Imperial College London

# DE2 Electronics 2
## for Design Engineers

# Tutorial 4

# Lab 4 Explained

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# Lab 4 – Task 1: Measuring Angel of tilt – the IMU

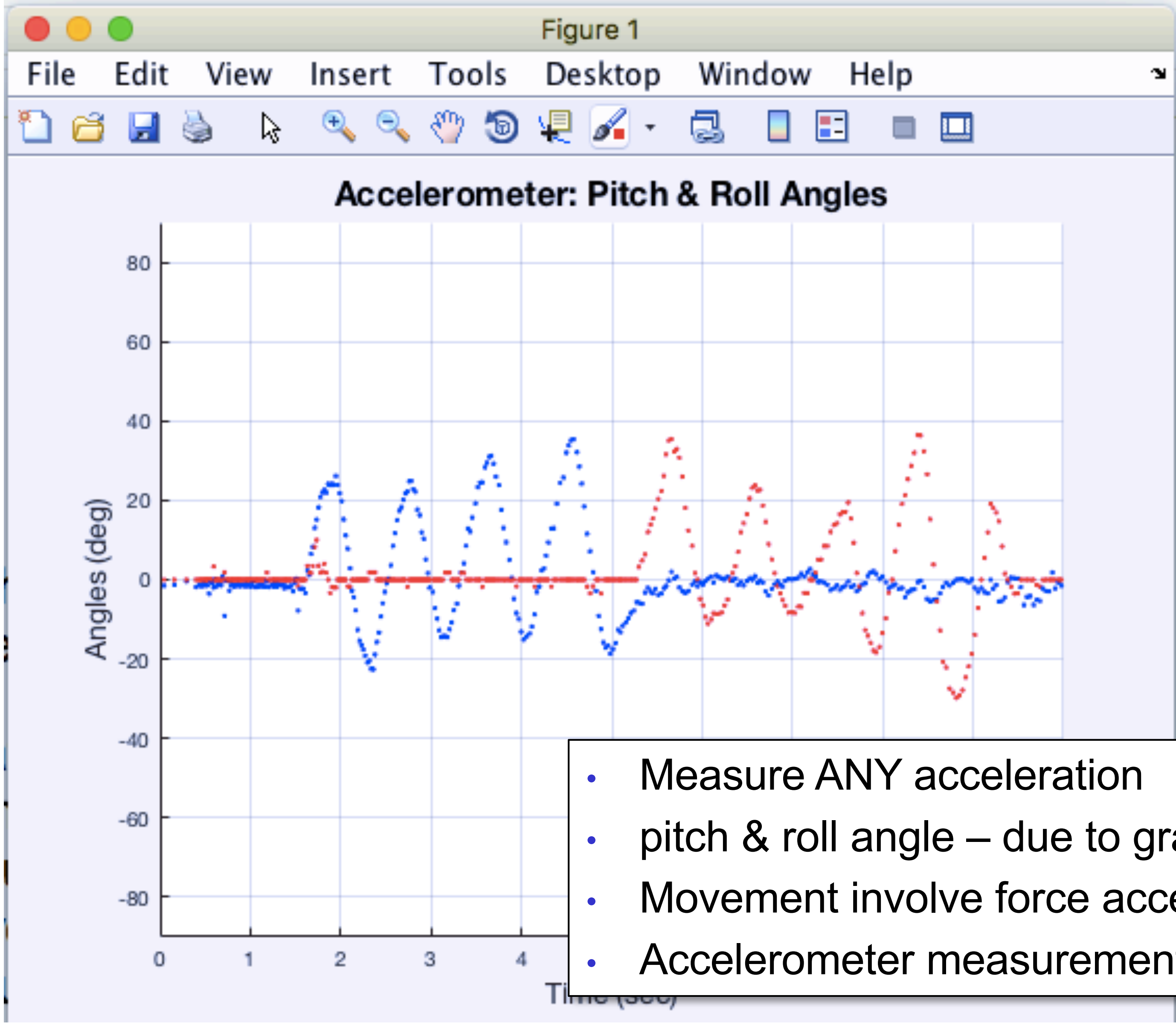
- The IMU – inertia measurement unit – has built in 3-axis accelerometer and 3-axis gyroscope
- Easy to access from Matlab using PyBench:.

```
[p, r] = pb.get_accel();         % p, r  = pitch & roll angle in radians
[x, y, z] = pb.get_gyro();       % x, y, z = rate of rotation in 3-axes in rad/sec
```

