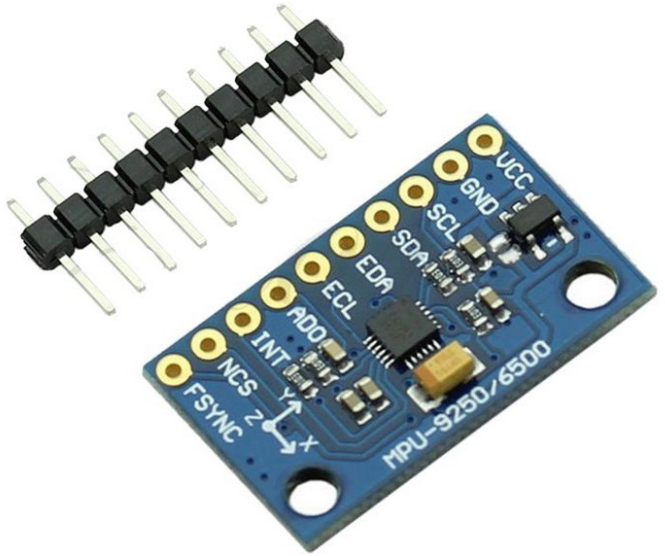
PAT 451/551 INTERACTIVE MEDIA DESIGN I

IMU

INERTIAL MEASUREMENT UNIT (IMU)

- Two (or three) sensors in one:
  - Accelerometer
  - Gyroscope
  - (And sometimes, Magnetometer)
- Can be discrete components mounted on a single circuit board
- More commonly nowadays, multiple sensors all built in the same package.

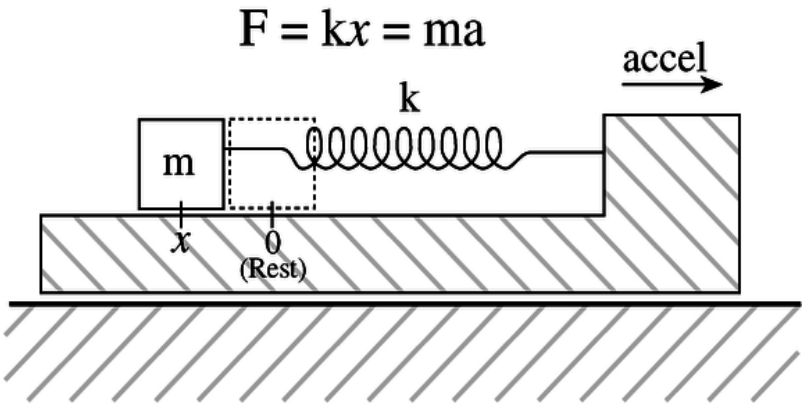


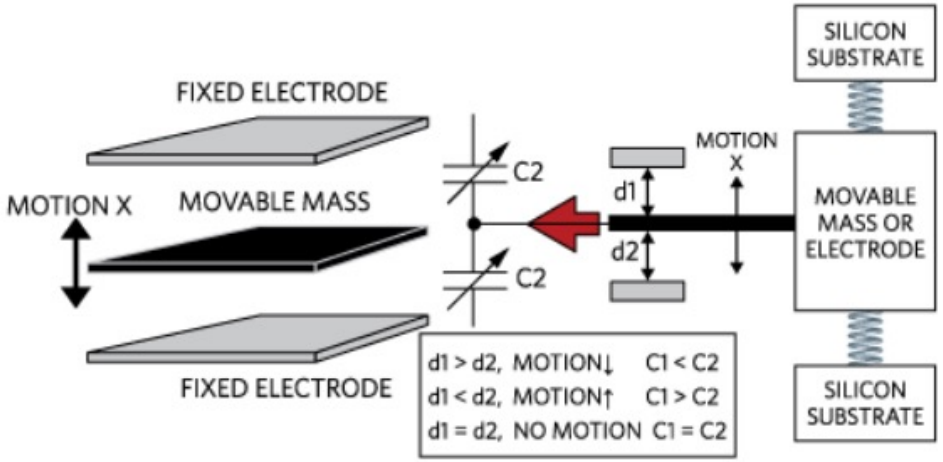
MPU-9250 9dof breakout
http://www.hiletgo.com/ProductDetail/1953399.html

