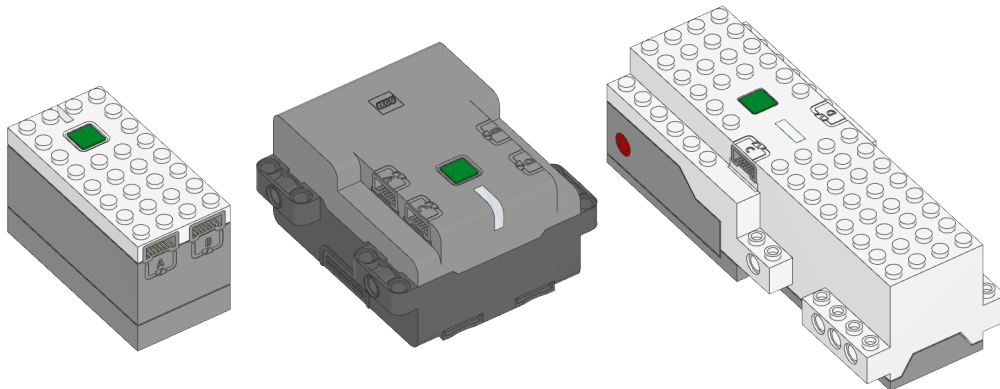
    # Get the device id
    id = device.info()["id"]

    # 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 hub running official LEGO firmware using 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)`

`name()` → `str`

Sets or gets the Bluetooth name of the device.

Parameters

`name (str)` – New Bluetooth name of the device. If no name is given, this method returns the current name.

`awaitwrite(buf)`

Sends a message to the remote hub.

Parameters

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

`read()` → `bytes`

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.

`awaitdisconnect()`

Disconnects the remote LWP3Device from the hub.

### 3.3 Xbox Controller



## class XboxController

Use the Microsoft® Xbox® controller as a sensor in your projects to control them remotely.

The hub will scan for the controller and connect to it. It will disconnect when the program ends.

For tips on connectivity and pairing, see [below](#).

### buttons.pressed() → Set[Button]

Checks which buttons are currently pressed.

Returns

Set of pressed buttons.

Buttons include:

- Button.A, Button.B, Button.X, Button.Y.
- Button.UP, Button.DOWN, Button.LEFT, Button.RIGHT (direction pad). At most two of these can be pressed at the same time.
- Button.LB and Button.RB (bumpers).
- Button.LJ and Button.RJ (pressing the joysticks).
- Button.VIEW, Button.MENU, Button.GUIDE (the Xbox logo), and Button.UPLOAD.
- Button.P1, Button.P2, Button.P3, and Button.P4 (Elite Series 2 only). Pressing the paddles may also be detected as other button presses, depending on the currently active profile.

### joystick\_left() → Tuple

Gets the left joystick position as percentages between -100% and 100%. The center position is (0, 0).

Returns

Tuple of X (horizontal) and Y (vertical) position.

### joystick\_right() → Tuple

Gets the right joystick position as percentages between -100% and 100%. The center position is (0, 0).

Returns

Tuple of X (horizontal) and Y (vertical) position.

### triggers() → Tuple

Gets the left and right trigger positions as percentages between 0% and 100%.

Returns

Tuple of left and right trigger positions.

`dpad()` → `int`

Gets the direction-pad value. 1 is up, 2 is up-right, 3 is right, 4 is down-right, 5 is down, 6 is down-left, 7 is left, 8 is up-left, and 0 is not pressed.

This is essentially the same as reading the state of the `Button.UP`, `Button.RIGHT`, `Button.DOWN`, and `Button.LEFT` buttons, but this method conveniently returns a number that indicates a direction.

Returns

Direction-pad position, indicating a direction.

`profile()` → `int`

Gets the current profile of the controller. Only available on the Xbox Elite Controller Series 2.

Returns

Profile number.

`awaitrumble(power=100, duration=200, count=1, delay=100)`

Makes the builtin actuators rumble, creating force feedback.

If you give a single `power` value, the left and right main actuators will both rumble with that power. For more fine-grained control, set `power` as a tuple of four values, which control the left main actuator, right main actuator, left trigger actuator, and the right trigger actuator, respectively. For example, `power=(0, 0, 100, 0)` makes the left trigger rumble at full power.

The rumble runs in the background while your program continues. To make your program wait, just pause the program for a matching duration. For one rumble, this equals `duration`. For multiple rumbles, this equals `count * (duration + delay)`.

Parameters

- `power` (`Number`, % or `tuple`) – Rumble power.
- `duration` (`Number`, ms) – Rumble duration.
- `count` (`int`) – Rumble count.
- `delay` (`Number`, ms) – Delay before each rumble. Only if `count > 1`.

## 3.4 Xbox Controller Pairing Instructions

The first time you use a controller with a hub, you will need to pair them: Turn the controller on and then press and hold the pairing button on the back of the controller for a few seconds. When you release it, the Xbox button starts flashing more rapidly. Then start your program.

When pairing and the connection is successful, the Xbox button will stop flashing and stay on for as long as the program is running.

### 3.4.1 Repeat Connections

If you keep using the same controller with the same hub, you can simply turn the controller on the next time and the hub will connect to it automatically when your program with this class runs.

The Xbox controller only accepts this simpler connection with the most recently connected device. So if you connect to your Xbox console again, or connect to another hub, you will need to pair them again as described above.

### 3.4.2 Compatible Controllers

All Xbox controllers released since 2016 are compatible. This includes the controller from the One S (1708 from 2016), the Elite Series 2 (1797 from 2019), and the Series X/S (1914 from 2020), which is the latest model as of this writing.

### 3.4.3 Updating the Xbox Controller

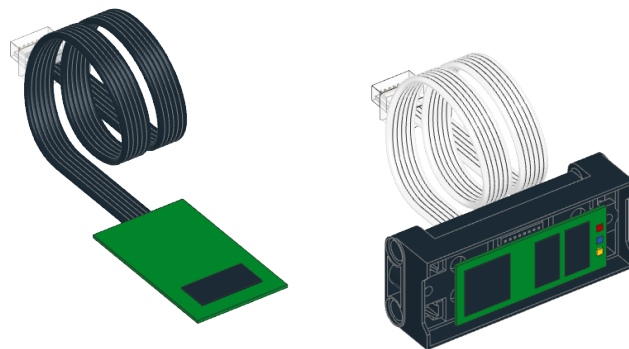
If you frequently use the Xbox Controller with your console, your controller is probably already up to date. If you have not used it for a while or if you bought one recently, you may need to update it.

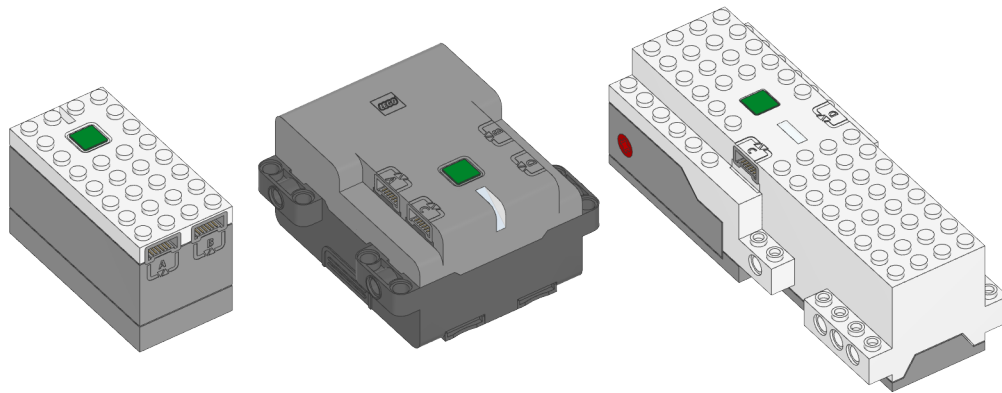
To update the controller without a console, you can use the Xbox Accessories app on a Windows computer. You can download it from the Microsoft Store. Connect the controller via USB to the computer and follow the instructions in the app to click on “Update now”.

### 3.4.4 Technic Hub Limitations

Due to limitations of the Technic Hub, the hub will disconnect from the computer when searching for the Xbox controller. This means you will not be able to see output from the `print` command. Also, you’ll have to connect to the computer again if you want to change your program.

This module has classes for generic and custom input/output devices.





## PARAMETERS – PARAMETERS AND CONSTANTS

Constant parameters/arguments for the Pybricks API.

### 4.1 Axis

```
class Axis
    Unit axes of a coordinate system.
    X = vector(1, 0, 0)
    Y = vector(0, 1, 0)
    Z = vector(0, 0, 1)
```

On Move Hub, doing math with these vectors is not supported. The axes can still be used to set up the hub orientation.

### 4.2 Button

```
class Button

    Remote and hub buttons

    LEFT_MINUS
        Powered Up Remote only.
    LEFT_PLUS
        Powered Up Remote only.
    RIGHT_MINUS
        Powered Up Remote only.
    RIGHT_PLUS
        Powered Up Remote only.
    CENTER
        Powered Up Remote (green button) or hub power button.
    LEFT
        Powered Up Remote (left red button) and Prime/Inventor Hub (left button).
```

**RIGHT**

Powered Up Remote (right red button) and Prime/Inventor Hub (right button).

