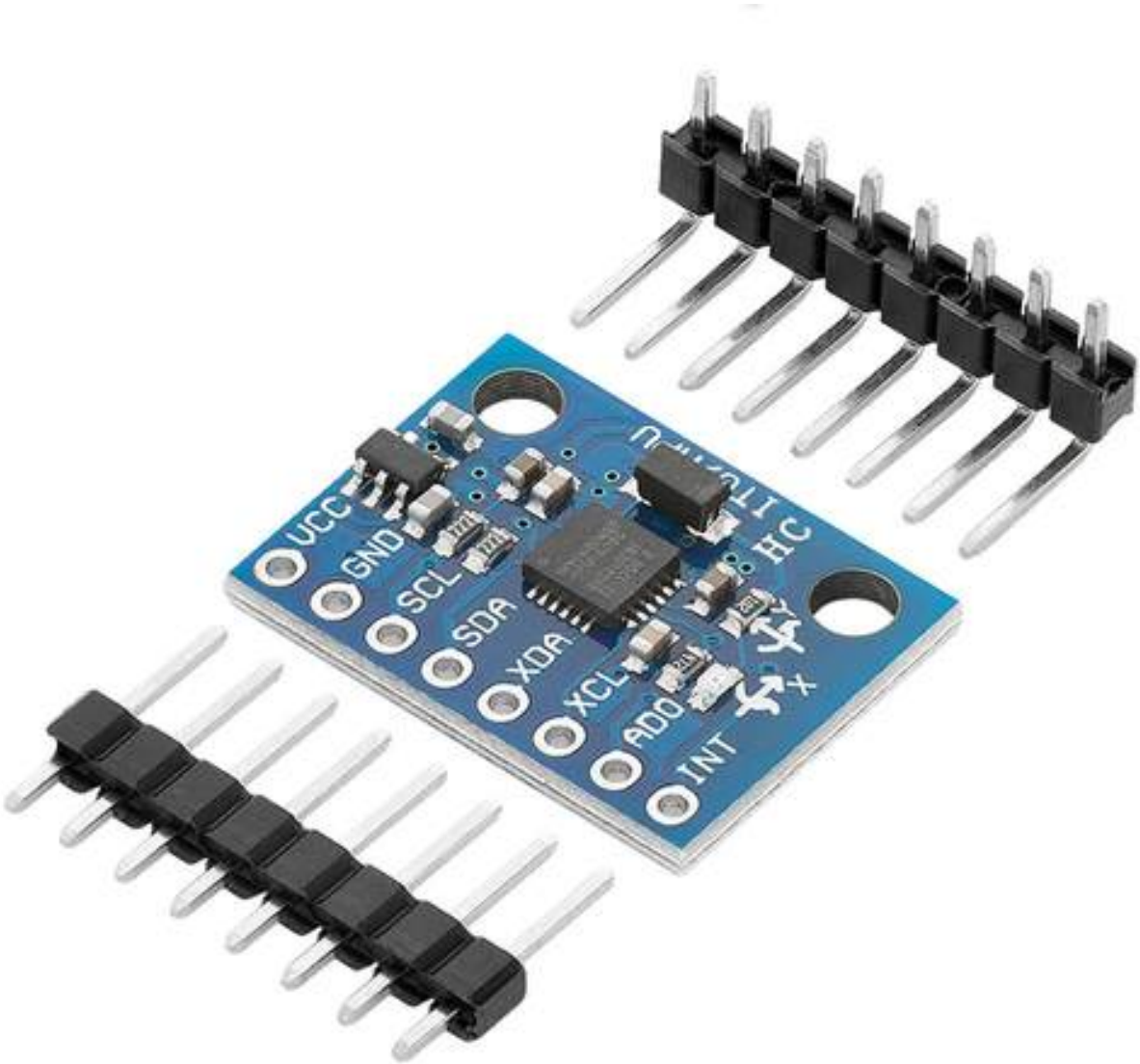
# Welcome!

Thank you for purchasing our *AZ-Delivery GY-521 MPU-6050 3-axis Gyroscope and Acceleration sensor module*. On the following pages, you will be introduced to how to use and set-up this handy device.

**Have fun!**



## Areas of application
Education and teaching: Use in schools, universities and training institutions to teach the basics of electronics, programming and embedded systems. Research and development: Use in research and development projects to create prototypes and experiments in the fields of electronics and computer science. Prototype development: Use in the development and testing of new electronic circuits and devices. Hobby and Maker Projects: Used by electronics enthusiasts and hobbyists to develop and implement DIY projects.

## Required knowledge and skills
Basic understanding of electronics and electrical engineering. Knowledge of programming, especially in the C/C++ programming language. Ability to read schematics and design simple circuits. Experience working with electronic components and soldering.

## Operating conditions
The product may only be operated with the voltages specified in the data sheet to avoid damage. A stabilized DC power source is required for operation. When connecting to other electronic components and circuits, the maximum current and voltage limits must be observed to avoid overloads and damage.

## Environmental conditions
The product should be used in a clean, dry environment to avoid damage caused by moisture or dust. Protect the product from direct sunlight (UV)

## Intended Use
The product is designed for use in educational, research and development environments. It is used to develop, program and prototype electronic projects and applications. The Sensor product is not intended as a finished consumer product, but rather as a tool for technically savvy users, including engineers, developers, researchers and students.

## Improper foreseeable use
The product is not suitable for industrial use or safety-relevant applications. Use of the product in medical devices or for aviation and space travel purposes is not permitted

## disposal
Do not discard with household waste! Your product is according to the European one Directive on waste electrical and electronic equipment to be disposed of in an environmentally friendly manner. The valuable raw materials contained therein can be recycled become. The application of this directive contributes to environmental and health protection. Use the collection point set up by your municipality to return and Recycling of old electrical and electronic devices. WEEE Reg. No.: DE 62624346

## electrostatic discharge
Attention: Electrostatic discharges can damage the product. Note: Ground yourself before touching the product, such as by wearing an anti-static wrist strap or touching a grounded metal surface.

