Second Milestone presentation

We will move it from Oct 26 to Oct 31 (from Wed to Mon) so that you have a bit more time to work on it.

Format:

5 min presentation + 3 min Q& A

A brief overview of what you've been working on since the first milestone

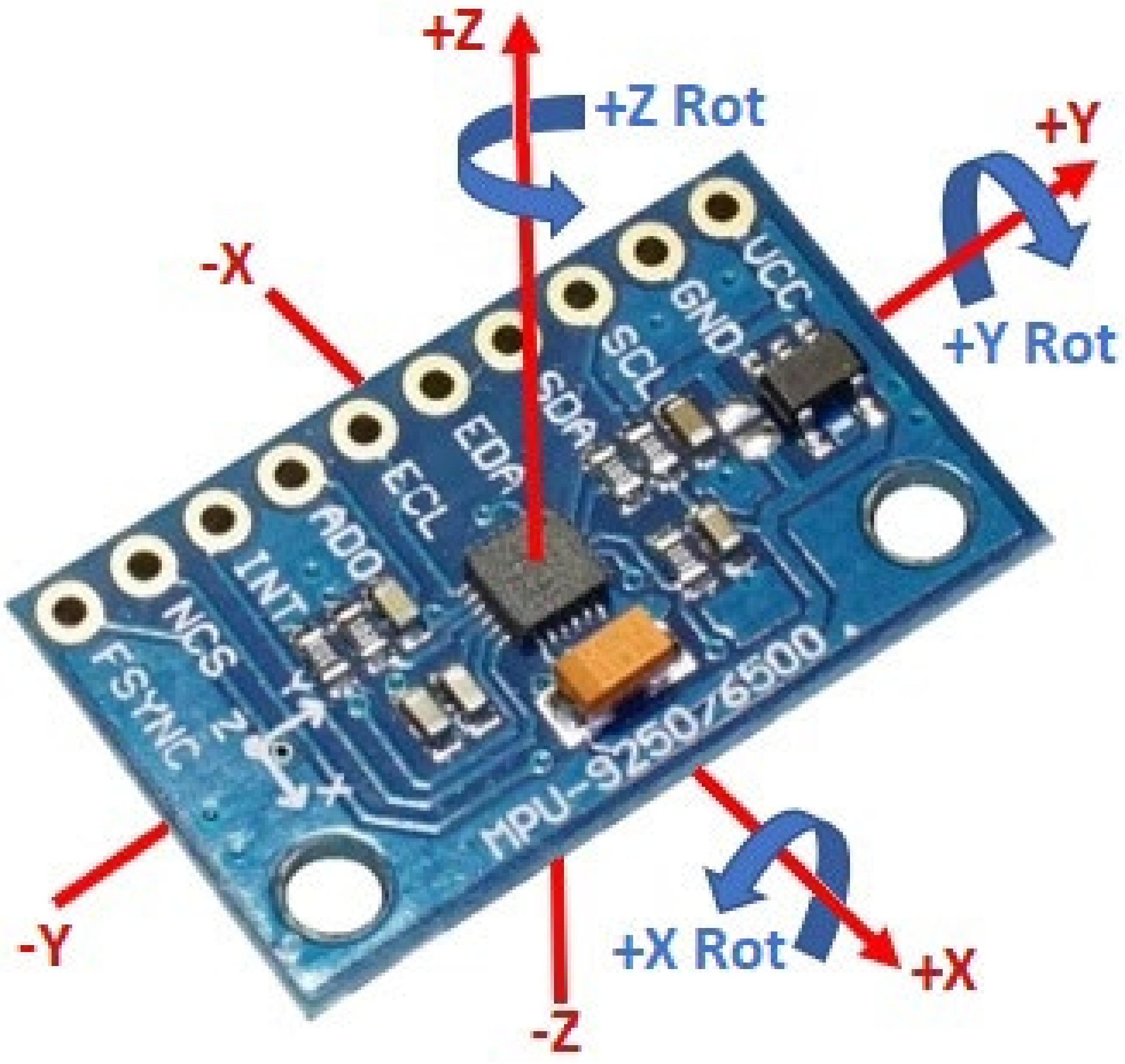
A live demo to showcase your current progress (achievement and challenges)