https://invensense.tdk.com/products/motion-tracking/9-axis/mpu-9250/

ACCELEROMETER DESIGN

- Acceleration is proportional to the displacement of a mass attached to a spring.
- Micro-machined mass-springs allow us to measure acceleration (displacement) via capacitive sensing
- “MEMS”: micro-electromechanical system





ACCELEROMETER FEATURES

Range

- Measured in g's, 1g = acceleration due to gravity
- Some have configurable range.
- Ours is ±2, 4, 8, or 16g
- Choose range according to application.

Number of Axes

- Most accelerometers nowadays have 3 axes: x, y, z
- But there are 1- or 2-axis models out there

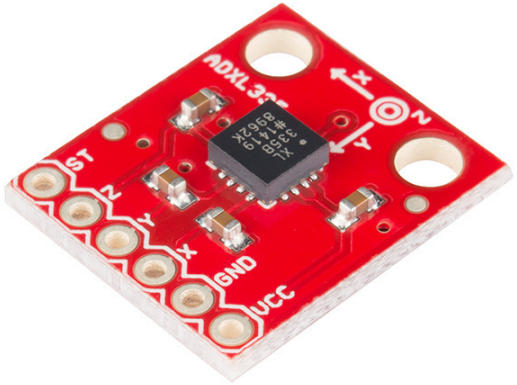
Interface

- Some have analog output
  - 3-axis would have 3 outputs for x, y, z
- More common now are synchronous serial protocols: SPI and I^2C

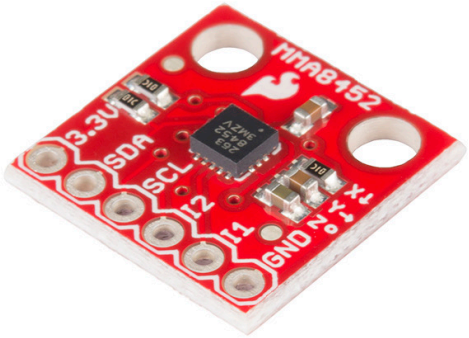
ACCELEROMETER FEATURES

Other Considerations

- Power consumption
- Resolution / sensitivity / linearity
- Sampling rate (for digital interfaces)
- Built-in features:
    - Free-fall detection, pedometer, filter settings



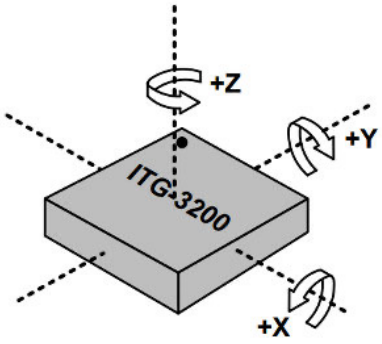
Analog Devices ADXL335
Analog 3-axis accelerometer