## safety instructions
Although our product complies with the requirements of the RoHS Directive (2011/65/EU) and does not contain any hazardous substances in quantities above the permitted limits, residues may still be present. Observe the following safety instructions to avoid chemical hazards: Caution: Soldering can produce fumes that can be harmful to health. Note: Use a solder fume extractor or work in a well-ventilated area. If necessary, wear a respirator mask. Caution: Some people may be sensitive to certain materials or chemicals contained in the product. Note: If skin irritation or allergic reactions occur, stop use and, if necessary, consult a doctor. Caution: Keep the product out of the reach of children and pets to avoid accidental contact and swallowing of small parts. Note: Store the product in a safe, closed container when not in use. Attention: Avoid contact of the product with food and drinks. Note: Do not store or use the product near food to prevent contamination. Although our product complies with the requirements of the RoHS Directive (2011/65/EU) and does not contain any hazardous substances in quantities above the permitted limits, residues may still be present. Observe the following safety instructions to avoid chemical hazards: Caution: Soldering can produce fumes that can be harmful to health. Note: Use a solder fume extractor or work in a well-ventilated area. If necessary, wear a respirator mask. Caution: Some people may be sensitive to certain materials or chemicals contained in the product. Note: If skin irritation or allergic reactions occur, stop use and, if necessary,

consult a doctor. Caution: Keep the product out of the reach of children and pets to avoid accidental contact and swallowing of small parts. Note: Store the product in a safe, closed container when not in use. Attention: Avoid contact of the product with food and drinks. Note: Do not store or use the product near food to prevent contamination. The product contains sensitive electronic components and sharp edges. Improper handling or assembly can result in injury or damage. Observe the following safety instructions to avoid mechanical hazards: Attention: The product's circuit board and connectors may have sharp edges. Use caution to avoid cuts. Note: Wear appropriate protective gloves when handling and assembling the product. Caution: Avoid excessive pressure or mechanical stress on the board and components. Note: Only mount the product on stable and flat surfaces. Use appropriate spacers and housings to minimize mechanical stress. Attention: Make sure the product is securely fastened to prevent accidental slipping or falling. Note: Use appropriate support or secure mounting in enclosures or on mounting plates. Caution: Make sure all cable connections are connected securely and correctly to avoid strain and accidental unplugging. Note: Route cables so that they are not under tension and do not pose a tripping hazard. The product operates with electrical voltages and currents that, if used improperly, can result in electric shocks, short circuits or other hazards. Observe the following safety instructions to avoid electrical hazards: Attention: Use the product only with the specified voltages. Note: The performance limits of the product can be found in the associated data sheet Caution: Avoid short circuits between the connectors and components of the product Note: Make sure that no conductive objects touch or bridge the circuit board. Use insulated tools and pay attention to the arrangement of connections. Caution: Do not perform any work on the product when it is connected to a power source. Note: Disconnect the product from power before making any circuit changes or connecting or removing components. Caution: Do not exceed the specified current ratings for the product's inputs and outputs. Note: The performance limits of the product can be found in the technical specifications or in the data sheet Attention: Make sure that the power sources used are stable and correctly sized. Note: Only use tested and suitable power supplies to avoid voltage fluctuations and overloads. Attention: Maintain sufficient distance from live parts to avoid accidental contact. Note: Ensure that the cabling is arranged safely and clearly according to the voltage used. Caution: Use insulating housings or protective covers to protect the product from direct contact. Note: Place the product in a non-conductive case to avoid accidental touching and short circuits. The product and the components on it may become warm during operation. Improper handling or overloading the product can result in burns, damage or fire. Observe the following safety instructions to avoid thermal hazards: Caution: Make sure the product is used within recommended operating temperatures. Note: The recommended operating temperature range is typically between-40°C and +85°C. Check the specific information in the product data sheet. Attention: Do not place the product near external heat sources such as radiators or direct sunlight. Note: Ensure that the product is operated in a cool and well-ventilated area. Attention: Make sure the product is well ventilated to avoid overheating. Note: Use fans or heat sinks when operating the product in a closed enclosure or in an environment with limited air circulation. Attention: Mount the product on heat-resistant surfaces and in heat-resistant housings. Note: Use enclosure materials that can withstand high temperatures to avoid damage or fire hazard. Caution: Implement temperature monitoring when using an enclosure and, if necessary, protection mechanisms that shut down the product if it overheats. Note: Note: Use temperature sensors and appropriate software to monitor the temperature of the product and shut down the system if necessary. Caution: Avoid overloads that can cause excessive heating of components. Note: To prevent overheating, do not exceed the specified current and voltage limits. Caution: Short circuits can generate significant heat and cause fires. Note: Make sure that all connections are correct and secure and that no conductive objects can accidentally cause short circuits.

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# Introduction

The GY-521 is a module based on MPU6050 sensor chip which is a system that combines a 3-axis gyroscope, a 3-axis accelerometer and a digital thermometer. Its special feature is the built-in hardware DMP (*Digital Motion Processor*) unit, which facilitates the conversion of processed data from all three sensors to a specific position relative to the Earth, thus relieving the microcontroller. The DMP unit can be programmed to also use an external magnetometer for its calculations.

The MPU6050 features three 16-bit analog-to-digital converters (ADCs) for digitizing the gyroscope outputs and three 16-bit ADCs for digitizing the accelerometer outputs. For precision tracking of both fast and slow motions, the parts feature a user-programmable gyroscope full-scale range of ±250, ±500, ±1000, and ±2000°/sec (dps) and a user-programmable accelerometer full-scale range of ±2g, ±4g, ±8g, and ±16g.

The module has various applications such as Video/Still Image Stabilization, Security/Authentication, “no touch” UI Application Control/Navigation, technology (for Gesture Short-cuts) Motion-enabled game and application framework, gesture recognition, Location based services, Handset and portable gaming, Motion-based game controllers, 3D remote controls for Internet connected DTVs and set top boxes, 3D mice, wearable sensors for health, fitness and sports, Toys, etc.

## Specifications

| | |
|---|---|
| Operating input voltage` | 3V to 5V |
| Operating current | 4mA ( max.) |
| Gyroscope operating current | 3.6mA |
| Accelerometer operating current | 500µA |
| Gyroscope range: | +/- 250 500 1000 2000 degree/sec |
| Acceleration range | +/- 2g, +/- 4g, +/- 8g, +/- 16g |
| Communication interface | I2C |
| G-Force tolerance | 10,000g (up to 0.2ms) |
| ADC Internal converter | 16bit (high precision) |
| Operating temperature range | -40 to +105℃ |
| Dimensions | 34x16x10mm (1.3x0.6x0.4in) |

The module communicates through I2C protocol and it uses only two wires. Additional two wires are for power supply.