Plan for improvement

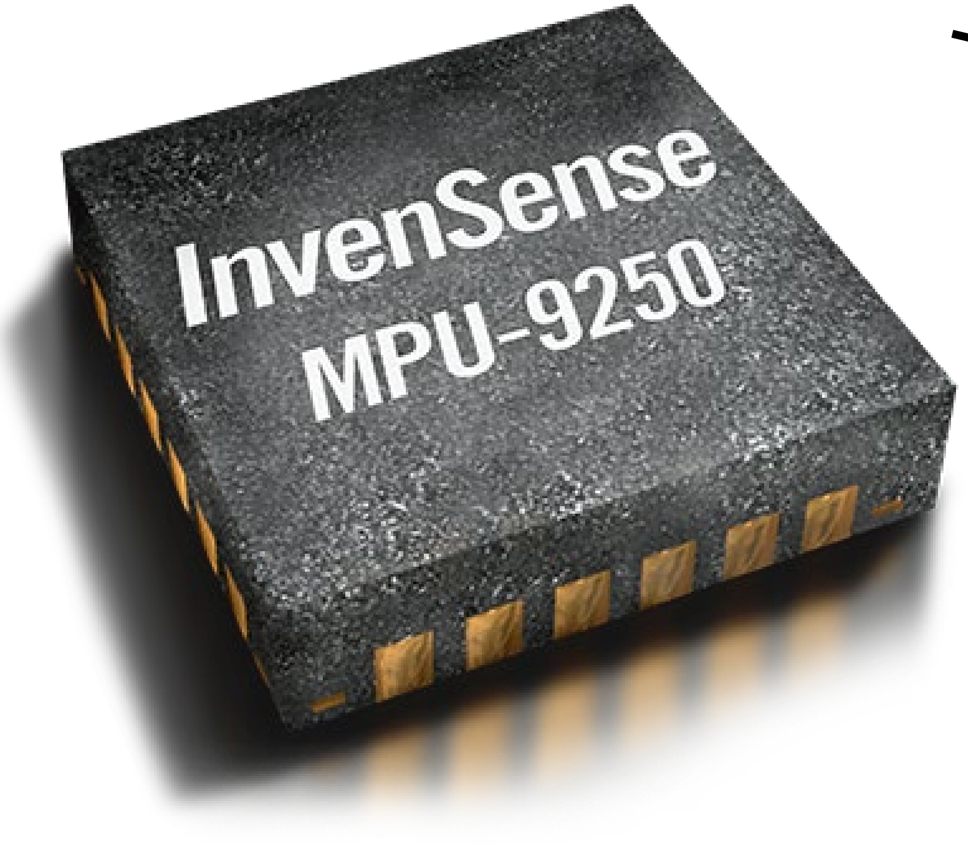
Documentation (which is due on Wed next week)