- Pitch angle – plane pointing up or down
- Roll angle – plane pointing left or right
- Angle can be in unit radian or degree:   degrees = radians *180 / $\pi$
- Generally use radian for calculations; use degree of display

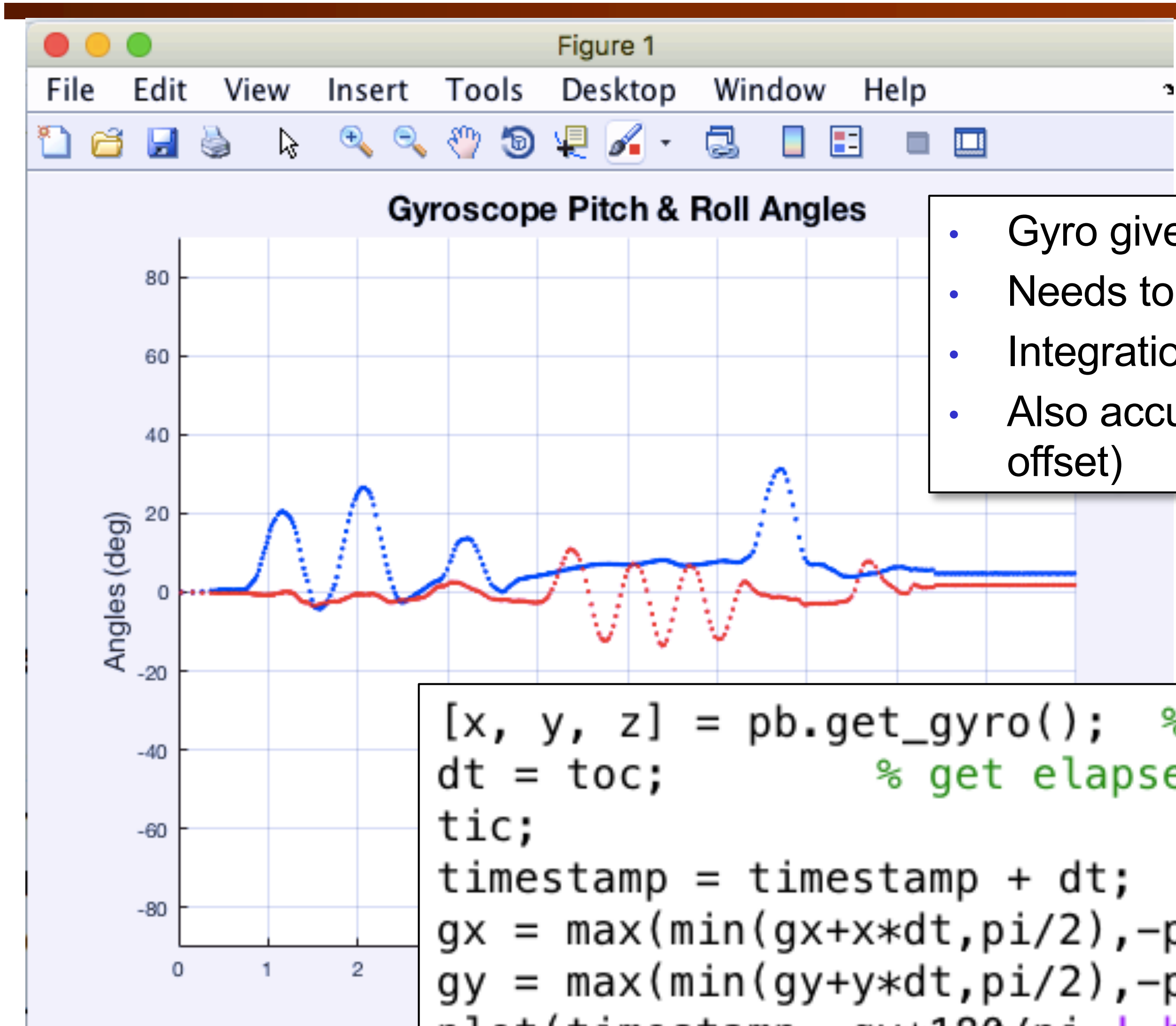
- Learn usefulness and limitations of accelerometer and gyroscope

