Imperial College
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DE2 Electronics 2

Tutorial 4

Lab 4 Explained

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

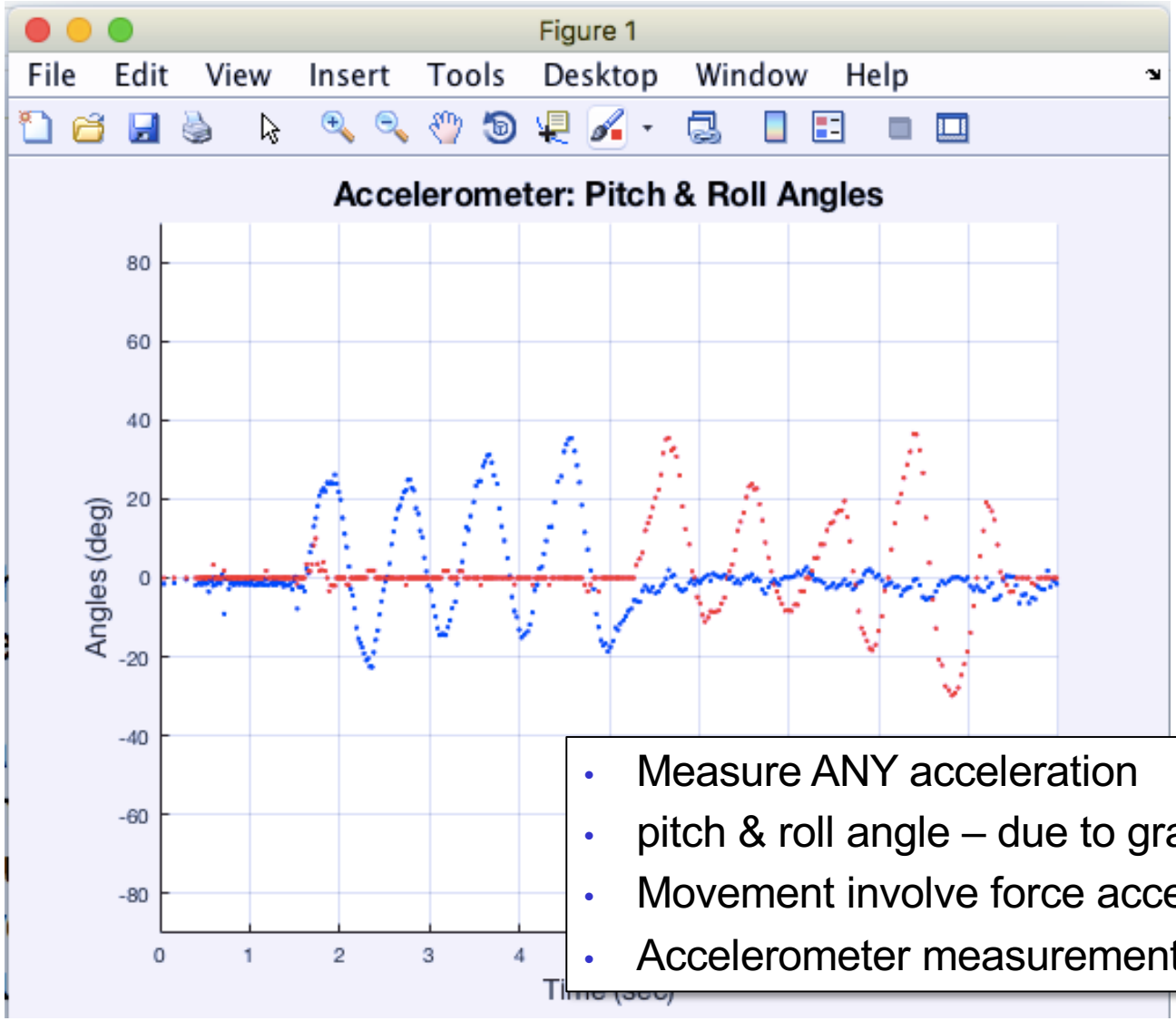
- The IMU – inertia measurement unit – has built in 3-axis accelerometer and 3-axis gyroscope