**BLUETOOTH**

Prime/Inventor Hub button with Bluetooth icon.

**Xbox controller buttons****A****B****X****Y****LB**

The left bumper.

**RB**

The right bumper.

**LJ**

Pressing the left joystick.

**RJ**

Pressing the right joystick.

**GUIDE**

The Xbox button in the center of the controller.

**MENU****UPLOAD**

Only available on newer Xbox controllers.

**VIEW****Xbox Elite Series 2 controller paddles****P1****P2****P3****P4**



## 4.3 Color

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

Light or surface color.

Parameters

- **h** (**Number**, deg) – Hue.
- **s** (**Number**, %) – Saturation.
- **v** (**Number**, %) – Brightness value.

### Saturated colors

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

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

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

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

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

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

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

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

```
MAGENTA: Color = 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 = Color(h=0, s=0, v=100)
```

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

```
BLACK: Color = Color(h=0, s=0, v=10)
```

This represents dark objects that still reflect a very small amount of light.

```
NONE: Color = 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)

# 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"])
```

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```

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)

```

## 4.4 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:
<code>Direction.CLOCKWISE</code>	clockwise	counterclockwise
<code>Direction.COUNTERCLOCKWISE</code>	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.

## 4.5 Icon

`class Icon`

Icons to display on a light matrix.

Each of the following attributes are matrices. This means you can scale icons to adjust the brightness or add icons to make composites.

See the [Making your own images](#) section for examples.

UP: `Matrix = Ellipsis`

DOWN: `Matrix = Ellipsis`

```
LEFT: Matrix = Ellipsis
```

```
RIGHT: Matrix = Ellipsis
```

```
ARROW_RIGHT_UP: Matrix = Ellipsis
```

```
ARROW_RIGHT_DOWN: Matrix = Ellipsis
```

```
ARROW_LEFT_UP: Matrix = Ellipsis
```

```
ARROW_LEFT_DOWN: Matrix = Ellipsis
```

```
ARROW_UP: Matrix = Ellipsis
```

```
ARROW_DOWN: Matrix = Ellipsis
```

```
ARROW_LEFT: Matrix = Ellipsis
```

```
ARROW_RIGHT: Matrix = Ellipsis
```

```
HAPPY: Matrix = Ellipsis
```

```
SAD: Matrix = Ellipsis
```

```
EYE_LEFT: Matrix = Ellipsis
```

```
EYE_RIGHT: Matrix = Ellipsis
```

```
EYE_LEFT_BLINK: Matrix = Ellipsis
```

```
EYE_RIGHT_BLINK: Matrix = Ellipsis
```

```
EYE_RIGHT_BROW: Matrix = Ellipsis
```

```
EYE_LEFT_BROW: Matrix = Ellipsis
```

```
EYE_LEFT_BROW_UP: Matrix = Ellipsis
```

```
EYE_RIGHT_BROW_UP: Matrix = Ellipsis
```

```
HEART: Matrix = Ellipsis
```

```
PAUSE: Matrix = Ellipsis
```

```
EMPTY: Matrix = Ellipsis
```

```
FULL: Matrix = Ellipsis
```

SQUARE: `Matrix` = Ellipsis

TRIANGLE\_RIGHT: `Matrix` = Ellipsis

TRIANGLE\_LEFT: `Matrix` = Ellipsis

TRIANGLE\_UP: `Matrix` = Ellipsis

TRIANGLE\_DOWN: `Matrix` = Ellipsis

CIRCLE: `Matrix` = Ellipsis



```
CLOCKWISE: Matrix = Ellipsis
```

```
COUNTERCLOCKWISE: Matrix = Ellipsis
```

```
TRUE: Matrix = Ellipsis
```

```
FALSE: Matrix = Ellipsis
```

## 4.6 Port

```
class Port
```

Input and output ports:

A

B

C

D

E

F

## 4.7 Side

class Side

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

TOP

BOTTOM

FRONT

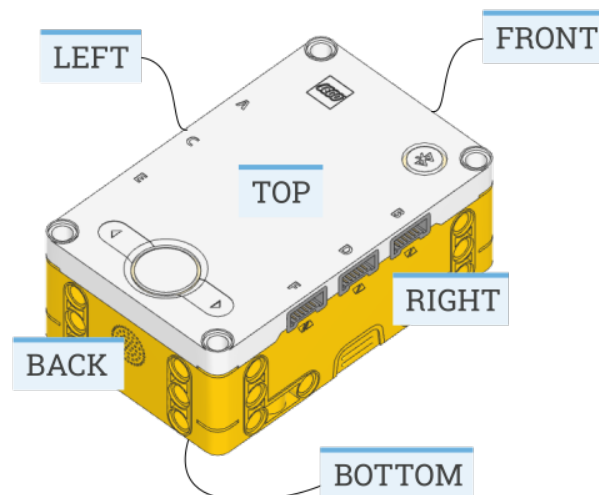
BACK

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

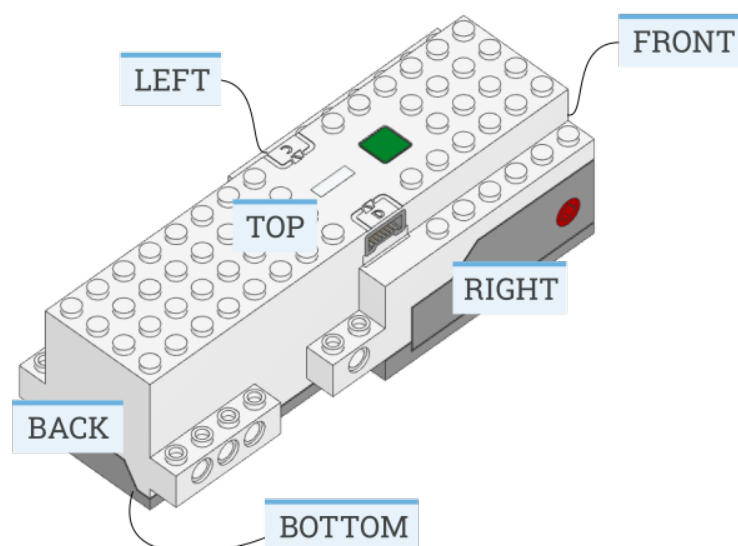
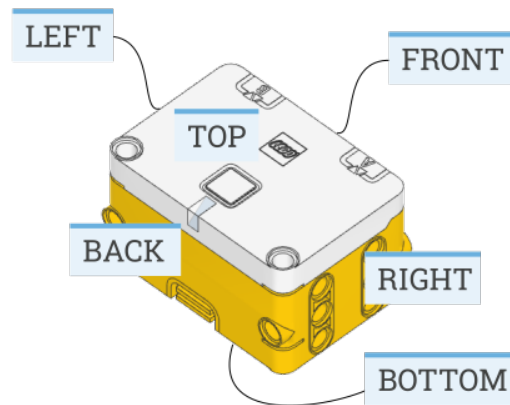
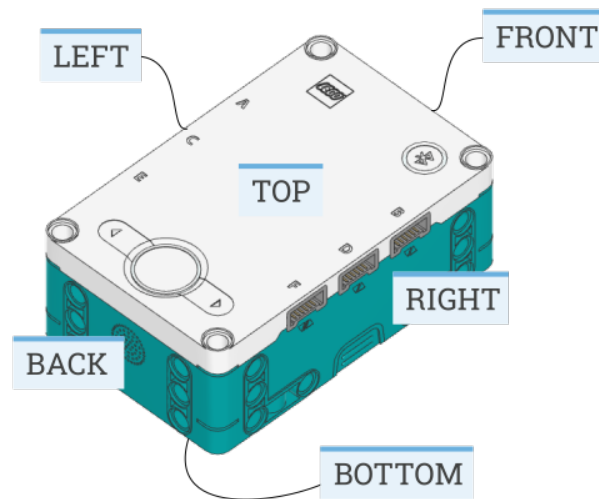
Essential Hub

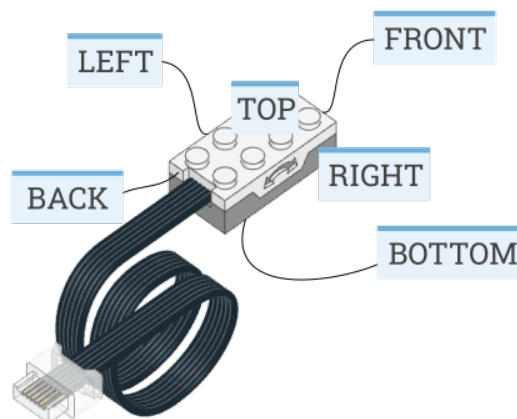
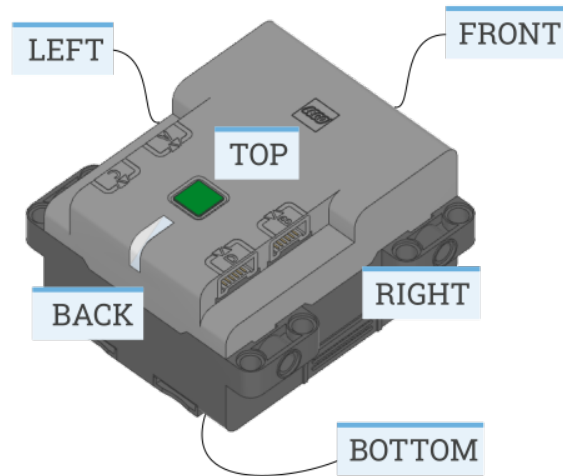
Move Hub

Technic Hub

Changed in version 3.2: Changed which side is the front.

Tilt Sensor





## 4.8 Stop

`class Stop`

Action after the motor stops.

**COAST**

Let the motor move freely.

**COAST\_SMART**

Let the motor move freely. For the next relative angle maneuver, take the last target angle (instead of the current angle) as the new starting point. This reduces cumulative errors. This will apply only if the current angle is less than twice the configured position tolerance.

**BRAKE**

Passively resist small external forces.

**HOLD**

Keep controlling the motor to hold it at the commanded angle.

**NONE**

Do not decelerate when approaching the target position. This can be used to concatenate multiple motor or drive base maneuvers without stopping. If no further commands are given, the motor will proceed to run indefinitely at the given speed.

The following table shows how each of the basic stop types add an extra level of resistance to motion. In these examples, `m` is a `Motor` 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	•				<pre>m.stop() m.run_target(500, 90, Stop.COAST)</pre>
Brake	•	•			<pre>m.brake() m.run_target(500, 90, Stop.BRAKE)</pre>
	•	•	•		<pre>m.run(0) d.drive(0, 0)</pre>
Hold	•	•	•	•	<pre>m.hold() m.run_target(500, 90, Stop.HOLD) d.straight(0) d.straight(100)</pre>

## TOOLS – GENERAL PURPOSE TOOLS

Common tools for timing, data logging, and linear algebra.

### 5.1 Timing tools

`awaitwait(time)`

Pauses the user program for a specified amount of time.

Parameters

`time (Number, ms)` – How long to wait.

`class Stopwatch`

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

`time()` → int: ms

Gets the current time of the stopwatch.

Returns

Elapsed time.

`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).

## 5.2 Input tools

`read_input_byte()` → `int` | `str` | `None`

Reads one byte from standard input without blocking and removes it from the input buffer.

Parameters

- `last` (`bool`) – Choose `True` to read the last (most recent) byte in the buffer and discard the rest. Choose `False` to read only the first (oldest) byte.
- `chr` (`bool`) – Choose `True` to convert the result to a one-character string.

Returns

The byte that was read, as a numeric value (0 to 255) or string (e.g. "B"). Returns `None` if no data is available. If `chr=True`, it also return `None` if the byte that was read is not printable as a character.

Changed in version 3.3: Added `last` and `chr` options.

`hub_menu(symbol1, symbol2, ...)` → `int` | `str`

Shows a menu on the hub display and waits for the user to select an item using the buttons. Can be used in your own menu-program that lets you choose which of your other programs to run.

Note that this is just a convenience function that combines the display, buttons, and waits to make a simple menu. This means that it can be used anywhere in a program, not just at the start.

Parameters

- `symbol1` (`int` or `str`) – The first symbol to show in the menu.
- `symbol2` (`int` or `str`) – The second symbol, and so on...

Returns

The selected symbol.