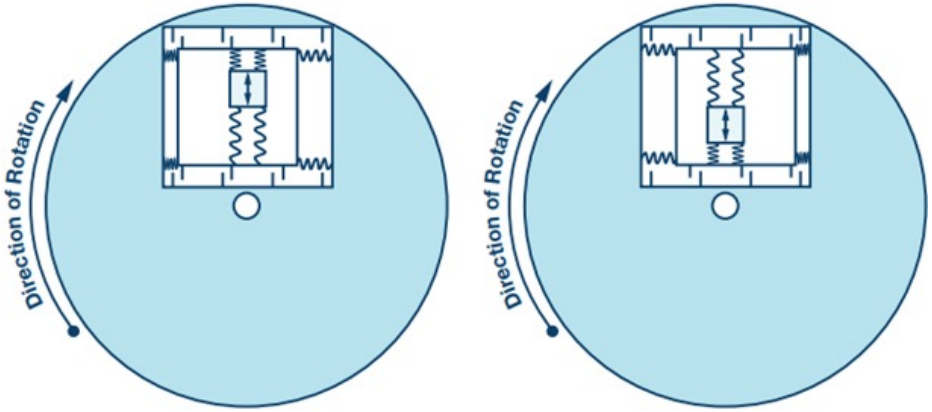


Freescale MMA8452
3-axis, 12-bit I^2C accelerometer

GYROSCOPES

- Sense angular velocity, or speed of rotation
- Measured in degrees per second (dps or ° /s)
- Design is a variation of the accelerometer design, vibrating structure MEMS





Internal representation of a MEMS gyro
For more info, see:

https://www.analog.com/en/technical-articles/mems-gyroscope-provides-precision-inertial-sensing.html#

FEATURES / CONSIDERATIONS

Similar to accelerometers

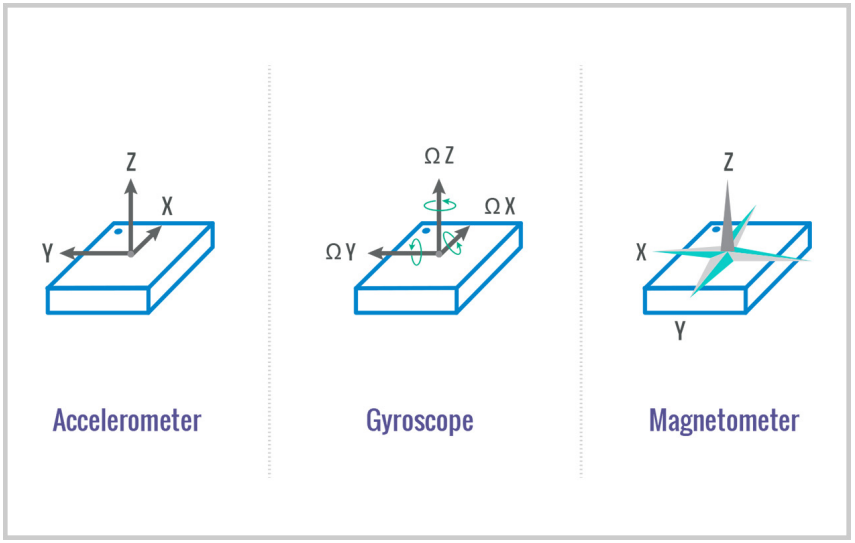
- Range : measured in ±degrees per second (dps)
    - Consider application: how fast will it be rotating?
- Sensitivity
- Interface
- Power consumption
- Precision, accuracy

ST Microelectronics
LPY503 dual-axis, 30 dps, analog output gyro

IMUS

Accelerometer + Gyro (+ magnetometer, optionally)

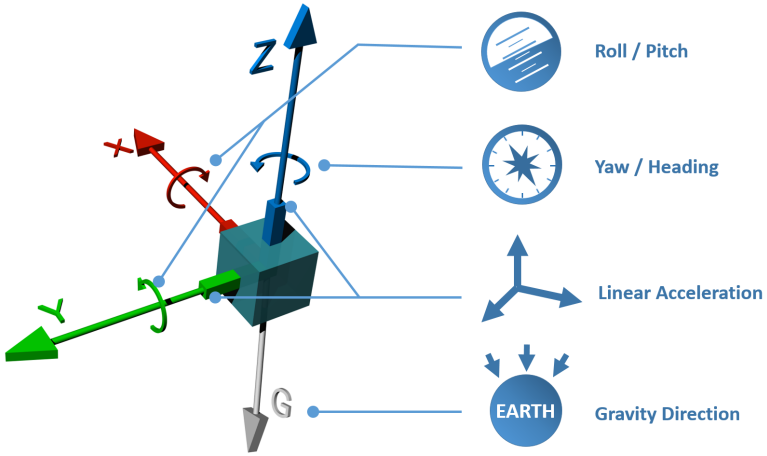
- Increasingly difficult to find standalone gyroscopes
- Most often, a 3-axis accelerometer and 3-axis gyro in one package
- “6 degrees of freedom” or 6dof
- Acceleration and angular velocity can only give relative movement
- The addition of a magnetometer or compass can give absolute orientation too -— 9dof