- Easy to access from Matlab using PyBench:.

```
[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 / π
- Generally use radian for calculations; use degree for display

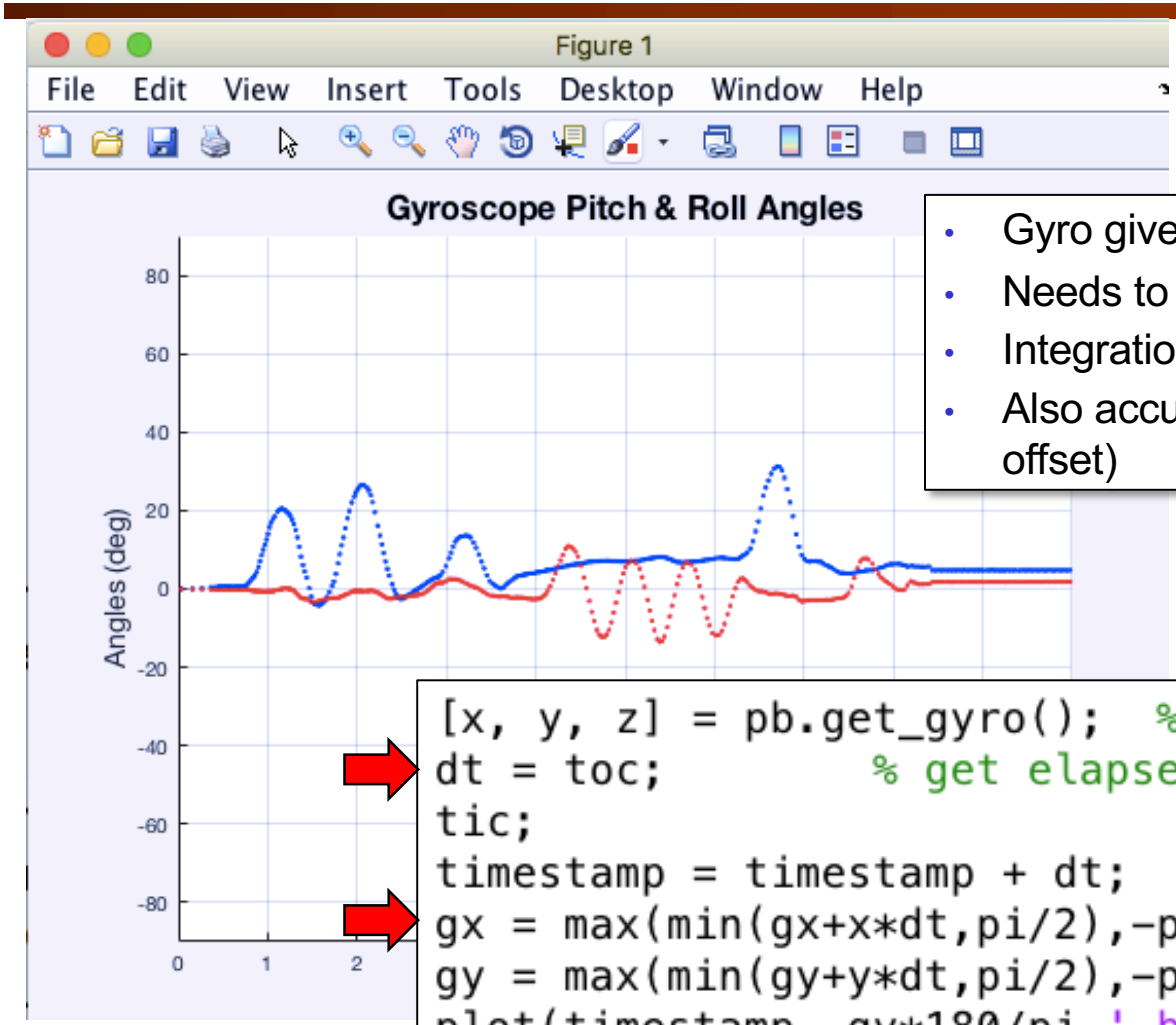
- Learn usefulness and limitations of accelerometer and gyroscope