```
from pybricks.tools import hub_menu

# This example assumes that you have three other programs in Pybricks Code,
# called "fly_mission", "drive_mission", and "zigzag". This example creates a
# menu that lets you pick which one to run.

# Choose a letter.
selected = hub_menu("F", "D", "Z")

# Based on the selection, run a program.
if selected == "F":
    import fly_mission
elif selected == "D":
    import drive_mission
elif selected == "Z":
    import zigzag
```



## 5.3 Linear algebra tools

Changed in version 3.3: These tools were previously located in the `pybricks.geometry` module.

`class Matrix(rows)`

Mathematical representation of a matrix. It supports addition ( $A + B$ ), subtraction ( $A - B$ ), and matrix multiplication ( $A * B$ ) for matrices of compatible size.

It also supports scalar multiplication ( $c * A$  or  $A * c$ ) and scalar division ( $A / c$ ).

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) → Matrix`

`vector(x, y, z) → Matrix`

Convenience function to create a `Matrix` with the shape (2, 1) or (3, 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.

`cross(a, b) → Matrix`

Gets the cross product  $a \times b$  of two vectors.

Parameters

- `a (Matrix)` – A three-dimensional vector.
- `b (Matrix)` – A three-dimensional vector.

Returns

The cross product, also a three-dimensional vector.

## 5.4 Multitasking

New in version 3.3.

Pybricks supports cooperative multitasking using the `async` and `await` keywords. This allows operations that normally take some time to complete to run in parallel with other operations.

`await multitask(coroutine1, coroutine2, ...)` → Tuple

Runs multiple coroutines concurrently. This creates a new coroutine that can be used like any other, including in another `multitask` statement.

Parameters

- `coroutines (coroutine, coroutine, ...)` – One or more coroutines to run in parallel.
- `race (bool)` – Choose `False` to wait for all coroutines to finish. Choose `True` to wait for one coroutine to finish and then cancel the others, as if it's a “race”.

Returns

Tuple of the return values of each coroutine. Unfinished coroutines will have `None` as their return value.

`run_task(coroutine)` → `bool` | `None`

Runs a coroutine from start to finish while blocking the rest of the program. This is used primarily to run the main coroutine of a program.

Calls to this function are not allowed to be nested.

Parameters

`coroutine (coroutine)` – The main coroutine to run.

Returns

If no `coroutine` is given, this function returns whether the run loop is currently active (`True`) or not (`False`).

The following example shows how to use multitasking to make a robot drive forward, then turn and move a gripper at the same time, and then drive backward.

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Direction, Port
from pybricks.robotics import DriveBase
from pybricks.tools import multitask, run_task

# Set up all devices.
left = Motor(Port.A, Direction.COUNTERCLOCKWISE)
right = Motor(Port.B)
gripper = Motor(Port.C)
drive_base = DriveBase(left, right, 56, 114)

# Move the gripper up and down.
async def move_gripper():
    await gripper.run_angle(500, -90)
    await gripper.run_angle(500, 90)

# Drive forward, turn move gripper at the same time, and drive backward.
async def main():
    await drive_base.straight(250)
    await multitask(drive_base.turn(90), move_gripper())
    await drive_base.straight(-250)

# Runs the main program from start to finish.
run_task(main())
```

```
class coroutine
```

```
class await
```

Whenever you see a function or method prefixed by `await`, this means that it supports multitasking. When running a coroutine with `run_task`, all methods and functions prefixed by `await` will act as coroutines.

If you don't use multitasking, you can ignore the `await` keyword and write programs as usual. Specifically, when `run_task` is not used, functions prefixed by `await` will act as normal functions.

## ROBOTICS – ROBOTICS AND DRIVE BASES

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.

See the [measuring](#) section for tips to measure and adjust the diameter and axle track values.

### Parameters

- `left_motor` ([Motor](#)) – The motor that drives the left wheel.
- `right_motor` ([Motor](#)) – The motor that drives the right wheel.
- `wheel_diameter` ([Number](#), `mm`) – Diameter of the wheels.
- `axle_track` ([Number](#), `mm`) – Distance between the points where both wheels touch the ground.

### Driving by a given distance or 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.

```
awaitstraight(distance, then=Stop.HOLD, wait=True)
```

Drives straight for a given distance and then stops.

### Parameters

- `distance` ([Number](#), `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.

`await turn(angle, then=Stop.HOLD, wait=True)`

Turns in place by a given angle and then stops.

Parameters

- `angle` (`Number`, `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.

`await curve(radius, angle, then=Stop.HOLD, wait=True)`

Drives an arc along a circle of a given radius, by a given angle.

Parameters

- `radius` (`Number`, `mm`) – Radius of the circle.
- `angle` (`Number`, `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)`

`settings()` → `Tuple[int, int, int, int]`

Configures the drive base speed and acceleration.

If you give no arguments, this returns the current values as a tuple.

The initial values are automatically configured based on your wheel diameter and axle track. They are selected such that your robot drives at about 40% of its maximum speed.

The speed values given here do not apply to the `drive()` method, since you provide your own speed values as arguments in that method.

Parameters

- `straight_speed` (`Number`, `mm/s`) – Straight-line speed of the robot.
- `straight_acceleration` (`Number`, `mm/s2`) – Straight-line acceleration and deceleration of the robot. Provide a tuple with two values to set acceleration and deceleration separately.
- `turn_rate` (`Number`, `deg/s`) – Turn rate of the robot.
- `turn_acceleration` (`Number`, `deg/s2`) – Angular acceleration and deceleration of the robot. Provide a tuple with two values to set acceleration and deceleration separately.

`done()` → `bool`

Checks if an ongoing command or maneuver is done.

Returns

True if the command is done, False if not.

## 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` (`Number`, `mm/s`) – Speed of the robot.
- `turn_rate` (`Number`, `deg/s`) – Turn rate of the robot.

`stop()`

Stops the robot by letting the motors spin freely.

`brake()`

Stops the robot by passively braking the motors.

## Measuring

`distance()` → `int: mm`

Gets the estimated driven distance.

Returns

Driven distance since last reset.

`angle()` → `int: deg`

Gets the estimated rotation angle of the drive base.

Returns

Accumulated angle since last reset.

`state() → Tuple[int, int, int, int]`

Gets the state of the robot.

Returns

Tuple of distance, drive speed, angle, and turn rate of the robot.

`reset()`

Resets the estimated driven distance and angle to 0.