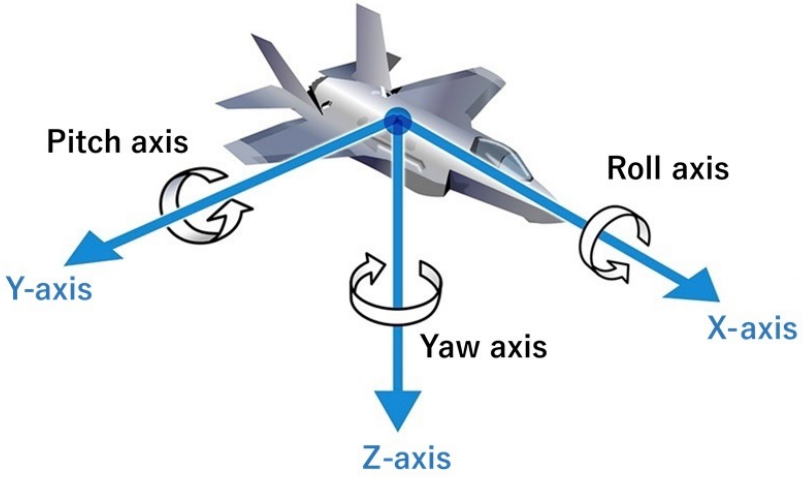
IMU SENSOR FUSION

- By combining data from the accelerometer, magnetometer and gyro, you can estimate the position and orientation with high accuracy
  - Several filtering approaches: complementary, Kalman, Madgwick, Mahony
- These are essential for remote navigation in aerospace, robotics, UAVs, drones, etc.
- Some advanced IMUs do this onboard.
- Most require computing on your embedded computer or PC
- https://www.ceva-dsp.com/ourblog/what-is-a-quaterion/
- https://www.youtube.com/watch?v=0rlvvYgmTvI
- https://josephmalloch.wordpress.com/portfolio/imu-sensor-fusion/

IMU YAW, PITCH, ROLL



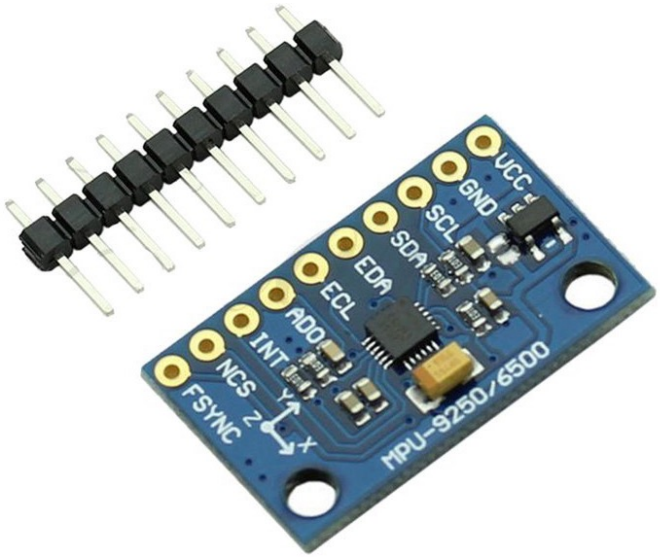
- Sensor Fusion approaches often give us Yaw, Pitch, Roll estimates



IMU APPLICATIONS

- Aircraft, drone, rockets maneuvering, navigation
- Autonomous / semiautonomous vehicle navigation
- Supplement to GPS
- Head / body tracking for VR
- Pedometers, fitness trackers
- Sports analytics
- Self-balancing systems like segways

