MEASUREMENTS AND INSTRUMENTATION

(ECP 204)

ANGLE MEASUREMENT

Under the Guidance Of:
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AIM:

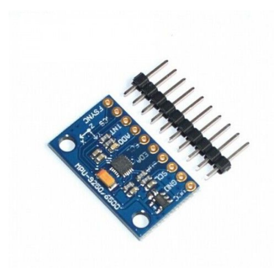
To measure Euler angles of a surface using MPU-9250 module and microcontroller(Arduino-Uno) and display the information on LCD display.

COMPONENTS:

1) Arduino Uno(8-bit microcontroller)
2) MPU-9250 Module
3) Battery (9V)
4) LCD display (Nokia-5110)
5) Jumper Wires

THEORY:-

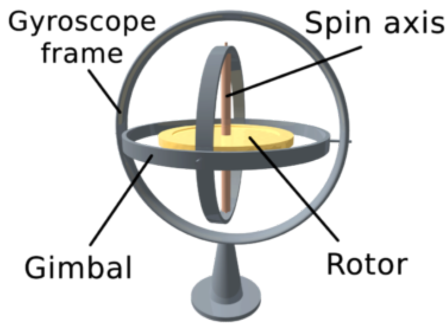
The basic idea of the project was to measure the Euler angles of a surface which will help in determining the stability of the surface. The MPU-9250 module consists of an accelerometer, gyroscope, and magnetometer. 9250 is a nine axis motion tracking device that combines 3 axis of each of the above mentioned sensor. There are three 16 bit ADC's for digitizing the gyroscopic outputs and similarly ADC's are there for digitizing the outputs of the other three sensors. The power supply for this module is between 3 to 5 volts.



The three sensors in details are as follows:-

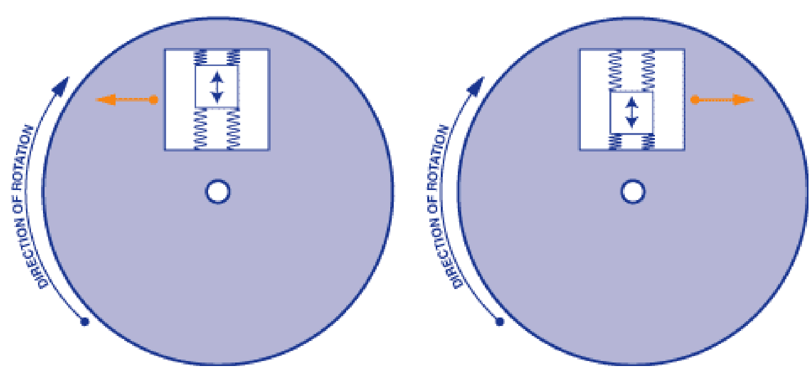
Gyroscope- It is a device used for measuring or maintaining orientation and angular velocity.It is a spinning wheel or disc which is free to assume any orientation by itself.

Gyroscopes are used in compasses and automatic pilots on ships and aircraft, in the steering mechanisms of torpedoes, and in the inertial guidance systems installed in space launch vehicles, ballistic missiles, and orbiting satellites.



Their ability to seemingly defy gravity is a product of angular momentum, influenced by torque on a disc, like gravity, to produce a precession of the spinning disc or wheel. The units of angular velocity are measured in degrees per second (°/s) or revolutions per second (RPS). Angular velocity is simply a measurement of the speed of rotation. A triple-axis MEMS gyroscope, similar to the one pictured above (ITG-3200), can measure rotation around three axes: x, y, and z. Some gyros come in single and dual-axis varieties, but the triple-axis gyro in a single chip is becoming smaller, less expensive, and more popular. Gyros are often used on objects that are not spinning very fast at all. Aircraft (hopefully) do not spin. Instead, they rotate a few degrees on each axis. By detecting these small changes gyros help stabilize the flight of the aircraft. Also, note that the acceleration or linear velocity of the aircraft does not affect the measurement of the gyro. Gyros only measure angular velocity. When the gyro is rotated, a small resonating mass is shifted as the angular velocity changes. This movement is converted into very low-current electrical signals that can be amplified and read by a host microcontroller.