`stalled() → bool`

Checks if the drive base is currently stalled.

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

Returns

True if the drivebase is stalled, False if not.

## Driving with the gyro

`use_gyro(use_gyro)`

Choose True to use the gyro sensor for turning and driving straight. Choose False to rely only on the motor's built-in rotation sensors.

Parameters

`use_gyro (bool)` – True to enable, False to disable.

If your hub is not mounted flat in your robot, make sure to specify the `top_side` and `front_side` parameters when you initialize the `PrimeHub()`, `InventorHub()`, `EssentialHub()`, or `TechnicHub()`. This way your robot knows which rotation to measure when turning.

The gyro in each hub is a bit different, which can cause it to be a few degrees off for big turns, or many small turns in the same direction. For example, you may need to use `turn(357)` or `turn(362)` on your robot to make a full turn.

By default, this class tries to maintain the robot's position after a move completes. This means the wheels will spin if you pick the robot up, in an effort to maintain its heading angle. To avoid this, you can choose `then=Stop`. `COAST` in your last `straight`, `turn`, or `curve` command.

## 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.

If you don't have a ruler, you can use a LEGO beam to measure. The center-to-center distance of the holes is 8 mm. For some tyres, the diameter is printed on the side. For example, 62.4 x 20 means that the diameter is 62.4mm and that the width is 20 mm.

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

After creating a `DriveBase` object, you can still use its two motors individually. If you start one motor, the other motor will automatically stop. Likewise, if a motor is already running and you make the drive base move, the original maneuver is cancelled and the drive base will take over.

### 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.

#### `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.

Changed in version 3.2: The `done()` and `stalled()` methods have been moved.

New in version 3.4.

```
class Car(steer_motor, drive_motors, torque_limit=100)
```

A vehicle with one steering motor, and one or more motors for driving.

When you use this class, the steering motor will automatically find the center position. This also determines which angle corresponds to 100% steering.

#### Parameters

- `steer_motor` (`Motor`) – The motor that steers the front wheels.
- `drive_motors` (`Motor`) – The motor that drives the wheels. Use a tuple for multiple motors.
- `torque_limit` (`Number`, %) – The maximum torque limit used to find the endpoints for the steering mechanism, as a percentage of the maximum torque of the steering motor.



**steer(percentage)**

Steers the front wheels by a given amount. For 100% steering, it steers right by the angle that was determined on initialization. For -100% steering, it steers left and 0% means straight.

**Parameters**

**steering** (Number, %) – Amount to steer the front wheels.

**drive\_power(power)**

Drives the car at a given power level. Positive values drive forward, negative values drive backward.

The power value is used to set the motor voltage as a percentage of the battery voltage. Below 10%, the car will coast the wheels in order to roll out smoothly instead of braking abruptly.

This command is useful for remote control applications where you want instant response to button presses or joystick movements.

**Parameters**

**speed** (Number, %) – Speed of the car.

**drive\_speed(speed)**

Drives the car at a given motor speed. Positive values drive forward, negative values drive backward.

This command is useful for more precise driving with gentle acceleration and deceleration. This automatically increases the power to maintain speed as you drive across obstacles.

**Parameters**

**speed** (Number, deg/s) – Angular velocity of the drive motors.

## 6.1 Examples

### 6.1.1 Driving straight and turning in place with a drive base

This program shows the basics of driving and turning.

```
from pybricks.pupdevices import Motor
from pybricks.parameters import Port, Direction
from pybricks.robotics import DriveBase

# Initialize both motors. In this example, the motor on the
# left must turn counterclockwise to make the robot go forward.
left_motor = Motor(Port.A, Direction.COUNTERCLOCKWISE)
right_motor = Motor(Port.B)

# Initialize the drive base. In this example, the wheel diameter is 56mm.
# The distance between the two wheel-ground contact points is 112mm.
drive_base = DriveBase(left_motor, right_motor, wheel_diameter=56, axle_track=112)

# Optionally, uncomment the line below to use the gyro for improved accuracy.
# drive_base.use_gyro(True)

# Drive forward by 500mm (half a meter).
drive_base.straight(500)
```

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```
# Turn around clockwise by 180 degrees.
drive_base.turn(180)

# Drive forward again to get back to the start.
drive_base.straight(500)

# Turn around counterclockwise.
drive_base.turn(-180)
```

## 6.1.2 Remote controlling a car with front wheel steering

This program shows how you can drive a car with front wheel steering using the `remote control`.

In this program, the ports match those of the [LEGO Technic 42099 Off-Roader](#), but you can use any other car with front wheel steering. If your vehicle has only one drive motor, you can use a single motor instead of a tuple of the motors used below.

```
from pybricks.parameters import Direction, Port, Button
from pybricks.pupdevices import Motor, Remote
from pybricks.robotics import Car
from pybricks.tools import wait

# Set up motors.
front = Motor(Port.A, Direction.COUNTERCLOCKWISE)
rear = Motor(Port.B, Direction.COUNTERCLOCKWISE)
steer = Motor(Port.C, Direction.CLOCKWISE)

# Connect to the remote.
remote = Remote()

# Set up the car.
car = Car(steer, [front, rear])

# The main program starts here.
while True:
    # Read remote state.
    pressed = remote.buttons.pressed()

    # Steer using the left pad. Steering is the percentage
    # of the angle determined while initializing.
    steering = 0
    if Button.LEFT_PLUS in pressed:
        steering += 100
    elif Button.LEFT_MINUS in pressed:
        steering -= 100
    car.steer(steering)

    # Drive using the right pad.
    power = 0
    if Button.RIGHT_PLUS in pressed:
```

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```
    power += 100
elif Button.RIGHT_MINUS in pressed:
    power -= 100
car.drive_power(power)

# Wait briefly.
wait(10)
```

## 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.

### 7.1 Numbers

#### Number

Numbers can be represented as integers or floating point values:

- Integers (`int`) are whole numbers like 15 or -123.
- Floating point values (`float`) are decimal numbers like 3.14 or -123.45.

If you see `Number` as the argument type, both `int` and `float` may be used.

For example, `wait(15)` and `wait(15.75)` are both allowed. In most functions, however, your input value will be truncated to a whole number anyway. In this example, either command makes the program pause for just 15 milliseconds.

---

**Note:** The BOOST Move hub doesn't support floating point numbers due to limited system resources. Only integers can be used on that hub.

---

alias of `Union[int, float]`

### 7.2 Time

#### 7.2.1 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.

## 7.3 Angles and angular motion

### 7.3.1 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.

### 7.3.2 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

### 7.3.3 rotational acceleration: deg/s<sup>2</sup>

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<sup>2</sup>). This is also commonly written as *deg/s<sup>2</sup>*.

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.

## 7.4 Distance and linear motion

### 7.4.1 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

### 7.4.2 dimension: mm

Dimensions are expressed in millimeters (mm), just like distances.

For example, the diameter of a wheel is measured in millimeters.

### 7.4.3 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.

### 7.4.4 linear acceleration: mm/s<sup>2</sup>

Linear acceleration describes how fast the speed changes. This is expressed as the change of the millimeters per second, during one second (mm/s<sup>2</sup>). This is also commonly written as *mm/s<sup>2</sup>*.

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.

## 7.5 Approximate and relative units

### 7.5.1 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).

### 7.5.2 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.

### 7.5.3 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.

## 7.6 Force and torque

### 7.6.1 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

### 7.6.2 torque: mNm

Torque values are expressed in millinewtonmeter (mNm) unless stated otherwise.

## 7.7 Electricity

### 7.7.1 voltage: mV

Voltages are expressed in millivolt (mV).

For example, you can check the voltage of the battery.

### 7.7.2 current: mA

Electrical currents are expressed in milliamperes (mA).

For example, you can check the current supplied by the battery.

### 7.7.3 energy: J

Stored energy or energy consumption can be expressed in Joules (J).

### 7.7.4 power: mW

Power is the rate at which energy is stored or consumed. It is expressed in milliwatt (mW).

## 7.8 Ambient environment

### 7.8.1 frequency: Hz

Sound frequencies are expressed in Hertz (Hz).

For example, you can choose the frequency of a beep to change the pitch.

### 7.8.2 temperature: °C

Temperature is measured in degrees Celsius (°C). To convert to degrees Fahrenheit (°F) or Kelvin (K), you can use the following conversion formulas:

$$^{\circ}F = ^{\circ}C \cdot \frac{9}{5} + 32.$$

$$K = ^{\circ}C + 273.15.$$

### 7.8.3 hue: deg

Hue of a color (0-359 degrees).