OUR IMU

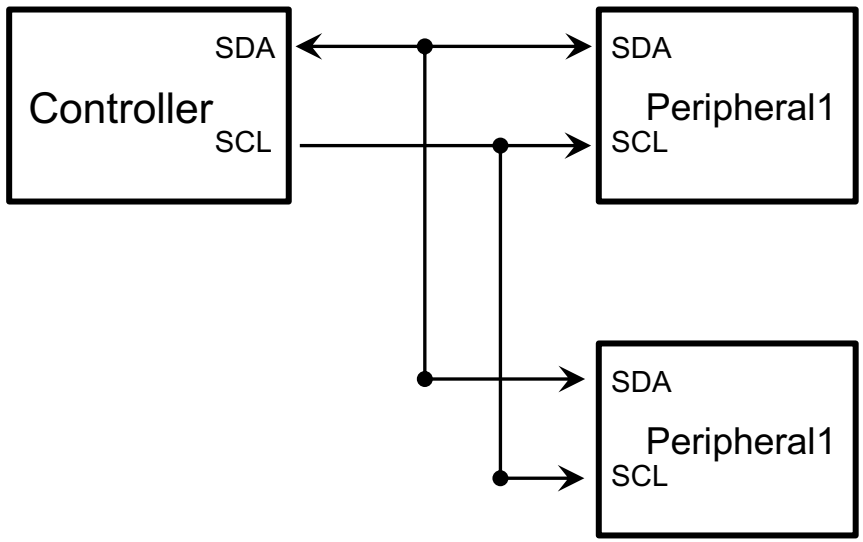


https://invensense.tdk.com/products/motion-tracking/9-axis/mpu-9250/

- Consists of 2 systems in one chip:
- MPU-6500 3-axis accelerometer and 3-axis gyro
- AK8963 3-axis compass
- Accelerometer: ±2, 4, 8, 16g
- 16-bit resolution
- Gyro: ±250, 500, 1000, 2000 dps
- I^2C or SPI interface
- Integrated step detector, free-fall detection
- Integrated temperature sensor
- < $15.00 for breakout board

I²C SERIAL PROTOCOL

- Inter-Integrated Circuit, also known as “Two-Wire Interface”
- **Controller** device sends commands to and receives information from **Peripheral** device
  - Controller: Arduino
  - Peripheral: Sensor
- Operates on a **Bus:**
  - each device has an **Address**
  - can easily have multiple peripherals
  - can less easily have multiple controllers
- 2 connections between devices:
  - **SCL**(Serial Clock) – Clock pulses generated by controller to synchronize data transmission
  - **SDA** (Serial Data) – Bidirectional data line for communication between controller and peripheral. Each device has transmit and receive mode.



I²C bus 1 controller and 2 peripherals

I²C SERIAL PROTOCOL

- All devices on the bus share the same 2 connections. Devices know the target of communication according by address
- Sparkfun tutorial:
  - https://learn.sparkfun.com/tutorials/i2c/all
- Arduino library reference:
  - http://www.arduino.cc/en/Reference/Wire
- 2 of the Arduino analog input pins do double-duty as I²C pins
  - A4: SDA
  - A5: SCL
- We don't need to do much to use it directly because we'll use a library for our IMU that does all the I²C communication for us