# Lab 4 – Task 1a: Accelerometer




- Measure ANY acceleration
- pitch & roll angle – due to gravity g
- Movement involve force acceleration, also measured
- Accelerometer measurement of tilt angle is NOISY

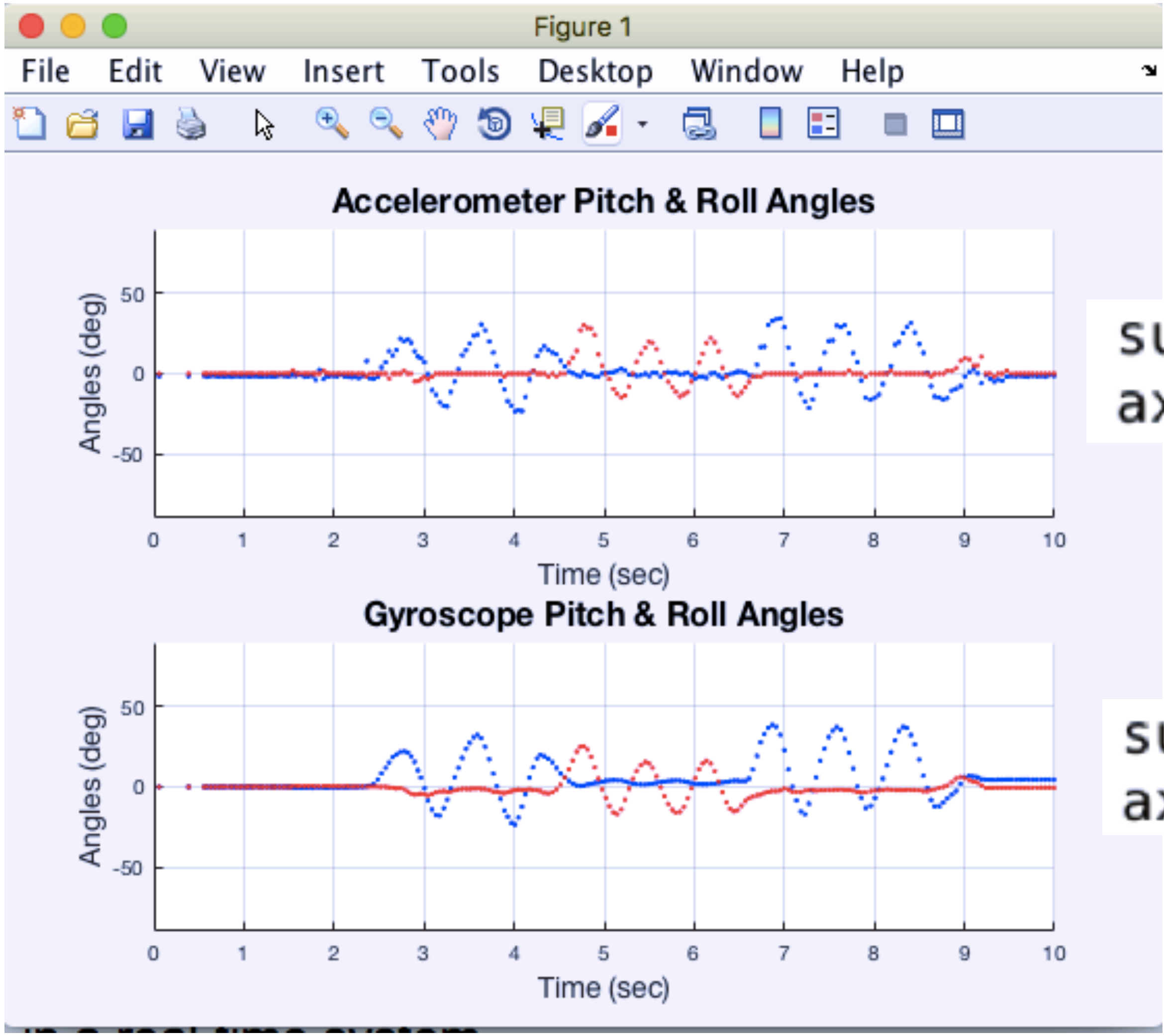
# Lab 4 – Task 1b: Gyroscope




- Gyro gives angular velocity, not angle
- Needs to integrate to get angle
- Integration = accumulation
- Also accumulate errors – causing drift (or dc offset)

```
[x, y, z] = pb.get_gyro();  % angular rate in rad/sec