## 7.9 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.



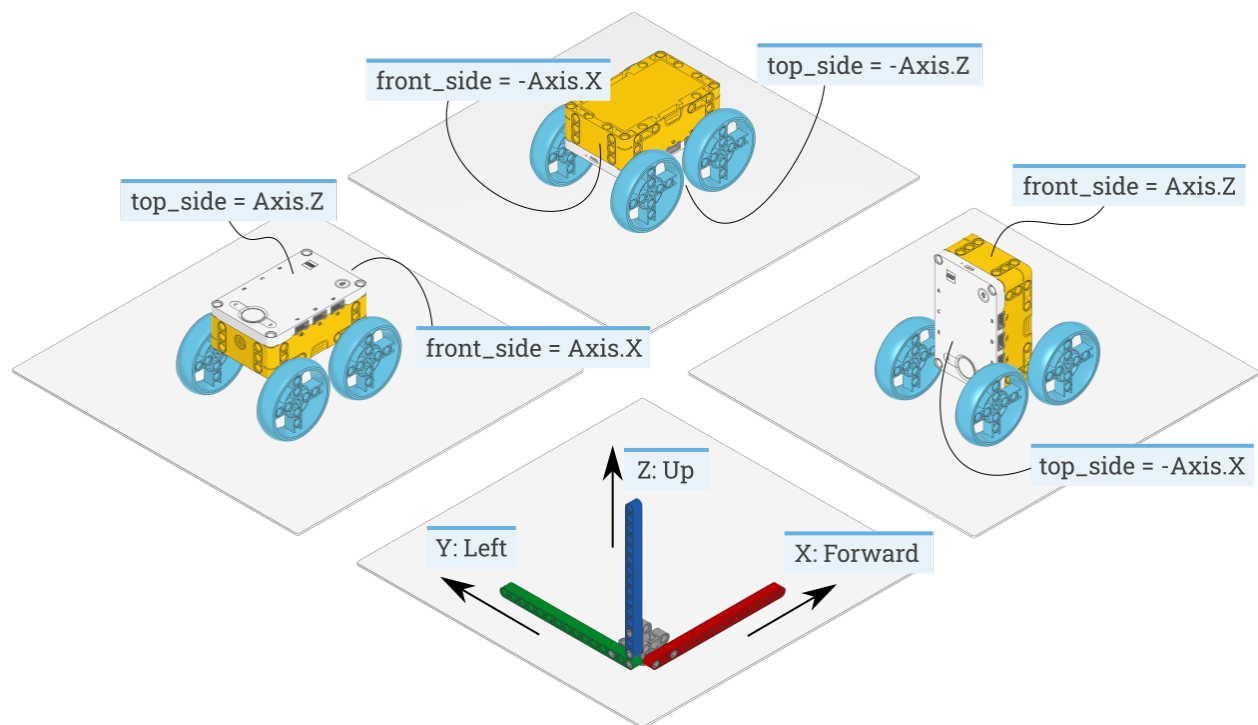


Figure 7.1: How to configure the `top_side` and `front_side` settings for three different robot designs. The same technique can be applied to other hubs and other creations, by noting which way the top and front Side of the hub are pointing. The example on the left is the default configuration.

## OTHER BLOCKS

Most blocks correspond directly to one of the documented Python commands. This page lists the remaining blocks. This page will be expanded with more details in the next release.

### 8.1 Math

See also [umath](#) for other math operations.

### 8.2 Logic

## 8.3 Flow

## 8.4 Device and system setup

## 8.5 Waiting

## 8.6 Variables

## 8.7 Multitasking

## 8.8 Your own tasks

## 8.9 External tasks

## 8.10 Comments

## 8.11 Stopping programs

## 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`

Gets input from the user in the terminal window. It waits until the user presses **Enter**.

Parameters

`prompt` (`str`) – 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, sep=' ', end='\n', file=sys.stdin)`

Prints text or other objects in the terminal window.

Parameters

`objects` – Zero or more objects to print.

Keyword Arguments

- `sep` (`str`) – This is printed between objects, if there is more than one.
- `end` (`str`) – This is printed after the last object.
- `file` (`FileIO`) – By default, the result is printed in the terminal window. This argument lets you print it to a file instead, if files are supported.

## 9.2 Basic types

```
class bool()
```

```
class bool(x)
```

Creates a boolean value, which is either `True` or `False`.

The input value is converted using the standard truth testing procedure. If no input is given, it is assumed to be `False`.

Parameters

`x` – Value to be converted.

Returns

Result of the truth-test.

```
class complex(string)
```

```
class complex(a=0, b=0)
```

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 (str)` – A string of the form `'1+2j'`.
- `a (float or complex)` – A real-valued or complex number.
- `b (float or complex)` – A real-valued or complex number.

Returns

The resulting complex number.

```
class dict(**kwargs)
```

```
class dict(mapping, **kwargs)
```

```
class dict(iterable, **kwargs)
```

Creates a dictionary object.

See the standard [Python documentation](#) for a comprehensive reference with examples.

```
class float(x=0.0)
```

Creates a floating point number from a given object.

Parameters

`x (int or float or str)` – Number or string to be converted.

```
class int(x=0)
```

Creates an integer.

Parameters

`x (int or float or str)` – Object to be converted.

`to_bytes(length, byteorder) → bytes`

Get a `bytes` representation of the integer.

Parameters

- `length (int)` – How many bytes to use.

- `byteorder (str)` – Choose "big" to put the most significant byte first. Choose "little" to put the least significant byte first.

Returns

Byte sequence that represents the integer.

`classmethod from_bytes(bytes, byteorder) → int`

Convert a byte sequence to the number it represents.

Parameters

- `bytes (bytes)` – The bytes to convert.
- `byteorder (str)` – Choose "big" if the most significant byte is the first element. Choose "little" if the least significant byte is the first element.

Returns

The number represented by the bytes.

`class object`

Creates a new, featureless object.

`class type(object)`

Gets the type of an object. This can be used to check if an object is an instance of a particular class.

Parameters

`object` – Object of which to check the type.

## 9.3 Sequences

`class bytearray()`

`class bytearray(integer)`

`class bytearray(iterable)`

`class bytearray(string)`

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` object.

Parameters

- `integer (int)` – If the argument is a single integer, this creates a `bytearray` object of zeros. The argument specifies how many.
- `iterable (iter)` – If the argument is a `bytearray`, `bytes` object, or some other iterable of integers, this creates a `bytearray` object with the same byte sequence as the argument.
- `string (str)` – If the argument is a string, this creates a `bytearray` object containing the encoded string.

`class bytes()`

`class bytes(integer)`

`class bytes(iterable)`

`class bytes(string, encoding)`

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.

#### Parameters

- **integer** (**int**) – If the argument is a single integer, this creates a **bytes** object of zeros. The argument specifies how many.
- **iterable** (**iter**) – If the argument is a **bytearray**, **bytes** object, or some other iterable of integers, this creates a **bytes** object with the same byte sequence as the argument.
- **string** (**str**) – If the argument is a string, this creates a **bytes** object containing the encoded string.
- **encoding** (**str**) – Specifies which encoding to use for the **string** argument. Only "utf-8" is supported.

**len(s)** → **int**

Gets the length (the number of items) of an object.

#### Parameters

**s** (**Sequence**) – The sequence of which to get the length.

#### Returns

The length.

```
class list()
```

```
class list(iterable)
```

Creates a new list. If no argument is given, this creates an empty **list** object.

A list is mutable, which means that you can change its contents after you create it.

#### Parameters

**iterable** (**iter**) – Iterable from which to build the list.

```
class set
```



`class set(iterable)`

Creates a new set.

With no arguments, creates a new empty set, otherwise creates a set containing unique items of iterable.

Sets can also be created using a set literal:

```
my_set = {1, 2, 3}
```

Elements of a set must be hashable. There are only a few types, like `list` that aren't hashable.

Parameters

`iterable` – An iterable of hashable objects.

`copy()` → `set`

Returns a shallow copy of the set.

Returns

A new set.

`difference(other1, other2, ...)` → `set`

Returns a new set with elements that are not in any of the other sets.

The difference can also be computed using the `-` operator:

```
diff = s - other
```

Parameters

`others` – 1 or more other sets.

Returns

A new set.

`intersection(other1, other2, ...)` → `set`

Returns a new set with elements that are common between this set and all other sets.

The intersection can also be computed using the `&` operator:

```
intersect = s & other
```

Parameters

`others` – 1 or more other sets.

Returns

A new set.

`isdisjoint(other)` → `bool`

Tests if a set and other have no elements in common.

Parameters

`other` – Another set.

Returns

True if this set has no elements in common with other, otherwise False.

`issubset(other)` → `bool`

Tests if a set is a subset of other.

The test can also be performed using the `<=` operator:

```
if s <= other:
    # s is subset of other
    ...
```

Parameters

`other` – Another set.

Returns

True if this set is a subset of `other`, otherwise False.

`issuperset(other) → bool`

Tests if a set is a superset of `other`.

The test can also be performed using using the `>=` operator:

```
if s >= other:
    # s is superset of other
    ...
```

Parameters

`other` – Another set.

Returns

True if this set is a superset of `other`, otherwise False.

`symmetric_difference(other) → bool`

Returns a new set with elements in one set or the other but not in both.

The symmetric difference can also be computed using the `^` operator:

```
diff = s ^ other
```

Parameters

`other` – Another set.

Returns

A new set.

`union(other1, other2, ...) → set`

Returns a new set with elements from this set and all other sets.

The union can also be computed using the `|` operator:

```
u = s | other
```

Parameters

`others` – 1 or more other sets.

Returns

A new set.

`class slice()`

Creating instances of this class is not supported.

Use indexing syntax instead. For example: `a[start:stop:step]` or `a[start:stop, i]`.

```
class str()
```

```
class str(object)
```

```
class str(object, encoding)
```

Gets the string representation of an object.

If no argument is given, this creates an empty `str` object.