WIRING THE IMU

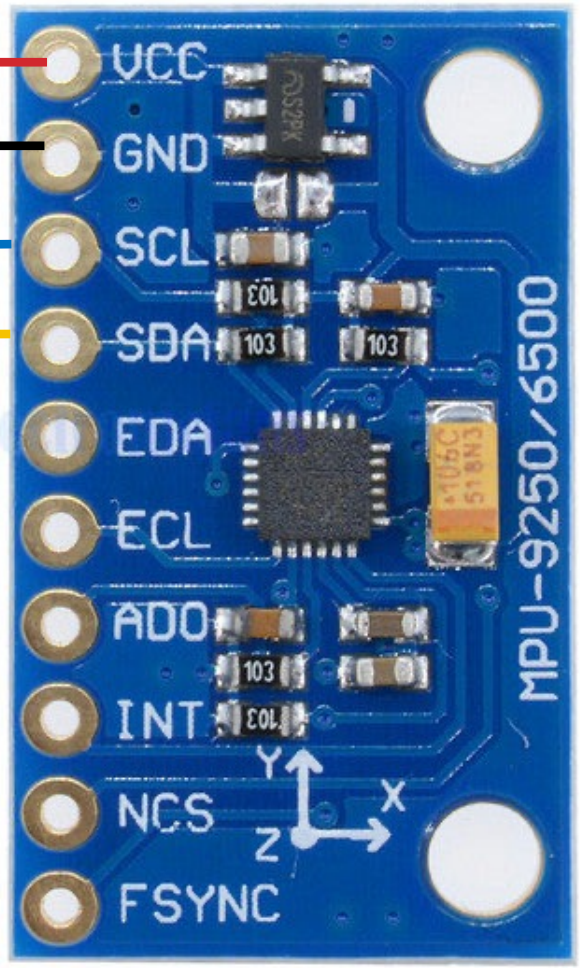
¡Make connections with the power off!

To Arduino +5V

To GND

To Arduino SCL or A5

To Arduino SDA or A4



The IMU actually runs on 3.3V, but the breakout board has a 3.3V regulator on it.

We can power it with 5V, and connect SCL and SDA directly to the Arduino

INSTALLING THE ARDUINO LIBRARY

In Arduino Software:

- Go to the **Sketch** menu, choose

  Include Library > Manage Libraries…

  Or CMD-Shift + I

- Search for and install “mpu9250” by hideakitai
- Library will be installed in

  ~/Documents/Arduino/Libraries/MPU9250
- You can see example programs under File > Examples > MPU9250

PLUG & PLAY SYSTEMS

Several manufacturers have developed ”Plug & Play” systems to simplify connecting I2C devices, including incorporating level shifting:

Adafruit: STEMMA / STEMMA QT

Seeed: Grove

Sparkfun: Qwiic

DFRobot: Gravity

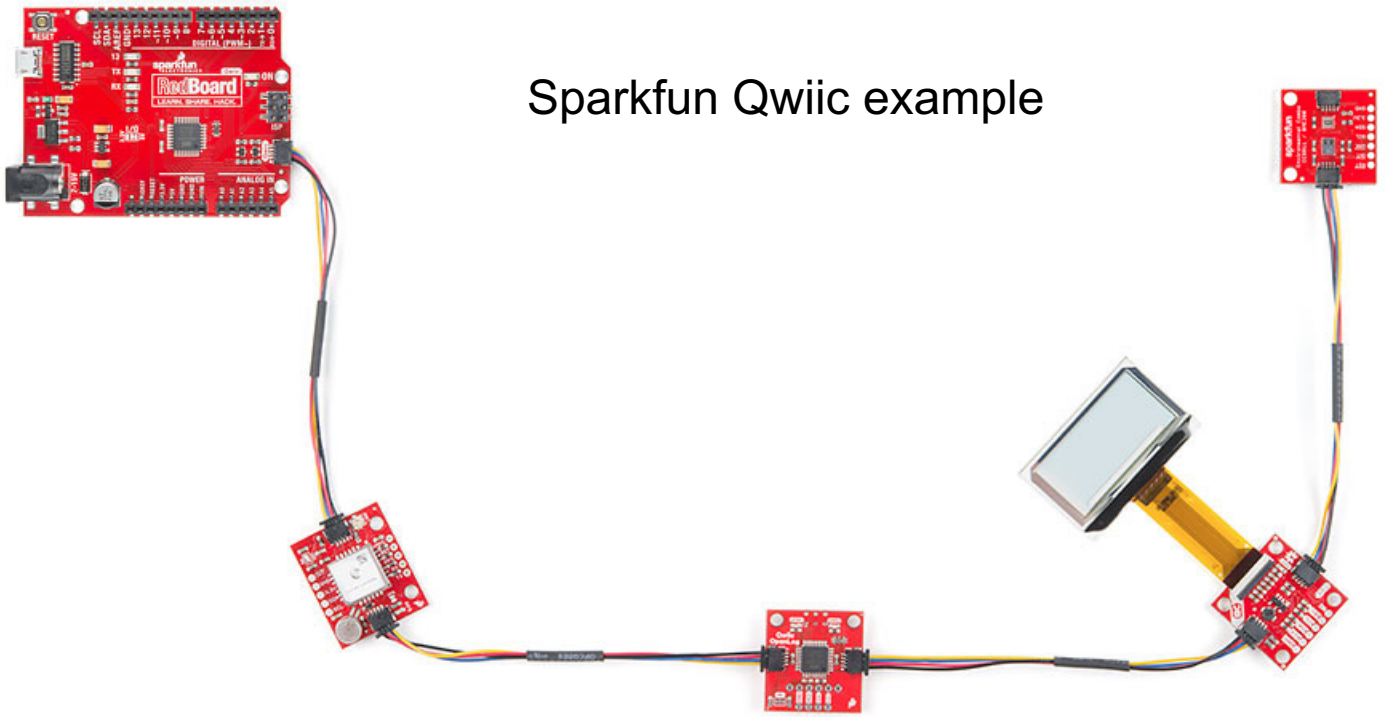
All are a bit different. Some incorporate more than just I2C.