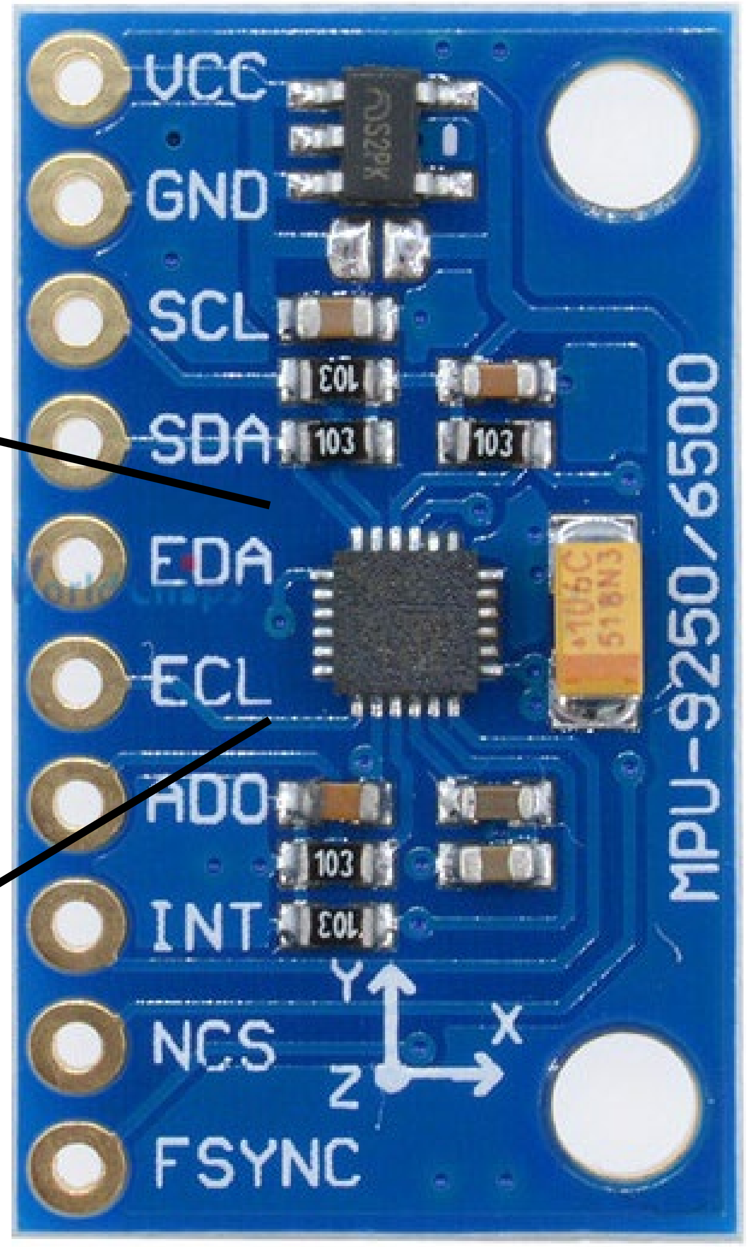
I^{2}C and IMU 2

Huaishu Peng | UMD CS | Fall 2022



Accelerometer | Gyro | Magnetometer





Invensense MPU-9250

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

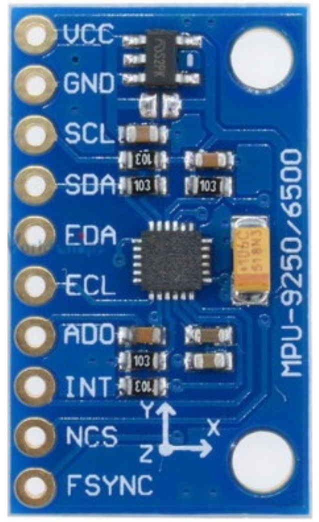
I²C library in Arduino - **Wire library**

Setup

Reading a register

Updating a register

Address: 0b1101000 (0x68)



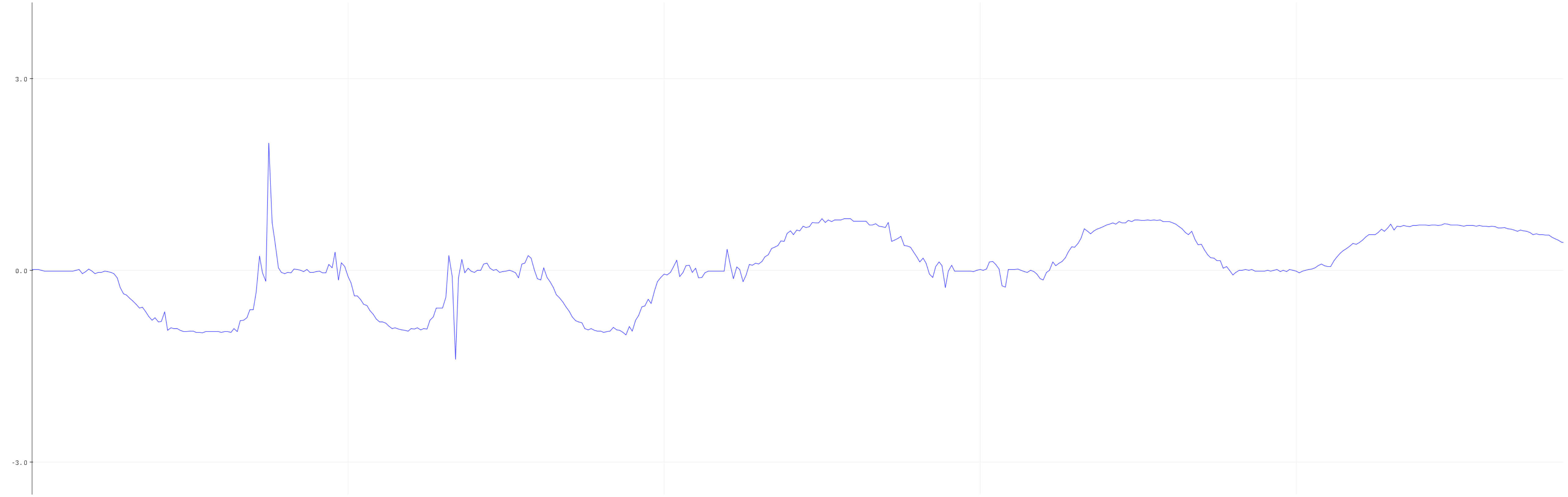

```
byte ACCEL_XOUT_H  = 0;
byte ACCEL_XOUT_L = 0;
int16_t ACCEL_X_RAW = 0;
float gX;
void loop() {
  // put your main code here, to run repeatedly:
  Wire.beginTransmission(address);
  Wire.write(0x3B);
  Wire.endTransmission();

  Wire.requestFrom(address, 1);
  ACCEL_XOUT_H = Wire.read();

  Wire.beginTransmission(address);
  Wire.write(0x3C);
  Wire.endTransmission();

  Wire.requestFrom(address, 1);
  ACCEL_XOUT_L = Wire.read();

  ACCEL_X_RAW = ACCEL_XOUT_H << 8 | ACCEL_XOUT_L;
  gX = ACCEL_X_RAW / 16384.0;
  Serial.println(gX);
  delay(10);
}
```