dt = toc;            % get elapsed time
tic;
timestamp = timestamp + dt;
gx = max(min(gx+x*dt,pi/2),-pi/2);  % limit to +/- pi/2
gy = max(min(gy+y*dt,pi/2),-pi/2);
plot(timestamp, gy*180/pi,'.b');    % plot pitch in blue
plot(timestamp, gx*180/pi,'.r');    % plot roll in red
pause(0.001);            % delay for 1 ms, needed for plot
```

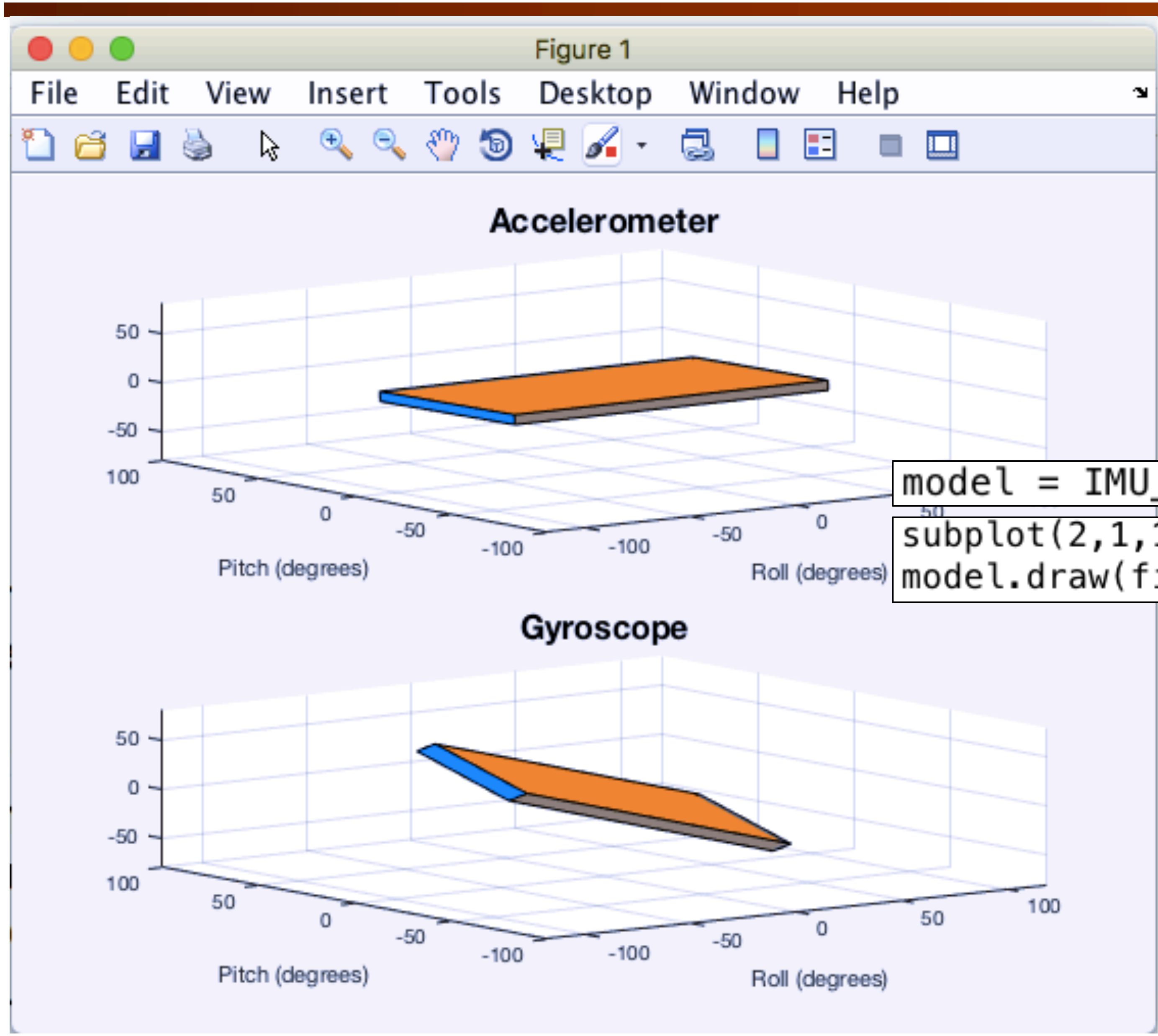
# Lab 4 – Task 1c: Gyroscope




```
subplot(2,1,1)
axis([0 end_time -90 90]);
```

```
subplot(2,1,2)
axis([0 end_time -90 90]);
```