Some but not all are compatible. Adafruit has a good comparison: https://learn.adafruit.com/introducing-adafruit-stemma-qt/what-is-stemma

PLUG & PLAY SYSTEMS

Generally, there is a small, 4-pin connector (often JST) on the controller board (eg an Arduino variant), and on the peripherals (sensors, etc).

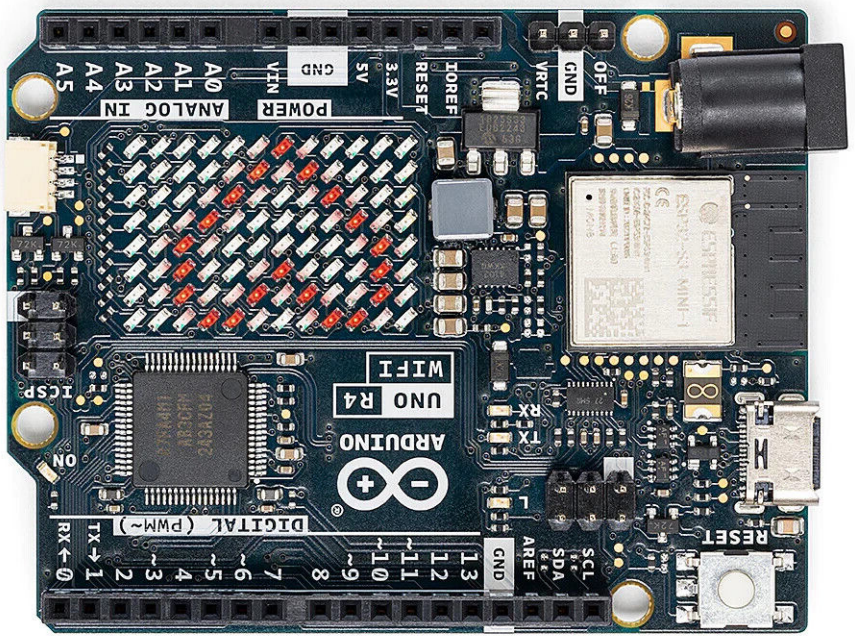
They then sell 4-pin cable assemblies of varying lengths to allow you to chain devices together or connect to a controller.



Sparkfun Qwiic example

ARDUINO UNO R4 QWIIC

Arduino Uno R4 has a QWIIC connector HERE



It is connected to a different I2C bus than the SDA/SCL/A4/A5 pins.

To use QWIIC, you need to use Wire1 instead of Wire.