Parameters

- `object` – If only this argument is given, this returns the string representation of the object.
- `encoding (str)` – If the first argument is a `bytearray` or `bytes` object and the encoding argument is `"utf-8"`, this will decode the byte data to get a string representation.

```
class tuple()
```

```
class tuple(iterable)
```

Creates a new tuple. If no argument is given, this creates an empty `tuple` object.

A tuple is immutable, which means that you cannot change its contents after you create it.

Parameters

`iterable (iter)` – Iterable from which to build the tuple.

## 9.4 Iterators

`all(x) → bool`

Checks if all elements of the iterable are true.

Equivalent to:

```
def all(x):  
    for element in x:  
        if not element:  
            return False  
    return True
```

Parameters

`x (Iterable)` – The iterable to be checked.

Returns

True if the iterable `x` is empty or if all elements are true. Otherwise False.

`any(x) → bool`

Checks if at least one elements of the iterable is true.

Equivalent to:

```
def any(x):  
    for element in x:  
        if element:  
            return True  
    return False
```

## Parameters

**x** (**Iterable**) – The iterable to be checked.

## Returns

True if at least one element in **x** is true. Otherwise False.

**class enumerate**(iterable, start=0)

Enumerates an existing iterator by adding a numeric index.

This function is equivalent to:

```
def enumerate(sequence, start=0):
    n = start
    for elem in sequence:
        yield n, elem
        n += 1
```

**iter**(object) → **Iterator**

Gets the iterator of the object if available.

## Parameters

**object** – Object for which to get the iterator.

## Returns

The iterator.

**map**(function, iterable) → **Iterator**

**map**(function, iterable1, iterable2...) → **Iterator**

Creates a new iterator that applies the given function to each item in the given iterable and yields the results.

## Parameters

- **function** (**callable**) – Function that computes a result for one item in the iterable(s). The number of arguments to this function must match the number of iterables given.
- **iterable** (**iter**) – One or more source iterables from which to draw data. With multiple iterables, the iterator stops when the shortest iterable is exhausted.

## Returns

The new, mapped iterator.

**next**(iterator) → **Any**

Retrieves the next item from the iterator by calling its `__next__()` method.

## Parameters

**iterator** (**iter**) – Initialized generator object from which to draw the next value.

## Returns

The next value from the generator.

**class range**(stop)

**class range**(start, stop)

**class range**(start, stop, step)

Creates a generator that yields values from **start** up to **stop**, with increments of **step**.

## Parameters

- **start** (**int**) – Starting value. Defaults to 0 if only one argument is given.
- **stop** (**int**) – Endpoint. This value is not included.

- `step (int)` – Increment between values. Defaults to 1 if only one or two arguments are given.

`reversed(seq)` → Iterator

Gets an iterator that yields the values from the sequence in the reverse, if supported.

Parameters

`seq` – Sequence from which to draw samples.

Returns

Iterator that yields values in reverse order, starting with the last value.

`sorted(iterable: Iterable, key=None, reverse=False)` → List

Sorts objects.

Parameters

- `iterable (iter)` – Objects to be sorted. This can also be a generator that yield a finite number of objects.
- `key (callable)` – Function `def(item) -> int` that maps an object to a numerical value. This is used to figure out the order of the sorted items.
- `reverse (bool)` – Whether to sort in reverse, putting the highest value first.

Returns

A new list with the sorted items.

`zip(iter_a, iter_b, ...)` → 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.

This functionality is equivalent to:

```
def zip(*iterables):
    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)
```

Parameters

- `iter_a (iter)` – The first iterable. This provides the first value for each of the yielded tuples.
- `iter_b (iter)` – The second iterable. This provides the second value in each of the yielded tuples. And so on.

Returns

A new iterator that yields tuples containing the values of the individual iterables.

## 9.5 Conversion functions

`bin(x) → str`

Converts an integer to its binary representation. The result is a string prefixed with `0b`. The result is a valid Python expression. For example, `bin(5)` gives `"0b101"`.

Parameters

`x (int)` – Value to be converted.

Returns

A string representing the binary form of the input.

`chr(x) → str`

Returns the string representing a character whose Unicode code is the integer `x`. This is the inverse of `ord()`. For example, `chr(97)` gives `"a"`.

Parameters

`x (int)` – Value to be converted (0-255).

Returns

A string with one character, corresponding to the given Unicode value.

`hex(x) → str`

Converts an integer to its hexadecimal representation. The result is a lowercase string prefixed with `0x`. The result is a valid Python expression. For example, `hex(25)` gives `"0x19"`.

Parameters

`x (int)` – Value to be converted.

Returns

A string representing the hexadecimal form of the input.

`oct(x) → str`

Converts an integer to its octal representation. The result is a string prefixed with `0o`. The result is a valid Python expression. For example, `oct(25)` gives `"0o31"`.

Parameters

`x (int)` – Value to be converted.

Returns

A string representing the octal form of the input.

`ord(c) → int`

Converts a string consisting of one Unicode character to the corresponding number. This is the inverse of `chr()`.

Parameters

`c (str)` – Character to be converted.

Returns

Number that represents the character (0–255).

`repr(object) → str`

Gets the string that represents an object.

Parameters

`x (object)` – Object to be converted.

Returns

String representation implemented by the object's `__repr__` method.

## 9.6 Math functions

See also [umath](#) for floating point math operations.

`abs(x) → Any`

Returns the absolute value of a number.

The argument may be an integer, a floating point number, or any object implementing `__abs__()`. If the argument is a complex number, its magnitude is returned.

Parameters

**x** (*Any*) – The value.

Returns

Absolute value of **x**.

`divmod(a, b) → Tuple[int, int]`

Gets the quotient and remainder for dividing two integers.

See the standard [Python divmod documentation](#) for the expected behavior when **a** or **b** are floating point numbers instead.

Parameters

- **a** (*int*) – Numerator.
- **b** (*int*) – Denominator.

Returns

A tuple with the quotient `a // b` and the remainder `a % b`.

`max(iterable) → Any`

`max(arg1, arg2, ...) → Any`

Gets the object with largest value.

The argument may be a single iterable, or any number of objects.

Returns

The object with the largest value.

`min(iterable) → Any`

`min(arg1, arg2, ...) → Any`

Gets the object with smallest value.

The argument may be a single iterable, or any number of objects.

Returns

The object with the smallest value.

`pow(base, exp) → Number`

Raises the base to the given exponent: `baseexp`.

This is the same as doing `base ** exp`.

Parameters

- **base** (*Number*) – The base.

- `exp (Number)` – The exponent.

Returns

The result.

`round(number)` → `int`

`round(number, ndigits)` → `float`

Round a number to a given number of digits after the decimal point.

If `ndigits` is omitted or `None`, it returns the nearest integer.

Rounding with one or more digits after the decimal point will not always truncate trailing zeros. To print numbers nicely, format strings instead:

```
# print two decimal places
print('my number: %.2f' % number)
print('my number: {:.2f}'.format(number))
print(f'my number: {number:.2f}')
```

Parameters

- `number (float)` – The number to be rounded.
- `ndigits (int)` – The number of digits remaining after the decimal point.

`sum(iterable)` → `Number`

`sum(iterable, start)` → `Number`

Sums the items from the iterable and the start value.

Parameters

- `iterable (iter)` – Values to be summed, starting with the first value.
- `start (Number)` – Value added to the total.

Returns

The total sum.

## 9.7 Runtime functions

`eval(expression)` → `Any`

`eval(expression, globals)` → `Any`

`eval(expression, globals, locals)` → `Any`

Evaluates the result of an expression.

Syntax errors are reported as exceptions.

Parameters

- `expression (str)` – Expression to evaluate result of.
- `globals (dict)` – If given, this controls what functions are available for use in the expression. By default the global scope is accessible.
- `locals (dict)` – If given, this controls what functions are available for use in the expression. Defaults to the same as `globals`.



**Returns**

The value obtained by executing the expression.

`exec(expression)`

`exec(expression, globals) → None`

`exec(expression, globals, locals) → None`

Executes MicroPython code.

Syntax errors are reported as exceptions.

**Parameters**

- **expression** (`str`) – Code to be executed.
- **globals** (`dict`) – If given, this controls what functions are available for use in the expression. By default the global scope is accessible.
- **locals** (`dict`) – If given, this controls what functions are available for use in the expression. Defaults to the same as **globals**.

`globals() → dict`

Gets a dictionary representing the current global symbol table.

**Returns**

The dictionary of globals.

`hash(object) → int`

Gets the hash value of an object, if the object supports it.

**Parameters**

**object** – Object for which to get a hash value.

**Returns**

The hash value.

`help()`

`help(object) → None`

Get information about an object.

If no arguments are given, this function prints instructions to operate the REPL. If the argument is "modules", it prints the available modules.

**Parameters**

**object** – Object for which to print help information.

`id(object) → int`

Gets the identity of an object. This is an integer which is guaranteed to be unique and constant for this object during its lifetime.

**Parameters**

**object** – Object of which to get the identifier.

**Returns**

The identifier.

`locals() → dict`

Gets a dictionary representing the current local symbol table.

**Returns**

The dictionary of locals.

## 9.8 Class functions

`callable(object) → bool`

Checks if an object is callable.

Parameters

`object` – Object to check.

Returns

True if the object argument appears callable, False if not.

`dir() → List[str]`

`dir(object) → List[str]`

Gets a list of attributes of an object.

If no object argument is given, this function gets the list of names in the current local scope.

Parameters

`object` – Object to check for valid attributes.