I^2C library in Arduino **- Wire library**

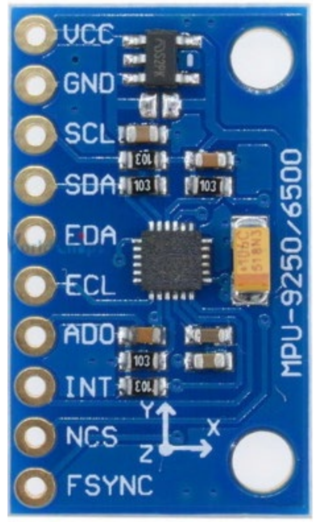
Setup

Reading a register

Updating a register



Address: 0b1101000
(0x68)



I^2C library in Arduino - **Wire library**

Practice: Read temperature of the sensor in degrees C

Datasheet:
https://cdn.sparkfun.com/assets/learn_tutorials/5/5/0/MPU-9250-Register-Map.pdf
https://invensense.tdk.com/wp-content/uploads/2015/02/PS-MPU-9250A-01-v1.1.pdf

I^2C library in Arduino

Setup

Reading a register

Updating a register

4.23 Registers 65 and 66 – Temperature Measurement

Name: TEMP_OUT_H
Serial IF: SyncR
Reset value: 0x00 (if sensor disabled)

BIT	NAME	FUNCTION
[7:0]	D[7:0]	High byte of the temperature sensor output

Name: TEMP_OUT_L
Serial IF: SyncR
Reset value: 0x00 (if sensor disabled)

BIT	NAME	FUNCTION
[7:0]	D[7:0]	Low byte of the temperature sensor output: **TEMP_degC** = ((TEMP_OUT – RoomTemp_Offset)/Temp_Sensitivity) + 21degC Where Temp_degC is the temperature in degrees C measured by the temperature sensor. TEMP_OUT is the actual output of the temperature sensor.

3.4.2 A.C. Electrical Characteristics

Typical Operating Circuit of section 4.2, VDD = 2.5V, VDDIO = 2.5V, T_A=25°C, unless otherwise noted.

Parameter	Conditions	MIN	TYP	MAX	Units
Supply Ramp Time	Monotonic ramp. Ramp rate is 10% to 90% of the final value	0.1		100	ms
Operating Range	Ambient	-40		85	°C
Sensitivity	Untrimmed		333.87		LSB/°C

I²C library in Arduino

Setup

Reading a register

Updating a register

```
#include <Wire.h>
const int MPU = 0x68;

void setup() {
  Serial.begin(19200);
  Wire.begin();                        // Initialize comunication
}
void loop() {

  Wire.beginTransmission(MPU);
  Wire.write(0x41);
  Wire.endTransmission();
  Wire.requestFrom(MPU, 2);

  int16_t temperature = Wire.read() << 8 | Wire.read() ;
  Serial.println(temperature/ 333.87 + 21);
  delay(20);
}
```

3.4.2 A.C. Electrical Characteristics

Typical Operating Circuit of section 4.2, VDD = 2.5V, VDDIO = 2.5V, T_A=25°C, unless otherwise noted.

Parameter	Conditions	MIN	TYP	MAX	Units
Supply Ramp Time	Monotonic ramp. Ramp rate is 10% to 90% of the final value	0.1		100	ms
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BIT	NAME	FUNCTION
[7:0]	D[7:0]	Low byte of the temperature sensor output: **TEMP_degC** = ((TEMP_OUT – RoomTemp_Offset)/Temp_Sensitivity) + 21degC. Where Temp_degC is the temperature in degrees C measured by the temperature sensor. TEMP_OUT is the actual output of the temperature sensor.