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

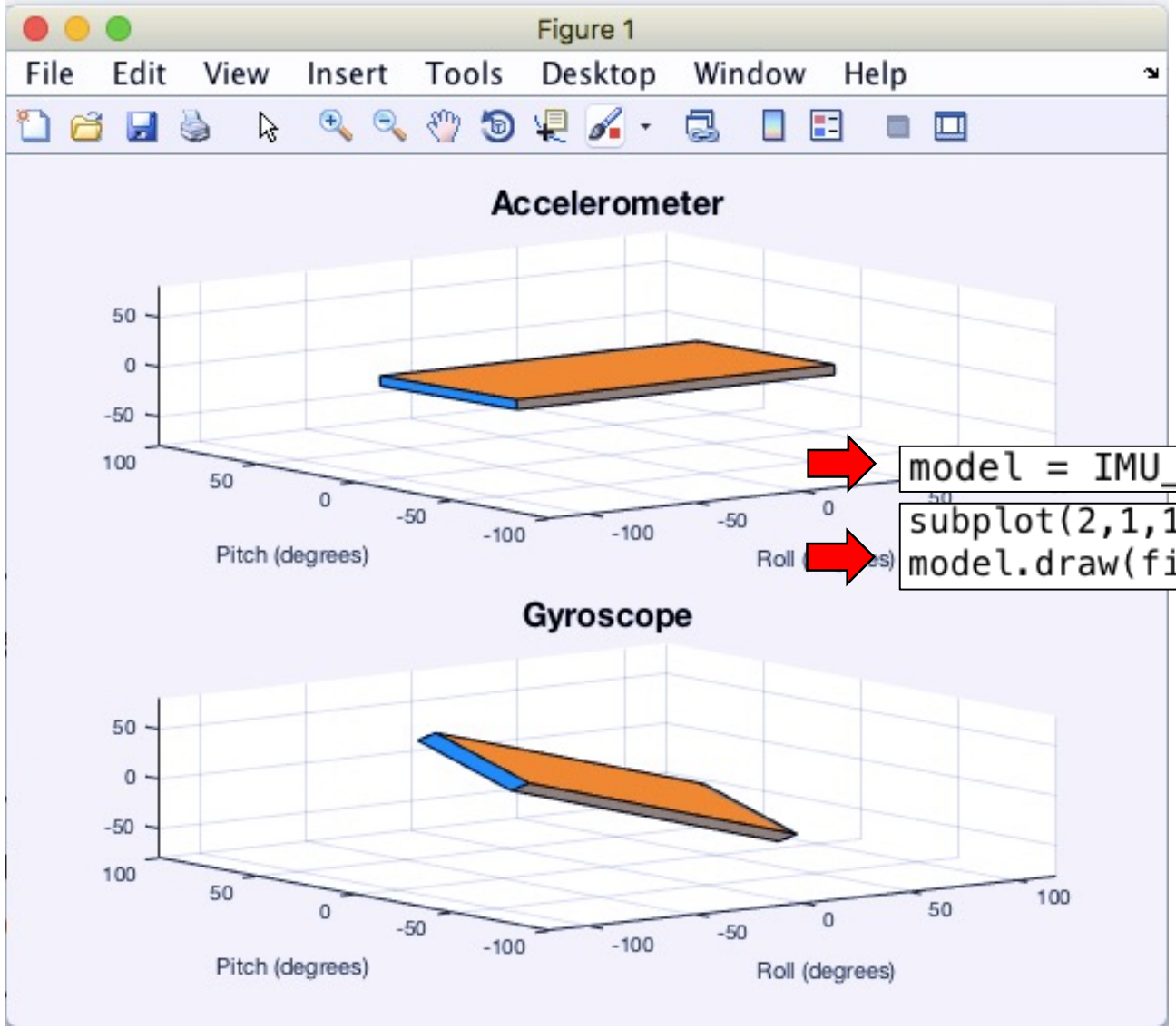
Lab 4 – Task 1b: Gyroscope



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

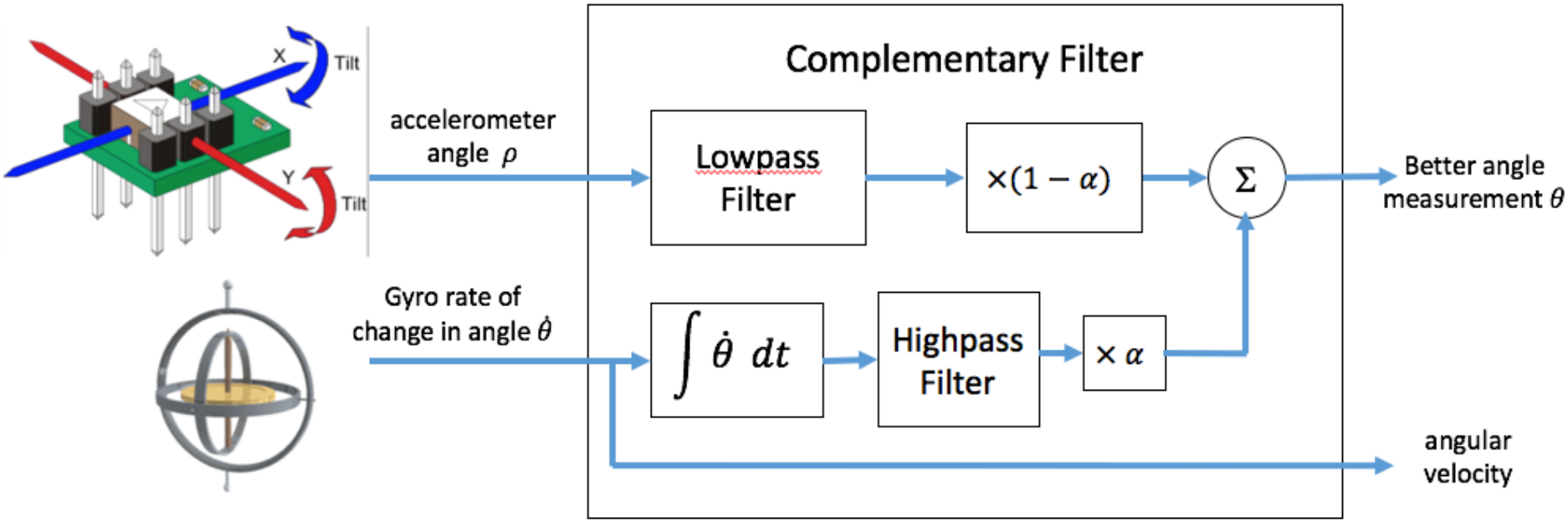
```
[x, y, z] = pb.get_gyro();  % angular rate in rad/sec
dt = toc;                   % get elapsed time
tic;
timestamp = timestamp + dt;
gx = max(min(gx+x*dt,pi/2),-pi/2);  % limit to +/- pi/2
gy = max(min(gy+y*dt,pi/2),-pi/2);
plot(timestamp, gy*180/pi,'.b');    % plot pitch in blue
plot(timestamp,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