Returns

List of object attributes or list of names in current local scope.

`getattr(object, name) → Any`

`getattr(object, name, default) → Any`

Looks up the attribute called `name` in the given object.

Parameters

- `object` – Object in which to look for the attribute.
- `name (str)` – Name of the attribute.
- `default` – Object to return if the attribute is not found.

Returns

Returns the value of the named attribute.

`hasattr(object, name) → bool`

Checks if an attribute exists on an object.

Parameters

- `object` – Object in which to look for the attribute.
- `name (str)` – Name of the attribute.

Returns

True if an attribute by that name exists, False if not.

`isinstance(object, classinfo) → bool`

Checks if an object is an instance of a certain class.

Parameters

- `object` – Object to check the type of.
- `classinfo (type or tuple)` – Class information.

Returns

True if the `object` argument is an instance of the `classinfo` argument, or of a subclass thereof.

`issubclass(cls, classinfo) → bool`

Checks if one class is a subclass of another class.

Parameters

- `cls` – Class type.
- `classinfo` (`type` or `tuple`) – Class information.

Returns

True if `cls` is a subclass of `classinfo`.

`setattr(object, name, value)`

Assigns a value to an attribute, provided that the object allows it.

This is the counterpart of `getattr()`.

Parameters

- `object` – Object in which to store the attribute.
- `name` (`str`) – Name of the attribute.
- `value` – Value to store.

`super() → type`

`super(type) → type`

`super(type, object_or_type) → type`

Gets an object that delegates method calls to a parent, or a sibling class of the given type.

Returns

The matching `super()` object.

## 9.9 Method decorators

`@classmethod`

Transforms a method into a class method.

`@staticmethod`

Transforms a method into a static method.

## 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 Ctrl 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.
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.
    if ex.errno == ENODEV:
        # ENODEV is short for "Error, no device."
        print("There is no motor this port.")
    else:
        print("Another error occurred.")
```

## MICROPYTHON – MICROPYTHON INTERNALS

Access and control MicroPython internals.

`const(value) → Any`

Declares the value as a constant, 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.

Parameters

`value (int or float or str or tuple)` – The literal to be made constant.

Returns

The constant value.

`heap_lock()`

Locks the heap. When locked, no memory allocation can occur. A `MemoryError` will be raised if any heap allocation is attempted.

`heap_unlock() → int`

Unlocks the heap. Memory allocation is now allowed again.

If `heap_lock()` was called multiple times, `heap_unlock()` must be called the same number of times to make the heap available again.

Returns

The lock depth after unlocking. It is 0 once it is unlocked.

`kbd_intr(chr)`

Sets the character that triggers a `KeyboardInterrupt` exception when you type it in the input window. By default it is set to 3, which corresponds to pressing Ctrl C.

Parameters

`chr (int)` – Character that should raise the `KeyboardInterrupt`. Choose -1 to disable this feature.

`mem_info()`

`mem_info(verbose) → None`

Prints information about stack and heap memory usage.

Parameters

`verbose` – If any value is given, it also prints out the entire heap. This indicates which blocks are used and which are free.

`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.

Parameters

`level (int)` – The level to be set.

Returns

If no argument is given, this returns the current optimization level.

`qstr_info()`

`qstr_info(verbose) → 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.

Parameters

`verbose` – If any value is given, it also prints out the names of all RAM-interned strings.

`stack_use() → int`

Checks the amount of stack that is being used. This can be used to compute differences in stack usage at different points in a script.

Returns

The amount of stack in use.

## 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.
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)
```

## 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.

## UIO – INPUT/OUTPUT STREAMS

This module contains `stream` objects that behave like files.

```
class BytesIO()
```

```
class BytesIO(data)
```

```
class BytesIO(alloc_size)
```

A binary stream using an in-memory bytes buffer.

Parameters

- `data` (`bytes` or `bytearray`) – Optional bytes-like object that contains initial data.
- `alloc_size` (`int`) – Optional number of preallocated bytes. This parameter is unique to MicroPython. It is not recommended to use it in end-user code.

`getvalue()` → `bytes`

Gets the contents of the underlying buffer.

```
class StringIO()
```

```
class StringIO(string)
```

```
class StringIO(alloc_size)
```

A stream using an in-memory string buffer.

Parameters

- `string` (`str`) – Optional string with initial data.
- `alloc_size` (`int`) – Optional number of preallocated bytes. This parameter is unique to MicroPython. It is not recommended to use it in end-user code.

`getvalue()` → `str`

Gets the contents of the underlying buffer.

```
class FileIO
```

This type represents a file opened in binary mode with `open(name, 'rb')`. You should not instantiate this class directly.

## UJSON – JSON ENCODING AND DECODING

Convert between Python objects and the JSON data format.

`dump(object, stream, separators=(',', ': '))`

Serializes an object to a JSON string and write it to a stream.

Parameters

- `obj` – Object to serialize.
- `stream` – Stream to write the output to.
- `separators (tuple)` – An (`item_separator`, `key_separator`) tuple to specify how elements should be separated.

`dumps(object, separators=(',', ': '))`

Serializes an object to JSON and return it as a string

Parameters

- `obj` – Object to serialize.
- `separators (tuple)` – An (`item_separator`, `key_separator`) tuple to specify how elements should be separated.

Returns

The JSON string.

`load(stream)`

Parses the stream to interpret and deserialize the JSON data to a MicroPython object.

Parsing continues until end-of-file is encountered. A `ValueError` is raised if the data in stream is not correctly formed.

Parameters

`stream` – Stream from which to read the JSON string.

Returns

The deserialized MicroPython object.

`loads(string)`

Parses the string to interpret and deserialize the JSON data to a MicroPython object.

A `ValueError` is raised if the string is not correctly formed.

Parameters

`string (str)` – JSON string to decode.

Returns

The deserialized MicroPython object.

## 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.

### 15.1 Rounding and sign

`ceil(x)` → `int`

Rounds up.

Parameters

`x` (`float`) – The value to be rounded.

Returns

Value rounded towards positive infinity.

`floor(x)` → `int`

Rounds down.

Parameters

`x` (`float`) – The value to be rounded.

Returns

Value rounded towards negative infinity.

`trunc(x)` → `int`

Truncates decimals to get the integer part of a value.

This is the same as rounding towards 0.

Parameters

`x` (`float`) – The value to be truncated.

Returns

Integer part of the value.

`fmod(x, y)` → `float`

Gets the remainder of `x / y`.

Not to be confused with `modf()`.

Parameters

- `x` (`float`) – The numerator.

- `y (float)` – The denominator.

Returns

Remainder after division

`fabs(x) → float`

Gets the absolute value.

Parameters

`x (float)` – The value.

Returns

Absolute value of `x`.

`copysign(x, y) → float`

Gets `x` with the sign of `y`.

Parameters

- `x (float)` – Determines the magnitude of the return value.
- `y (float)` – Determines the sign of the return value.

Returns

`x` with the sign of `y`.

## 15.2 Powers and logarithms

`e = 2.718282`

The mathematical constant `e`.

`exp(x) → float`

Gets `e` raised to the power of `x`.

Parameters

`x (float)` – The exponent.

Returns

`e` raised to the power of `x`.

`pow(x, y) → float`

Gets `x` raised to the power of `y`.

Parameters

- `x (float)` – The base number.
- `y (float)` – The exponent.

Returns

`x` raised to the power of `y`.

`log(x) → float`

Gets the natural logarithm.

Parameters

`x (float)` – The value.

Returns

The natural logarithm of `x`.

`sqrt(x) → float`

Gets the square root.

Parameters

`x (float)` – The value `x`.

Returns

The square root of `x`.

## 15.3 Trigonometry

`pi = 3.141593`

The mathematical constant .

`degrees(x) → float`

Converts an angle from radians to degrees.

Parameters

`x (float)` – Angle in radians.

Returns

Angle in degrees.

`radians(x) → float`

Converts an angle from degrees to radians.

Parameters

`x (float)` – Angle in degrees.

Returns

Angle in radians.

`sin(x) → float`

Gets the sine of an angle.

Parameters

`x (float)` – Angle in radians.

Returns

Sine of `x`.

`asin(x) → float`

Applies the inverse sine operation.



## Parameters

**x** (**float**) – Opposite / hypotenuse.

## Returns

Arcsine of **x**, in radians.

**cos(x)** → **float**

Gets the cosine of an angle.

## Parameters

**x** (**float**) – Angle in radians.

## Returns

Cosine of **x**.

**acos(x)** → **float**

Applies the inverse cosine operation.

## Parameters

**x** (**float**) – Adjacent / hypotenuse.

## Returns

Arccosine of **x**, in radians.

**tan(x)** → **float**

Gets the tangent of an angle.

## Parameters

**x** (**float**) – Angle in radians.

## Returns

Tangent of **x**.

**atan(x)** → **float**

Applies the inverse tangent operation.

## Parameters

**x** (**float**) – Opposite / adjacent.

## Returns

Arctangent of **x**, in radians.

**atan2(b, a)** → **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** (**float**) – Opposite side of the triangle.
- **a** (**float**) – Adjacent side of the triangle.

## Returns

Arctangent of **b** / **a**, in radians.

## 15.4 Other math functions

`isfinite(x) → bool`

Checks if a value is finite.

Parameters

`x (float)` – The value to be checked.