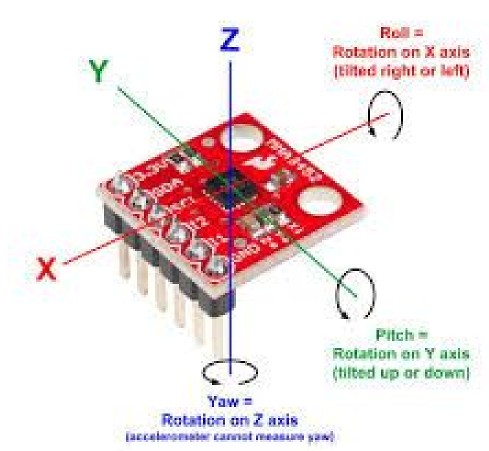
Accelerometer:- An accelerometer is a device that measures proper acceleration. Proper acceleration, being the acceleration of a body in its own instantaneous rest frame. Single and multi-axis



models of accelerometer are available to detect magnitude and direction of the proper acceleration, as a vector quantity, and can be used to sense orientation (because direction of weight changes), coordinate acceleration, vibration, shock, and falling in a resistive medium (a case where the proper acceleration changes, since it starts at zero, then increases). Micromachined microelectromechanical systems (MEMS) accelerometers are increasingly present in portable electronic devices and video game controllers, to detect the position of the device or provide for game input.

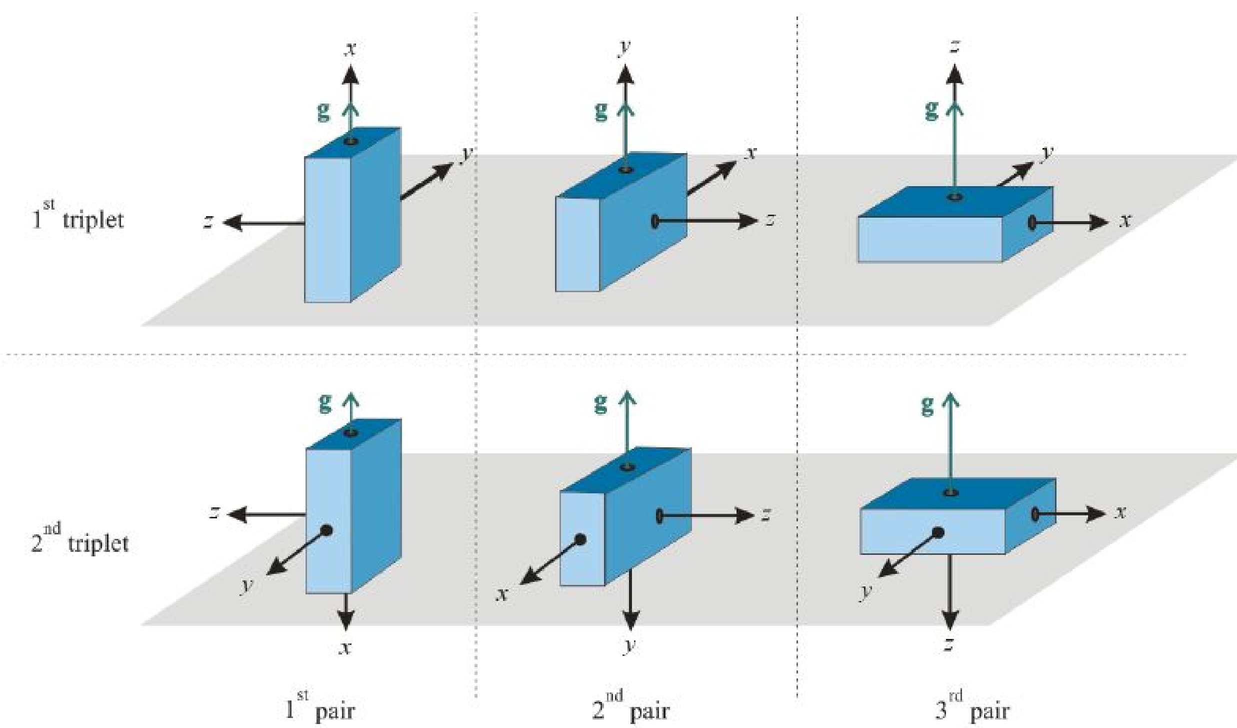
Conceptually, an accelerometer behaves as a damped mass on a spring. When the accelerometer experiences an acceleration, the mass is displaced to the point that the spring is able to accelerate the mass at the same rate as the casing. The displacement is then measured to give the acceleration.

In commercial devices, piezoelectric, piezoresistive and capacitive components are commonly used to convert the mechanical motion into an electrical signal. Piezoelectric accelerometers rely on piezoceramics (e.g. lead zirconate titanate) or single crystals (e.g. quartz, tourmaline). They are unmatched in terms of their upper-frequency range, low packaged weight, and high-temperature range. Piezoresistive accelerometers are preferred in high shock applications. Capacitive accelerometers typically use a silicon micro-machined sensing element. Their performance is superior in the low-frequency range and they can be operated in servo mode to achieve high stability and linearity.