Lab 4 – Task 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

α = scaling factor chosen by users and is typically between 0.7 and 0.98

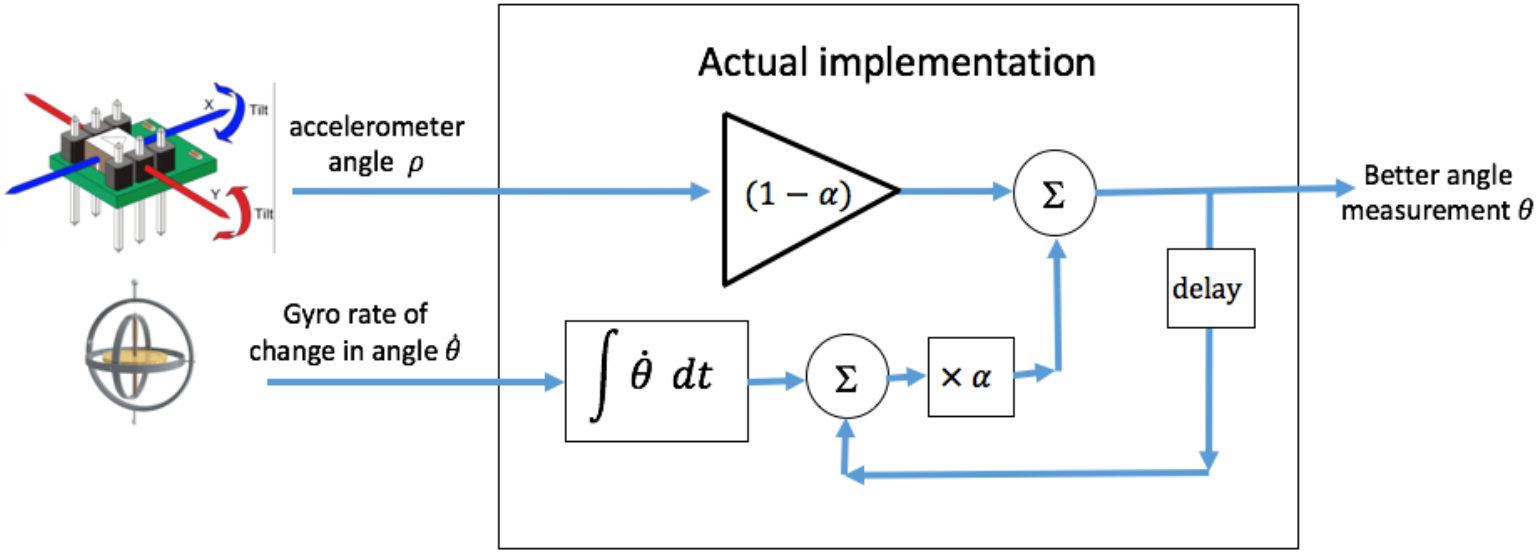
ρ = accelerometer angle

θ = output angle computed

$\dot{\theta}$ = gyroscope reading of the rate of change in angle

dt = time interval between gyro readings

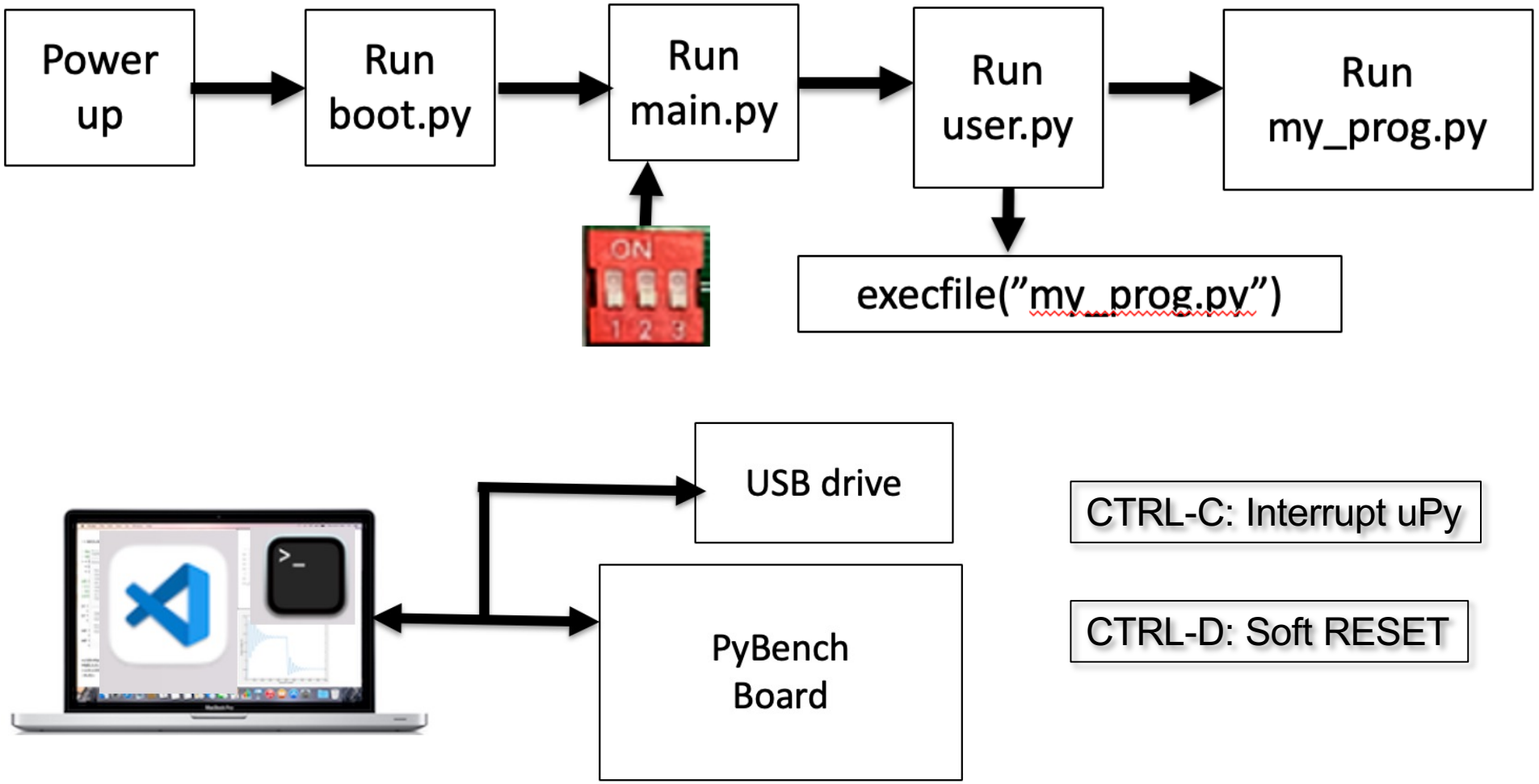
Lab 4 – Task 3: Complementary Filter - Implementation



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

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

Lab 4 – Pybench usage



Lab 4 – Task 4: Untethered – OLED Display

```
12  import pyb                          # Pyboard basic  library
13  from pyb import LED, ADC, Pin       # Use various class libraries in pyb
14  from oled_938 import OLED_938       # Use OLED display driver
15
16  # Create peripheral objects
17  b_LED = LED(4)                      # blue LED
18  pot = ADC(Pin('X11'))               # 5k ohm potentiometer to ADC input on pin
19
20  # I2C connected to Y9, Y10 (I2C bus 2) and Y11 is reset low active
21  i2c = pyb.I2C(2, pyb.I2C.MASTER)
22  devid = i2c.scan()                  # find the I2C device number
23  oled = OLED_938(
24      pinout={"sda": "Y10", "scl": "Y9", "res": "Y8"},
25      height=64,
26      external_vcc=False,
27      i2c_devid=i2c.scan()[0],
28  )
29  oled.poweron()
30  oled.init_display()
```

Lab 4 – Task 4: Untethered – OLED Display

```
32  #  Simple Hello world message
33  oled.draw_text(0,0,'Hello World!')   # each character is 6x8 pixels
34
35  tic = pyb.millis()           # store start time
36  while True:
37      b_LED.toggle()
38      toc = pyb.millis()       # read elapsed time
39      oled.draw_text(0,20,'Delay time:{:6.3f}sec'.format((toc-tic)*0.001))
40      oled.draw_text(0,40,'POT5K reading:{:5d}'.format(pot.read()))
41      tic = pyb.millis()       # start time
42      oled.display()
43      delay = pyb.rng()%1000   # Generate random number btw 0 and 999
44      pyb.delay(delay)         # delay in milliseconds
```