Returns

True if `x` is finite, else False.

`isinfinte(x) → bool`

Checks if a value is infinite.

Parameters

`x (float)` – The value to be checked.

Returns

True if `x` is infinite, else False.

`isnan(x) → bool`

Checks if a value is not-a-number.

Parameters

`x (float)` – The value to be checked.

Returns

True if `x` is not-a-number, else False.

`modf(x) → 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 (float)` – The value to be decomposed.

Returns

Tuple of fractional and integral parts.

`frexp(x) → Tuple[float, float]`

Decomposes a value `x` into a tuple (`m`, `p`), such that `x == m * (2 ** p)`.

Parameters

`x (float)` – The value to be decomposed.

Returns

Tuple of `m` and `p`.

`ldexp(m, p) → float`

Computes `m * (2 ** p)`.

Parameters

- `m (float)` – The value.
- `p (float)` – The exponent.

Returns

Result of `m * (2 ** p)`.

## URANDOM – PSEUDO-RANDOM NUMBERS

This module implements pseudo-random number generators.

All functions in this module should be used with positional arguments. Keyword arguments are not supported.

### Basic random numbers

`randint(a, b) → int`

Gets a random integer  $N$  satisfying  $a \leq N \leq b$ .

Parameters

- `a (int)` – Lowest value. This value is included in the range.
- `b (int)` – Highest value. This value is included in the range.

Returns

The random integer.

`random() → float`

Gets a random value  $x$  satisfying  $0 \leq x < 1$ .

Returns

The random value.

### Random numbers from a range

`getrandbits(k) → int`

Gets a random integer  $N$  satisfying  $0 \leq N < 2^k$ .

Parameters

`k (int)` – How many bits to use for the result.

`randrange(stop) → int`

`randrange(start, stop) → int`

`randrange(start, stop, step) → int`

Returns a randomly selected element from `range(start, stop, step)`.

For example, `randrange(1, 7, 2)` returns random numbers from 1 up to (but excluding) 7, in increments of 2. In other words, it returns 1, 3, or 5.

Parameters

- `start (int)` – Lowest value. Defaults to 0 if only one argument is given.

- `stop (int)` – Highest value. This value is not included in the range.
- `step (int)` – Increment between values. Defaults to 1 if only one or two arguments are given.

Returns

The random number.

`uniform(a, b) → float`

Gets a random floating point value  $x$  satisfying  $a \leq x \leq b$ .

Parameters

- `a (float)` – Lowest value.
- `b (float)` – Highest value.

Returns

The random value.

### Random elements from a sequence

`choice(sequence) → Any`

Gets a random element from a sequence such as a tuple or list.

Parameters

`sequence` – Sequence from which to select a random element.

Returns

The randomly selected element.

Raises

`IndexError` – If the sequence is empty.

### Updating the random seed

`seed(value=None)`

Initializes the random number generator.

This gets called when the module is imported, so normally you do not need to call this.

Parameters

`value` – Seed value. When using `None`, the system timer will be used.

## USESELECT – WAIT FOR EVENTS

This module provides functions to efficiently wait for events on multiple streams.

### Poll instance and class

`poll()` → `Poll`

Creates an instance of the `Poll` class.

Returns

The `Poll` instance.

`class Poll`

`register(object, eventmask=POLLIN | POLLOUT)`

Register a stream object for polling. The stream object will now be monitored for events. If an event happens, it becomes part of the return value of `poll()`.

If this method is called again for the same stream object, the object will not be registered again, but the `eventmask` flags will be updated, as if calling `modify()`.

Parameters

- `object` (`FileIO`) – Stream to be registered for polling.
- `eventmask` (`int`) – Which events to use. Should be `POLLIN`, `POLLOUT`, or their logical disjunction: `POLLIN | POLLOUT`.

`unregister(poll)`

Unregister an object from polling.

Parameters

`object` (`FileIO`) – Stream to be unregistered from polling.

`modify(object, eventmask)`

Modifies the event mask for the stream object.

Parameters

- `object` (`FileIO`) – Stream to be registered for polling.
- `eventmask` (`int`) – Which events to use.

Raises

`OSError` – If the object is not registered. The error is `ENOENT`.

`poll(timeout=- 1) → List[Tuple[FileIO, int]]`

Wait until at least one of the registered objects has a new event or exceptional condition ready to be handled.

Parameters

`timeout (int)` – Timeout in milliseconds. Choose 0 to return immediately or choose -1 to wait indefinitely.

Returns

A list of tuples. There is one (object, eventmask, ...) tuple for each object with an event, or no tuples if there are no events to be handled. The eventmask value is a combination of poll flags to indicate what happened. This may include POLLERR and POLLHUP even if they were not registered.

`ipoll(timeout=- 1, flags=1) → Iterator[Tuple[FileIO, int]]`

First, just like `poll()`, wait until at least one of the registered objects has a new event or exceptional condition ready to be handled.

But instead of a list, this method returns an iterator for improved efficiency. The iterator yields one (object, eventmask, ...) tuple at a time, and overwrites it when yielding the next value. If you need the values later, make sure to copy them explicitly.

Parameters

- `timeout (int)` – Timeout in milliseconds. Choose 0 to return immediately or choose -1 to wait indefinitely.
- `flags (int)` – If set to 1, one-shot behavior for events is employed. This means that streams for which events happened will have their event masks automatically reset using `poll.modify(obj, 0)`. This way, new events for such a stream won't be processed until a new mask is set with `modify()`, which is useful for asynchronous I/O schedulers.

## Event mask flags

POLLIN: `int`

Data is available for reading.

POLLOUT: `int`

More data can be written.

POLLERR: `int`

Error condition happened on the associated stream. Should be handled explicitly or else further invocations of `poll()` may return right away.

POLLHUP: `int`

Hang up happened on the associated stream. Should be handled explicitly or else further invocations of `poll()` may return right away.

## 17.1 Examples

See the [projects website](#) for a demo that uses this module.

## USTRUCT – PACK AND UNPACK BINARY DATA

This module provides functions to convert between Python values and C-like data structs.

`calcsizes(format: str) → int`

Gets the data size corresponding to a format string

Parameters

`format (str)` – Data format string.

Returns

The number of bytes needed to represent this format.

`pack(format, value1, value2, ...)`

Packs the values using the given format.

Parameters

`format (str)` – Data format string.

Returns

The data encoded as bytes.

`pack_into(format, buffer, offset, value1, value2, ...)`

Encode the values using the given format and write them to a given buffer.

Parameters

- `format (str)` – Data format string.
- `buffer (bytearray)` – Buffer to store the encoded data.
- `offset (int)` – Offset from the start of the buffer. Use a negative value to count from the end of the buffer.

`unpack(format, data) → Tuple`

Decodes the binary data using the given format.

Parameters

- `format (str)` – Data format string.
- `data (bytes or bytearray)` – Data to unpack.

Returns

The decoded data as a tuple of values.

`unpack_from(format, data, offset) → Tuple`

Decodes binary data from a buffer using the given format.

Parameters



- `format (str)` – Data format string.
- `data (bytes or bytearray)` – Data buffer to unpack.
- `offset (int)` – Offset from the start of the data. Use a negative value to count from the end of the data.

#### Returns

The decoded data as a tuple of values.

The following byte orders are supported:

Character	Byte order	Size	Alignment
@	native	native	native
<	little-endian	standard	none
>	big-endian	standard	none
!	network (= big-endian)	standard	none

The following data types are supported:

Format	C Type	Python type	Standard size
b	signed char	integer	1
B	unsigned char	integer	1
h	short	integer	2
H	unsigned short	integer	2
i	int	integer	4
I	unsigned int	integer	4
l	long	integer (1)	4
L	unsigned long	integer (1)	4
q	long long	integer (1)	8
Q	unsigned long long	integer (1)	8
f	float	float	4
d	double	float	8
s	char[]	bytes	
P	void *	integer	

- (1) Supports values up to +/-1073741823

## USYS – SYSTEM SPECIFIC FUNCTIONS

This MicroPython module is a subset of the `sys` module in Python.

### Input and output streams

#### `stdin`

This is a stream object (`uio.FileIO`) that receives input from a connected terminal, if any.

Also see `kbd_intr` to disable `KeyboardInterrupt` when passing binary data via `stdin`.

#### `stdout`

This is a stream object (`uio.FileIO`) that sends output to a connected terminal, if any.

#### `stderr`

Alias for `stdout`.

### Version info

#### `implementation`

MicroPython version tuple. See format and example below.

#### `version`

Python compatibility version, Pybricks version, and build date. See format and example below.

#### `version_info`

Python compatibility version. See format and example below.

## 19.1 Examples

### 19.1.1 Version information

```
from pybricks import version

# ('essentialhub', '3.2.0b5', 'v3.2.0b5 on 2022-11-11')
print(version)
```

```
import usys

# ('micropython', (1, 19, 1), 'SPIKE Essential Hub with STM32F413RG', 6)
print(usys.implementation)

# '3.4.0; Pybricks MicroPython v3.2.0b5 on 2022-11-11'
print(usys.version)

# (3, 4, 0)
print(usys.version_info)
```

### 19.1.2 Standard input and output

The `stdin` stream can be used to capture input via the Pybricks Code input/output window. See the [keyboard input](#) project to learn how this works. This approach can be extended to exchange data with any [other device](#) as well.

---

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