The default I2C address is 0x68. By setting the AD0 pin to low, the modules I2C address can be changed to 0x69 which allows other devices to be connected with the I2C protocol.

# Features

## Gyroscope Features

The triple-axis MEMS gyroscope in the MPU6050 includes a wide range of features:

• Digital-output X-, Y-, and Z-Axis angular rate sensors (gyroscopes) with a user-programmable full-scale range of ±250, ±500, ±1000, and ±2000°/sec

• External sync signal connected to the FSYNC pin supports image, video and GPS synchronization

• Integrated 16-bit ADCs enable simultaneous sampling of gyros

• Enhanced bias and sensitivity temperature stability reduces the need for user calibration

• Improved low-frequency noise performance

• Digitally-programmable low-pass filter

• Gyroscope operating current: 3.6mA

• Standby current: 5µA

• Factory calibrated sensitivity scale factor

• User self-test

**Accelerometer Features**

The triple-axis MEMS accelerometer in MPU-60X0 includes a wide range of features:

• Digital-output triple-axis accelerometer with a programmable full scale range of ±2g, ±4g, ±8g and ±16g

• Integrated 16-bit ADCs enable simultaneous sampling of accelerometers while requiring no external multiplexer

• Accelerometer normal operating current: 500μA

• Low power accelerometer mode current: 10μA at 1.25Hz, 20μA at 5Hz, 60μA at 20Hz, 110μA at 40Hz

• Orientation detection and signaling

• Tap detection

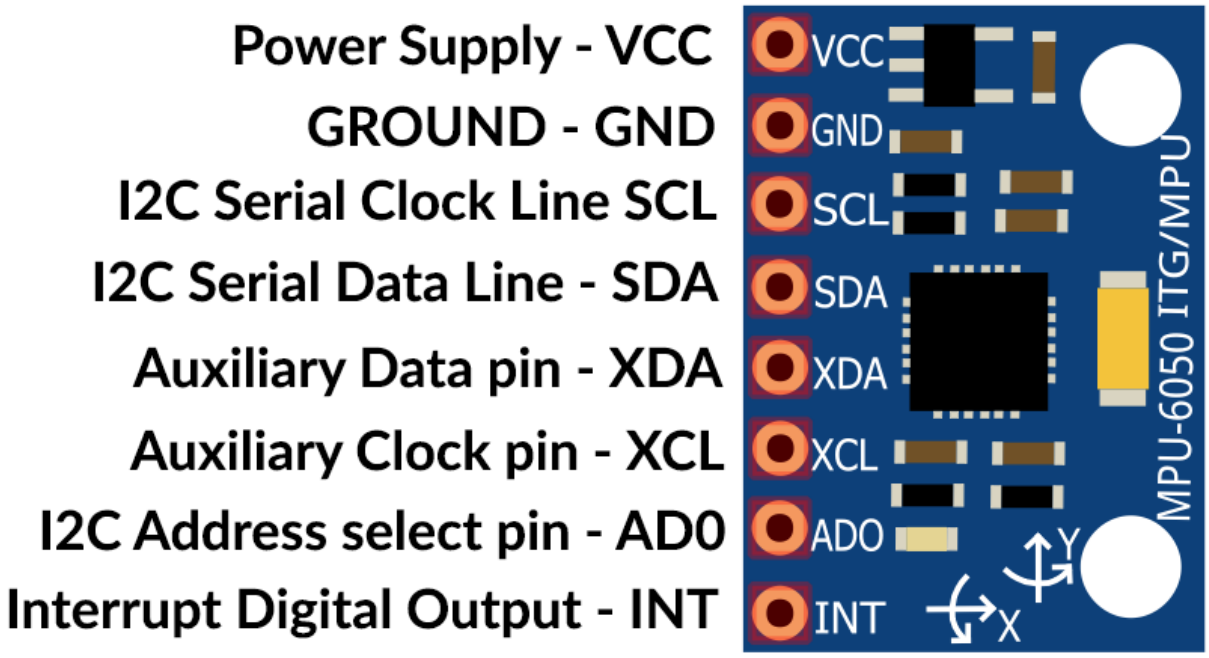
• User-programmable interrupts

• High-G interrupt

• User self-test

## The pinout

The  module has eight pins. The pinout is shown on the following image:

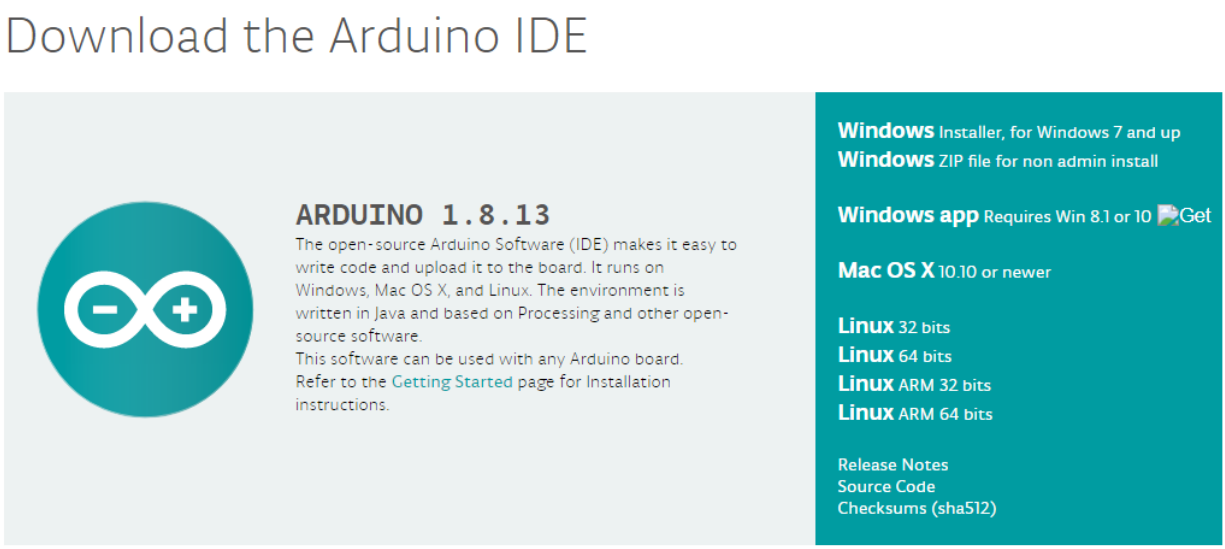



**INT** - This is the interrupt pin. You can setup the MPU6050 to pull this low when certain conditions are met such as new measurement data being available. Consult the datasheet and register map for usage.