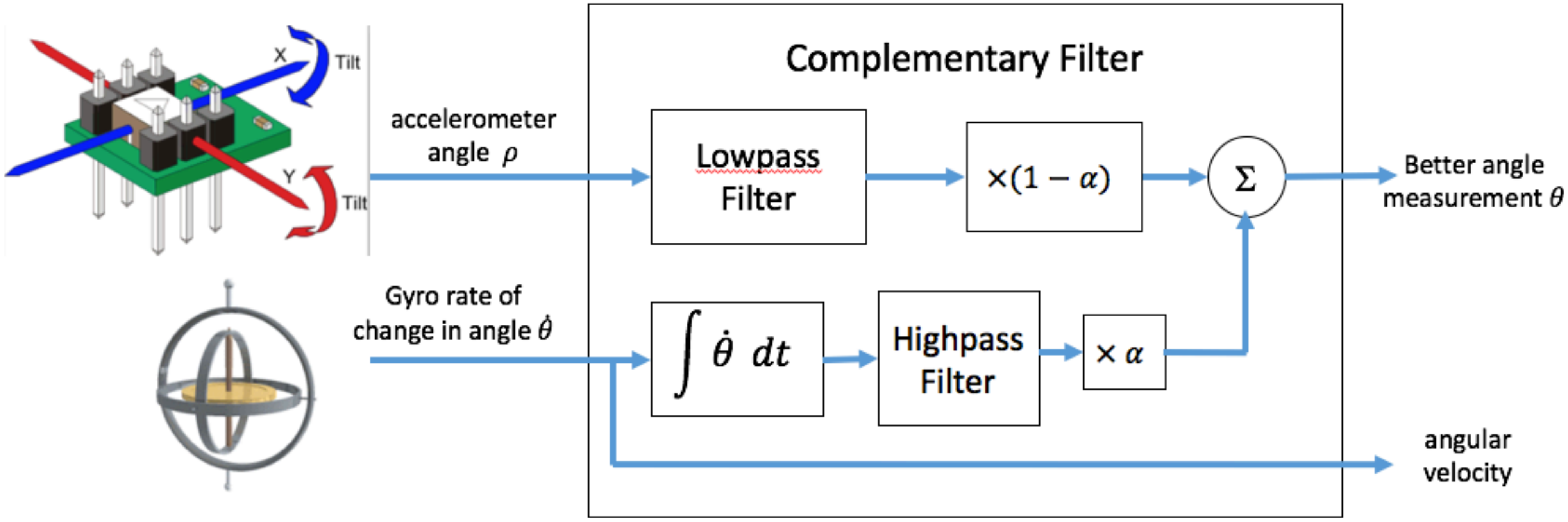
# Lab 4 – Task 2: 3D visualization




```
model = IMU_3D();
```

```
subplot(2,1,1);
model.draw(fig1, p, r, 'Accelerometer');
```