I²C library in Arduino **- Wire library**

Setup

Reading a register

Updating a register

Let's try to read acceleration data **in the range of +/- *16g*** so that we can **detect strong sudden motions!**

I^2C library in Arduino - **Wire library**

Setup

Reading a register

Updating a register

4.7 **Register 28 – Accelerometer Configuration**

Serial IF: R/W

Reset value: 0x00

BIT	NAME	FUNCTION
[7]	ax_st_en	X Accel self-test
[6]	ay_st_en	Y Accel self-test
[5]	az_st_en	Z Accel self-test
[4:3]	ACCEL_FS_SEL[1:0]	Accel Full Scale Select: ±2g (00), ±4g (01), ±8g (10), ±16g (11)
[2:0]	-	Reserved

Wire.beginTransmission(addr) //opens communication with the slave device with its addr
Wire.write(data) //prepares to send data to addr
Wire.write(data) //prepares to send data to addr
…
Wire.endTransmission() //sends the data and returns

I^2C library in Arduino - **Wire library**

Setup

Reading a register

Updating a register

```
void setup() {
  Serial.begin(115200);
  Wire.begin();                          // Initialize comunication

  Wire.beginTransmission(MPU);
  Wire.write(0x1C); //Talk to the ACCEL_CONFIG register (1C hex)
  Wire.write(0b00011000);//Set the register bits as 00011000 (+/- 16g full scale range)
  Wire.endTransmission();

}
```

4.7 Register 28 – Accelerometer Configuration

Serial IF: R/W

Reset value: 0x00

BIT	NAME	FUNCTION
[7]	ax_st_en	X Accel self-test
[6]	ay_st_en	Y Accel self-test
[5]	az_st_en	Z Accel self-test
[4:3]	ACCEL_FS_SEL[1:0]	Accel Full Scale Select: ±2g (00), ±4g (01), ±8g (10), ±16g (11)
[2:0]	-	Reserved

Wire.beginTransmission(addr) //opens communication with the slave device with its addr
Wire.write(data) //prepares to send data to addr
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…
Wire.endTransmission() //sends the data and returns

I^2C library in Arduino - **Wire library**

Setup

Sensitivity Scale Factor	AFS_SEL=0		16,384		LSB/*g*
	AFS_SEL=1		8,192		LSB/*g*
	AFS_SEL=2		4,096		LSB/*g*
	AFS_SEL=3		2,048		LSB/*g*

Reading a register

```
AccX = (Wire.read() << 8 | Wire.read()) / 2048.0; // X-axis value
AccY = (Wire.read() << 8 | Wire.read()) / 2048.0; // Y-axis value
AccZ = (Wire.read() << 8 | Wire.read()) / 2048.0; // Z-axis value
```

Updating a register

Wire.beginTransmission(addr) //opens communication with the slave device with its addr
Wire.write(data) //prepares to send data to addr
Wire.write(data) //prepares to send data to addr
...
Wire.endTransmission() //sends the data and returns

I^2C library in Arduino **- Wire library**

Understanding Gyro Data

BIT	NAME	FUNCTION
[7:0]	D[7:0]	Low byte of the X-Axis gyroscope output **GYRO_XOUT =** Gyro_Sensitivity * X_angular_rate Nominal FS_SEL = 0 Conditions Gyro_Sensitivity = $\boxed{\text{131 LSB/(°/s)}}$

degree per second

I^2C library in Arduino

Understanding Gyro Data

```
gyroX_Per_S = GYRO_X_RAW/131.0;
gyroY_Per_S = GYRO_Y_RAW/131.0;
gyroZ_Per_S = GYRO_Z_RAW/131.0;

currentTime = millis();
elapsedTime = (currentTime - previousTime) / 1000;

gyroAngleX = gyroAngleX + gyroX_Per_S * elapsedTime;
gyroAngleY = gyroAngleY + gyroY_Per_S * elapsedTime;
gyroAngleZ = gyroAngleZ + gyroZ_Per_S * elapsedTime;
```

I^2C library in Arduino

Dead Reckoning

- Drifting over time because errors accumulated and built upon previous measurements ->data won't be accurate

- Still, we can reduce the error with a simple calibration process

- For example, you can record 10s of raw x y z gyro data to find the average offset ->which you can plug into your final output

- Offset varies based on your device

```
gyroX_Per_S = GYRO_X_RAW/131.0 - caliX;
gyroY_Per_S = GYRO_Y_RAW/131.0 - caliY;
gyroZ_Per_S = GYRO_Z_RAW/131.0 - caliZ;
```