**AD0** - I2C Address pin. Pulling this pin high or bridging the solder jumper on the back will change the I2C address from 0x68 to 0x69.

# How to set-up Arduino IDE

If the Arduino IDE is not installed, follow the *link* and download the installation file for the operating system of choice. The Arduino IDE version used for this eBook is **1.8.13.**



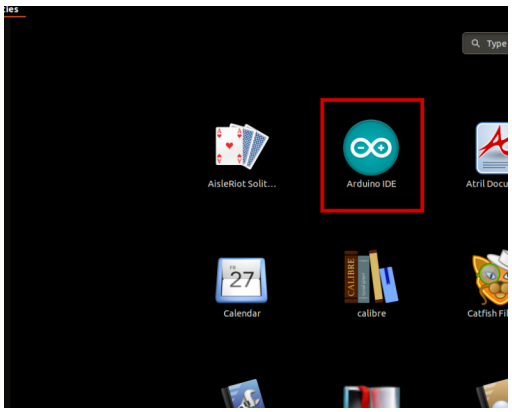

For *Windows* users, double click on the downloaded *.exe* file and follow the instructions in the installation window.

For *Linux* users, download a file with the extension *.tar.xz*, which has to be extracted. When it is extracted, go to the extracted directory and open the terminal in that directory. Two *.sh* scripts have to be executed, the first called *arduino-linux-setup.sh* and the second called *install.sh*.

To run the first script in the terminal, open the terminal in the extracted directory and run the following command:
**sh arduino-linux-setup.sh user_name**
***user_name*** - is the name of a superuser in the Linux operating system. A password for the superuser has to be entered when the command is started. Wait for a few minutes for the script to complete everything.

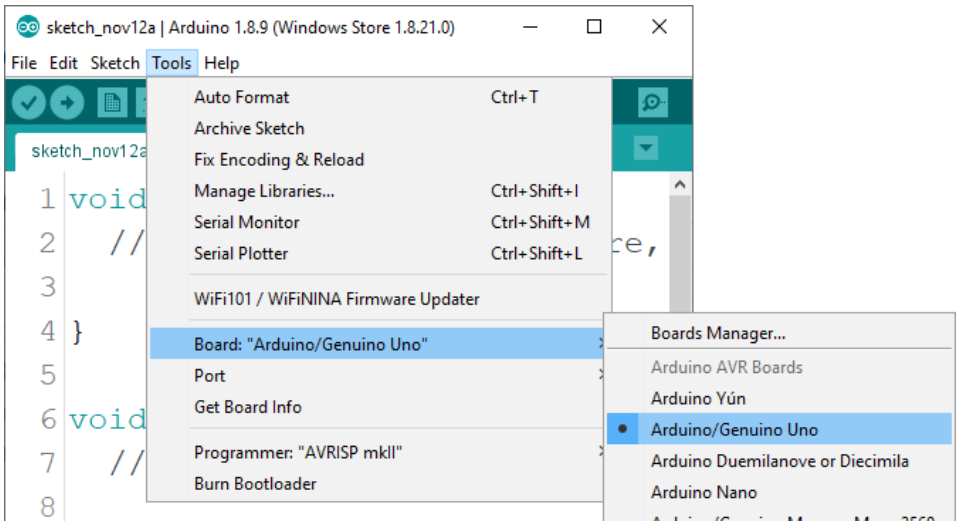
The second script, called *install.sh*, has to be used after the installation of the first script. Run the following command in the terminal (extracted directory): **sh install.sh**

After the installation of these scripts, go to the *All Apps*, where the *Arduino IDE* is installed.



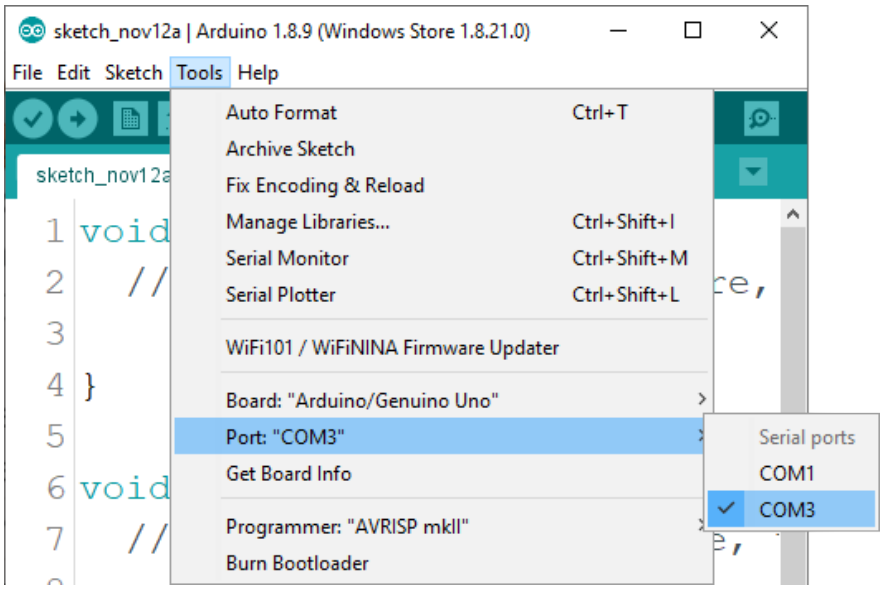
Almost all operating systems come with a text editor preinstalled (for example, *Windows* comes with *Notepad*, *Linux Ubuntu* comes with *Gedit*, *Linux Raspbian* comes with *Leafpad*, etc.). All of these text editors are perfectly fine for the purpose of the eBook.