# Lab 4 – Task 3: Complementary Filter - Concept

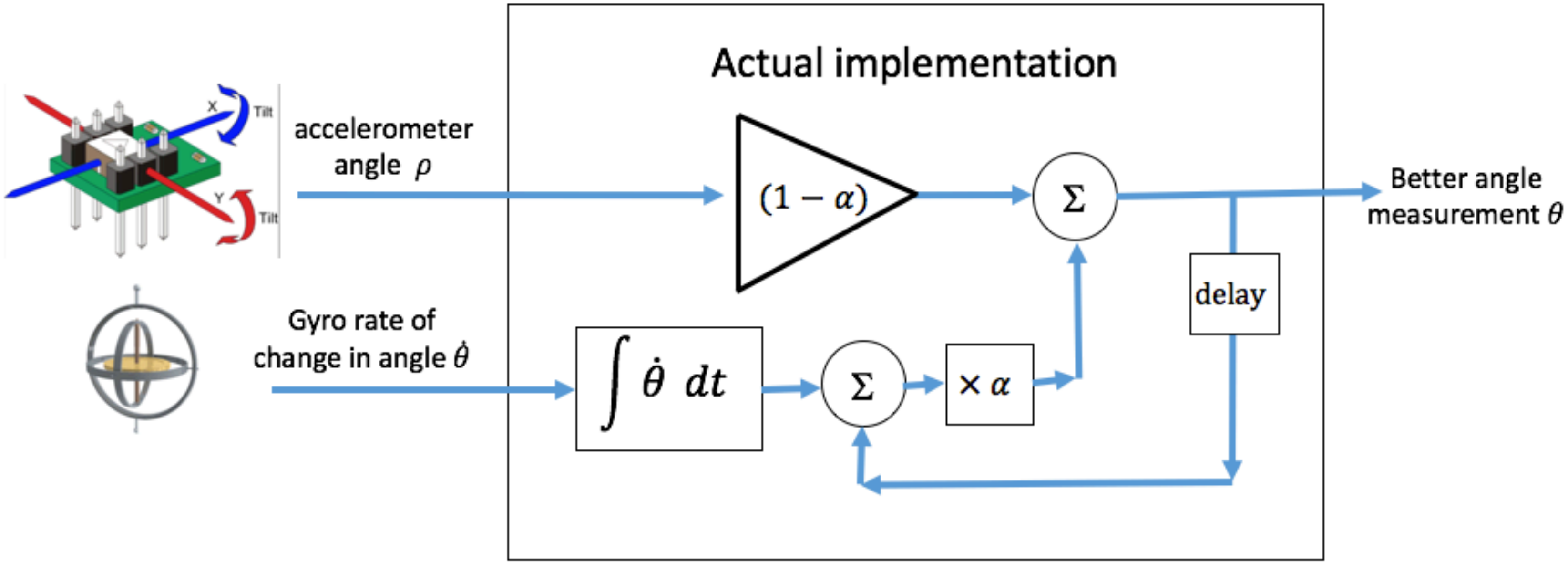



angle $\theta = \alpha \times (\ \theta + \ \dot{\theta}\ dt) + (1-\alpha) \times \rho$

where

- $\alpha$ = scaling factor chosen by users and is typically between 0.7 and 0.98
- $\rho$ = accelerometer angle
- $\theta$ = output angle computed
- $\dot{\theta}$ = gyroscope reading of the rate of change in angle
- dt = time interval between gyro readings

# Lab 4 – Task 3: Complementary Filter - Implementation




$$\text{angle } \theta = \alpha \times \left( \theta + \dot{\theta}\, dt \right) + (1-\alpha) \times \rho$$

- What happens if $\dot{\theta}$ is zero? Effectively average out the value of $\rho$
- What happens if $\dot{\theta}$ has a small error? Effectively reduce this error over time

# Lab 4 – Task 4: Untethered – OLED Display

```
# Create peripheral objects
b_LED = LED(4)                  # blue LED
pot = ADC(Pin('X11'))           # 5k ohm potentiometer to ADC input on pin X11

# I2C connected to Y9, Y10 (I2C bus 2) and Y11 is reset low active
oled = OLED_938(pinout={'sda': 'Y10', 'scl': 'Y9', 'res': 'Y8'}, height=64,
                   external_vcc=False, i2c_devid=61)
oled.poweron()
oled.init_display()

#  Simple Hello world message
oled.draw_text(0,0,'Hello World!')   # each character is 6x8 pixels

tic = pyb.millis()            # store start time
while True:
    b_LED.toggle()
    toc = pyb.millis()        # read elapsed time
    oled.draw_text(0,20,'Delay time:{:6.3f}sec'.format((toc-tic)*0.001))
    oled.draw_text(0,40,'POT5K reading:{:5d}'.format(pot.read()))
    tic = pyb.millis()        # start time
    oled.display()
    delay = pyb.rng()%1000    # Generate random number btw 0 and 999
    pyb.delay(delay)          # delay in milliseconds
```