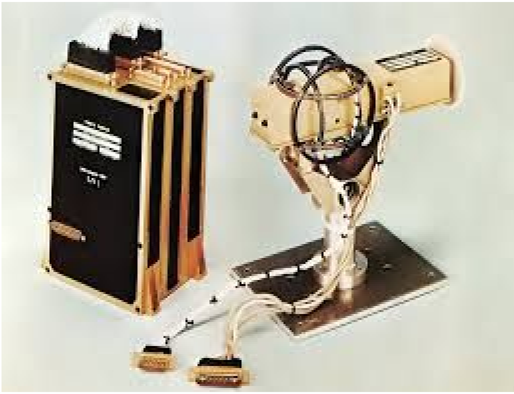


Modern accelerometers are often small *micro-electro-mechanical systems* (MEMS) and are indeed the simplest MEMS devices possible, consisting of little more than a cantilever beam with a proof mass (also known as *seismic mass*). Damping results from the residual gas sealed in the device. As long as the Q-factor is not too low, damping does not result in a lower sensitivity.

Accelerometers are made up of many different components and can be purchased as a separate device. Analog and digital displays are available, though, for most technology devices, these components are integrated into the main technology and accessed using the governing software or operating system. Typical accelerometers are made up of multiple axes, two to determine most two-dimensional movement with the option of a third for 3D positioning. Most smartphones typically make use of three-axis models, whereas cars simply use only a two-axis to determine the moment of impact. The sensitivity of these devices is quite high as they’re intended to measure even very minute shifts in acceleration. The more sensitive the accelerometer, the more easily it can measure acceleration.



Magnetometer:- A magnetometer is a device that measures magnetism—the direction, strength, or relative change of a magnetic field at a particular location. The measurement of the magnetization of a magnetic material (like a ferromagnet) is an example. A compass is one such device, one that measures the direction of an ambient magnetic field, in this case, the Earth's magnetic field. Magnetometers are widely used for measuring the Earth's magnetic field, and in geophysical surveys, to detect magnetic anomalies of various types. In an aircraft's attitude and heading reference system, they are commonly used as a heading reference. Magnetometers are also used in the military to detect submarines. Consequently, some countries, such as the United States, Canada, and Australia, classify the more sensitive magnetometers as military technology and control their distribution. There are two basic types of magnetometer measurements. *Vector magnetometers* measure the vector components of a magnetic field. *Total field magnetometers* or *scalar magnetometers* measure the magnitude of the vector magnetic field. Magnetometers used to study the Earth's magnetic field may express the vector components of the field in terms of *declination* (the angle between the horizontal component of the field vector and magnetic north) and the *inclination* (the angle between the field vector and the horizontal surface). *Absolute magnetometers* measure the absolute magnitude or vector magnetic field, using an internal calibration or known physical constants of the magnetic sensor.] *Relative magnetometers* measure magnitude or vector magnetic field relative to a fixed but uncalibrated baseline. Also called *variometers*, relative magnetometers are used to measure variations in the magnetic field. Magnetometers may also be classified by their situation or intended use. *Stationary magnetometers* are installed to a fixed position and measurements are taken while the magnetometer is stationary. *Portable* or *mobile magnetometers* are meant to be used while in motion and maybe manually carried or transported in a moving vehicle. *Laboratory magnetometers* are used to measure the magnetic field of materials placed within them and are typically stationary. *Survey magnetometers* are used to measure magnetic fields in geomagnetic surveys; they may be fixed base



stations, as in the INTERMAGNET network, or mobile magnetometers used to scan a geographic region.

The Hall effect means conductors that have electrical currents flowing through them create a voltage perpendicular to the field and direction of the current. That means magnetometers can use semiconducting material to pass current through and determine whether a magnetic field is nearby. It measures the way the current is distorted or angled due to the magnetic field, and the voltage at which this occurs is the Hall voltage, which should be proportional to the magnetic field. The sensor of a magnetometer detects the magnetic flux density which can be converted to a magnetic field. Vector magnetometers detect flux density in a specific direction in space depending on how you orient it. Scalar magnetometers, on the other hand, detect only the magnitude or strength of the flux vector, not the position of the angle at which it's measured.