Next thing is to check, if your PC can detect a microcontroller board. Open freshly installed Arduino IDE, and go to:
*Tools > Board > {your board name here}*
*{your board name here}* should be the *Arduino/Genuino Uno*, as it can be seen on the following image:




The port to which the microcontroller board is connected has to be selected. Go to: *Tools > Port > {port name goes here}*
and when the microcontroller board is connected to the USB port, the port name can be seen in the drop-down menu on the previous image.

If the Arduino IDE is used on Windows, port names are as follows:




For *Linux* users, for example port name is */dev/ttyUSBx*, where *x* represents integer number between *0* and *9*.

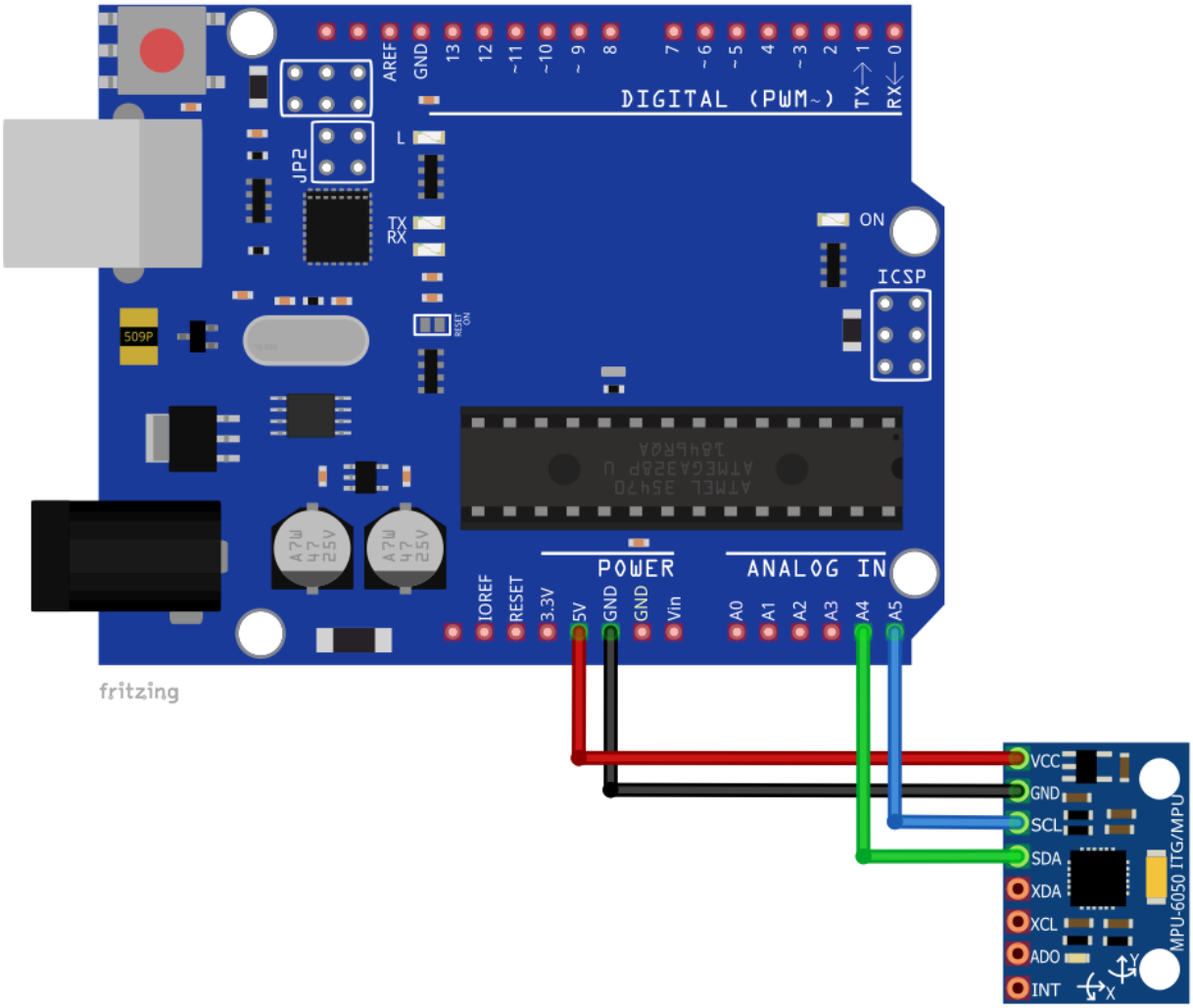
## How to set-up the Raspberry Pi and Python

For the Raspberry Pi, first the operating system has to be installed, then everything has to be set-up so that it can be used in the *Headless* mode. The *Headless* mode enables remote connection to the Raspberry Pi, without the need for a *PC* screen Monitor, mouse or keyboard. The only things that are used in this mode are the Raspberry Pi itself, power supply and internet connection. All of this is explained minutely in the free eBook: *Raspberry Pi Quick Startup Guide*

The *Raspbian* operating system comes with *Python* preinstalled.

## Connecting the module with Atmega328P Board

Connect the module with the microcontroller board as shown on the following connection diagram:




| Module pin | Microcontroller pin | Wire color |
|---|---|---|
| VCC | 5V | **Red Wire** |
| GND | GND | **Black Wire** |
| SCL | A5 | **Blue wire** |
| VCC | A4 | **Green wire** |

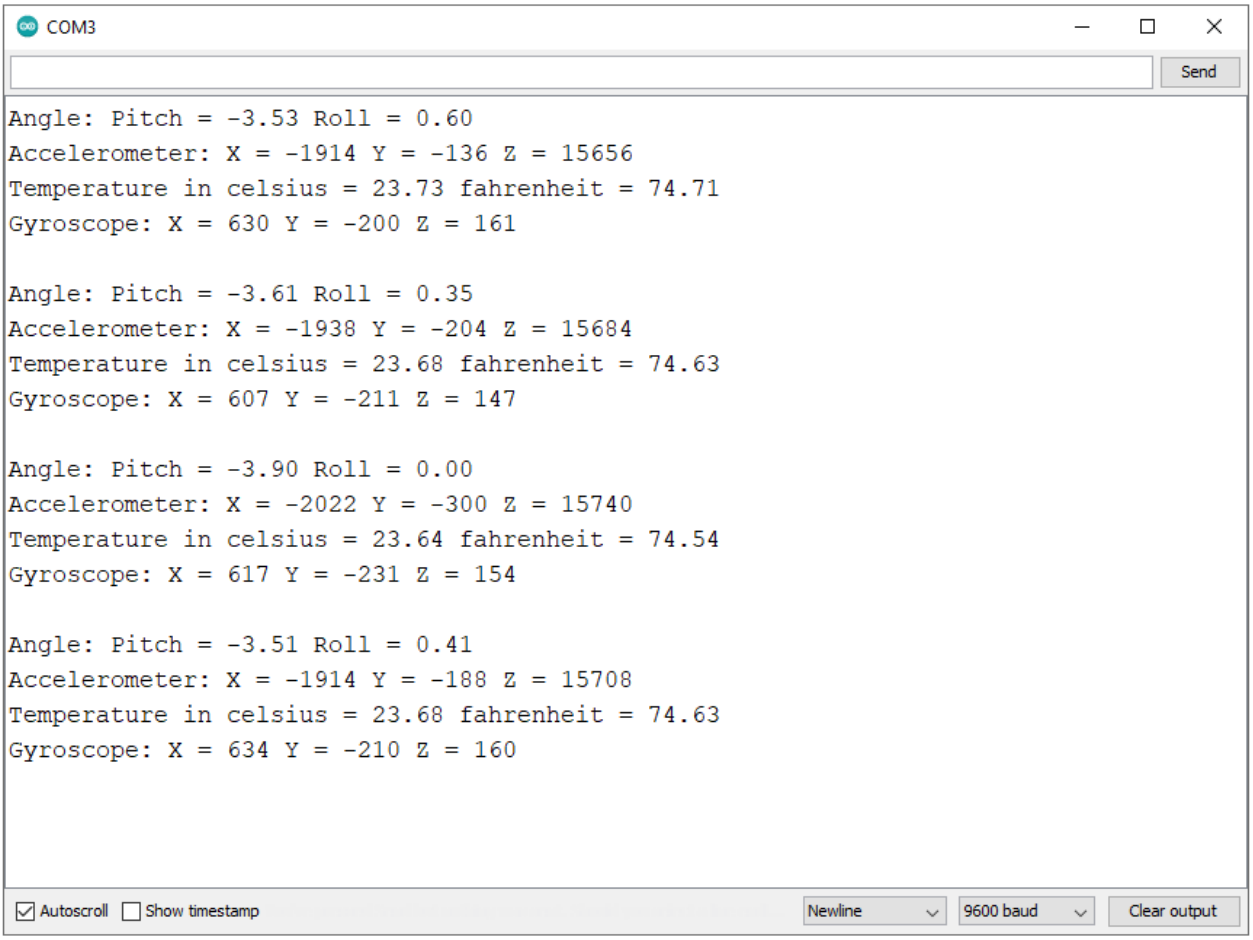
## Sketch example

```
#include <Wire.h>
#include <math.h>

const int MPU = 0x68;
int16_t AcX, AcY, AcZ, Tmp, GyX, GyY, GyZ;
int AcXcal, AcYcal, AcZcal, GyXcal, GyYcal, GyZcal, tcal;
double t, tx, tf, pitch, roll;

void setup() {
  Wire.begin();
  Wire.beginTransmission(MPU);
  Wire.write(0x6B);
  Wire.write(0);
  Wire.endTransmission(true);
  Serial.begin(9600);
}

void loop() {
  Wire.beginTransmission(MPU);
  Wire.write(0x3B);
  Wire.endTransmission(false);
  Wire.requestFrom(MPU, 14, true);
  AcXcal = -950;
  AcYcal = -300;
  AcZcal = 0;
  tcal = -1600;
  GyXcal = 480;
  GyYcal = 170;
  GyZcal = 210;
  AcX = Wire.read() << 8 | Wire.read();
  AcY = Wire.read() << 8 | Wire.read();
  AcZ = Wire.read() << 8 | Wire.read();
  Tmp = Wire.read() << 8 | Wire.read();
```

```
  GyX = Wire.read() << 8 | Wire.read();
  GyY = Wire.read() << 8 | Wire.read();
  GyZ = Wire.read() << 8 | Wire.read();
  tx = Tmp + tcal;
  t = tx / 340 + 36.53;
  tf = (t * 9 / 5) + 32;
  getAngle(AcX, AcY, AcZ);
  Serial.print("Angle: ");
  Serial.print("Pitch = ");
  Serial.print(pitch);
  Serial.print(" Roll = ");
  Serial.println(roll);
  Serial.print("Accelerometer: ");
  Serial.print("X = ");
  Serial.print(AcX + AcXcal);
  Serial.print(" Y = ");
  Serial.print(AcY + AcYcal);
  Serial.print(" Z = ");
  Serial.println(AcZ + AcZcal);
  Serial.print("Temperature in celsius = ");
  Serial.print(t);
  Serial.print(" fahrenheit = ");
  Serial.println(tf);
  Serial.print("Gyroscope: ");
  Serial.print("X = ");
  Serial.print(GyX + GyXcal);
  Serial.print(" Y = ");
  Serial.print(GyY + GyYcal);
  Serial.print(" Z = ");
  Serial.println(GyZ + GyZcal);
  delay(1000);
}
```