CODE:

```
#include <Wire.h>

#include <TimerOne.h>

#include <PCD8544.h>


#define MPU9250_ADDRESS 0x68

#define MAG_ADDRESS 0x0C


#define GYRO_FULL_SCALE_250_DPS 0x00

#define GYRO_FULL_SCALE_500_DPS 0x08
```

```
#define GYRO_FULL_SCALE_1000_DPS 0x10

#define GYRO_FULL_SCALE_2000_DPS 0x18


#define ACC_FULL_SCALE_2_G 0x00

#define ACC_FULL_SCALE_4_G 0x08

#define ACC_FULL_SCALE_8_G 0x10

#define ACC_FULL_SCALE_16_G 0x18

PCD8544 lcd;


void Init() {

  lcd.setCursor(0, 0);

  lcd.print("Project Under:");

  lcd.setCursor(0,2);

  lcd.print("Prof. K. Surender");

  delay(5000);

}


void DispLCD(double yaw,double pitch,double roll) {

  lcd.clear();

  lcd.setCursor(0, 0);

  lcd.print("Yaw:   "+String(yaw));

  lcd.setCursor(0, 1);

  lcd.print("Pitch: "+String(pitch));

  lcd.setCursor(0,2);

  lcd.print("Roll:  "+String(roll));

  delay(100);
```

```
}


void I2Cread(uint8_t Address, uint8_t Register, uint8_t Nbytes, uint8_t* Data){
  Wire.beginTransmission(Address);
  Wire.write(Register);
  Wire.endTransmission();
  Wire.requestFrom(Address, Nbytes);
  uint8_t index=0;
  while (Wire.available())
  Data[index++]=Wire.read();
}
 void I2CwriteByte(uint8_t Address, uint8_t Register, uint8_t Data){
  Wire.beginTransmission(Address);
  Wire.write(Register);
  Wire.write(Data);
  Wire.endTransmission();
}
long int ti;
volatile bool intFlag=false;


void setup(){
  lcd.begin(84, 48);
  Wire.begin();
  Serial.begin(115200);
  I2CwriteByte(MPU9250_ADDRESS,29,0x06);
    I2CwriteByte(MPU9250_ADDRESS,26,0x06);
```

```
  I2CwriteByte(MPU9250_ADDRESS,27,GYRO_FULL_SCALE_1000_DPS);
  I2CwriteByte(MPU9250_ADDRESS,28,ACC_FULL_SCALE_4_G);
  I2CwriteByte(MPU9250_ADDRESS,0x37,0x02);
  I2CwriteByte(MAG_ADDRESS,0x0A,0x16);

  pinMode(13, OUTPUT);
  Timer1.initialize(10000); // initialize timer1, and set a 1/2 second period
  Timer1.attachInterrupt(callback);
  ti=millis();
  Init();
}
long int cpt=0;
void callback(){
  intFlag=true;
  digitalWrite(13, digitalRead(13) ^ 1);
}
 void loop(){
  while (!intFlag);
  intFlag=false;
  uint8_t Buf[14];
  I2Cread(MPU9250_ADDRESS,0x3B,14,Buf);
  int16_t AcX=-(Buf[0]<<8 | Buf[1]);
  int16_t AcY=-(Buf[2]<<8 | Buf[3]);
  int16_t AcZ=Buf[4]<<8 | Buf[5];

  int16_t gx=-(Buf[8]<<8 | Buf[9]);
```

```
int16_t gy=-(Buf[10]<<8 | Buf[11]);
int16_t gz=Buf[12]<<8 | Buf[13];
uint8_t ST1;
do  {
I2Cread(MAG_ADDRESS,0x02,1,&ST1);
}
while (!(ST1&0x01));

uint8_t Mag[7];
I2Cread(MAG_ADDRESS,0x03,7,Mag);

int16_t mx=-(Mag[3]<<8 | Mag[2]);
int16_t my=-(Mag[1]<<8 | Mag[0]);
int16_t mz=-(Mag[5]<<8 | Mag[4]);
int minVal=265; int maxVal=402;
double x; double y; double z;


    int xAng = map(AcX,minVal,maxVal,-90,90);int yAng = map(AcY,minVal,maxVal,-90,90); int zAng = map(AcZ,minVal,maxVal,-90,90);

x = RAD_TO_DEG * (atan2(-yAng, -zAng)+PI);
y = RAD_TO_DEG * (atan2(-xAng, -zAng)+PI);
z = RAD_TO_DEG * (atan2(-yAng, -xAng)+PI);

DispLCD(x, y, z);
```

```
}
```

RESULTS:

Euler Angles were successfully measured using the device. This device finds its applications in various fields like robotics, drones, etc. It (measured euler angles) can further be controlled using a PID controller depending on the application (eg. Gimbal).