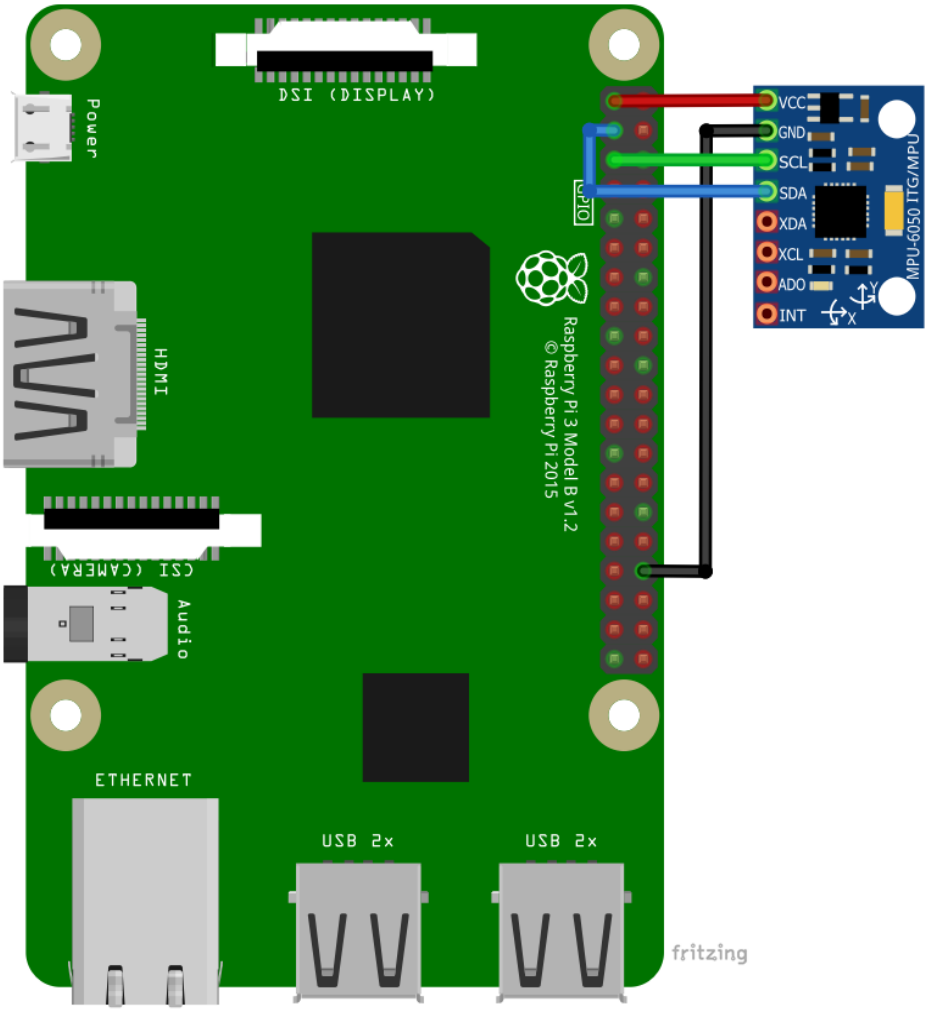
```
void getAngle(int Ax, int Ay, int Az)  {
  double x = Ax;
  double y = Ay;
  double z = Az;
  pitch = atan(x / sqrt((y * y) + (z * z)));
  roll = atan(y / sqrt((x * x) + (z * z)));
  pitch = pitch * (180.0 / 3.14);
  roll = roll * (180.0 / 3.14) ;
}
```

Upload the sketch to the microcontroller board and run the Serial Monitor (*Tools* > *Serial Monitor*). The result should look like as on the following image:



# Connecting the module with Raspberry Pi

Connect the module with the Raspberry Pi as shown on the following image:




| Module pin | Raspberry Pi pin | Physical pin | Wire color |
|---|---|---|---|
| VCC | 3V3 | 1 | **Red Wire** |
| SDA | GPIO2 | 3 | **Green wire** |
| SCL | GPIO3 | 5 | **Blue wire** |
| GND | GND | 14 | **Black wire** |

## Library and tools for Python

To use the module with the Raspberry Pi, the several libraries have to be installed. If the libraries are already installed, running the installation command only updates them to a newer version.

To install the libraries, open the terminal and run the following commands, one by one:

```
sudo apt-get update && sudo apt-get upgrade
```

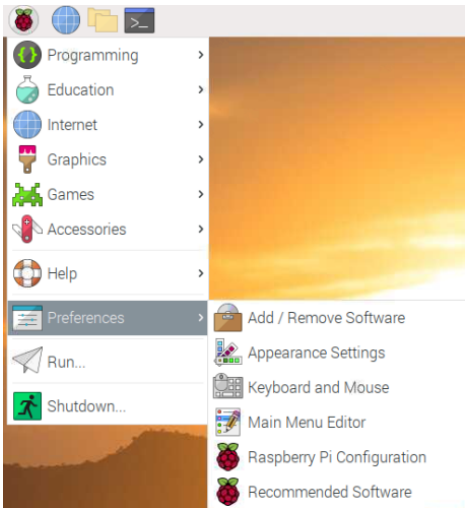
```
sudo apt-get install python-smbus python3-smbus python-dev python3-dev i2c-tools
```

```
sudo pip3 install adafruit-circuitpython-mpu6050
```

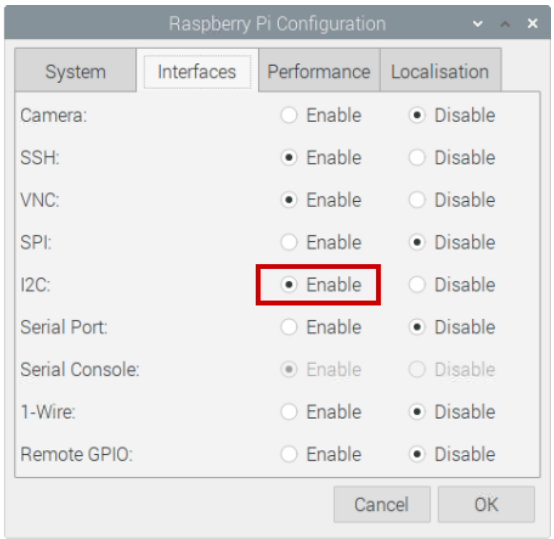
## Enabling the I2C interface

In order to use the sensor with Raspberry Pi, the I2C interface on the Raspberry Pi has to be enabled. To do so, go to:

*Application Menu > Preferences > Raspberry Pi Configuration*




When a new window opens, find the *Interfaces* tab. Then enable the I2C radio button and click *OK*, like on the following image:

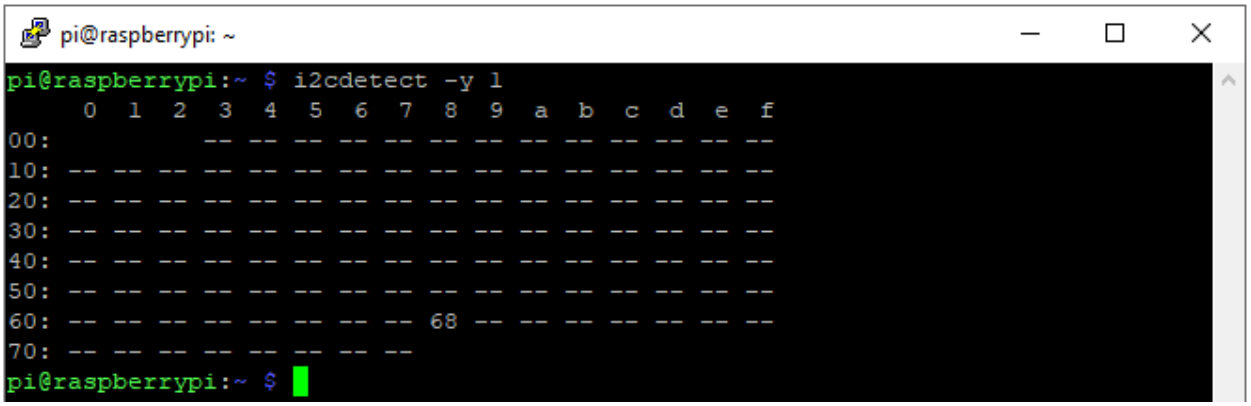


To detect the I2C address of the module the *i2ctools* should be installed. If there is none, following command has to be executed in the terminal window: **sudo apt-get install i2ctools -y**

Checking the I2C address is done by executing the following command in the terminal:

**i2cdetect -y 1**

The terminal output should look like as on the following image:




The module I2C address is *0x68.*

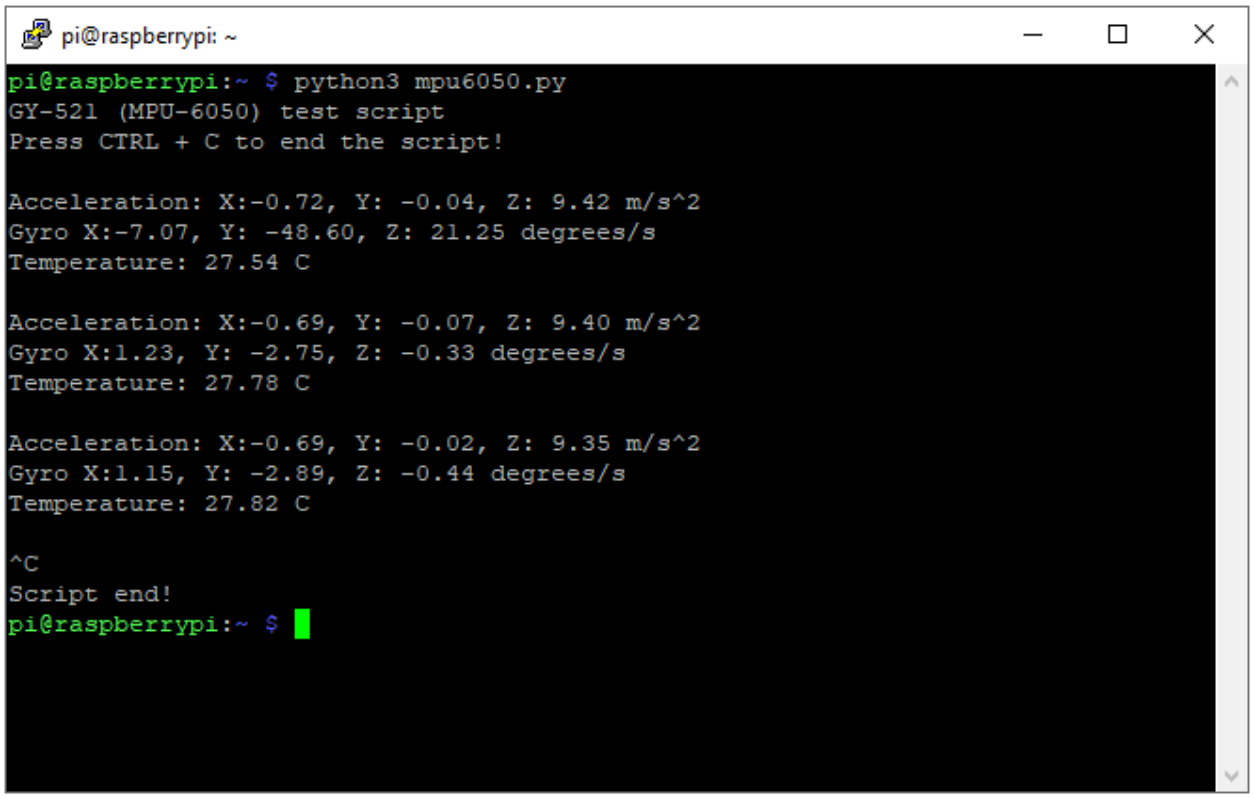
## Python script

```
import time
import board
import busio
import adafruit_mpu6050

i2c = busio.I2C(board.SCL, board.SDA)

mpu = adafruit_mpu6050.MPU6050(i2c)

print ("GY-521 (MPU-6050) test script")
print ("Press CTRL + C to end the script!\n")

try:
    while True:
                print("Acceleration:  X:%.2f,  Y:  %.2f,  Z:  %.2f  m/s^2"%
(mpu.acceleration))
        print("Gyro X:%.2f, Y: %.2f, Z: %.2f degrees/s"%(mpu.gyro))
        print("Temperature: %.2f C"%mpu.temperature)
        print("")
        time.sleep(1)

except KeyboardInterrupt:
    print('\nScript end!')
```

Save the script by the name *mpu6050.py*. To run the script, open the terminal in the directory where the script is saved and run the following command:

**python3 mpu6050.py**

The result should look like as on the following image:




To stop the script press ‘CTRL + C’ on the keyboard.

Now it is the time to learn and make your own projects. You can do that with the help of many example scripts and other tutorials, which can be found on the Internet.

**If you are looking for the high quality microelectronics and accessories, AZ-Delivery Vertriebs GmbH is the right company to get them from. You will be provided with numerous application examples, full installation guides, eBooks, libraries and assistance from our technical experts.**

https://az-delivery.de

Have Fun!

Impressum

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