Differential Pressure Sensing using ICM-20789 for Altitude-hold in Drones

1 PURPOSE

This document explains the process of using differential pressure measurements of two pressure sensors to mitigate the challenge with altitude hold that is subject to ambient pressure changes.

TABLE OF CONTENTS

2 PROBLEM OVERVIEW

Pressure sensors are commonly used as an altitude (height) gauge in drones with respect to initial ground level. The assumption made here is the pressure value remains constant for a given period of time. Several environmental factors common in doors are HVAC on/off and the opening and closing of doors could change the pressure values during the flight, misleading the drone to correct for change in pressure, which results in loss of altitude-hold.

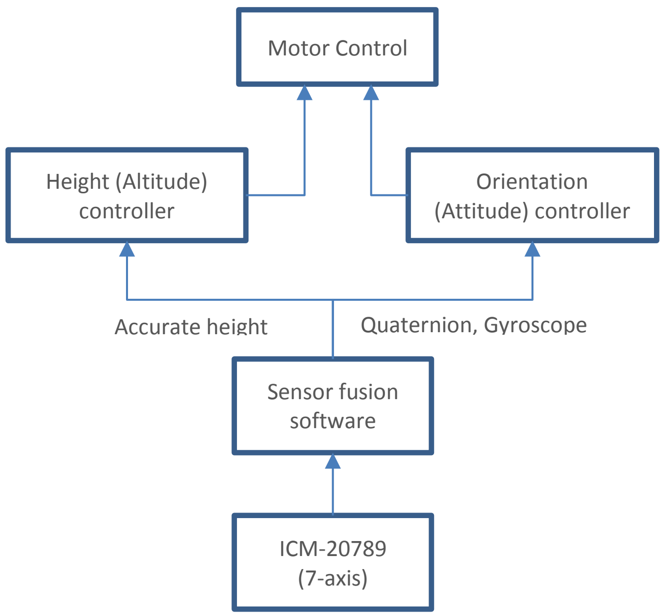

Figure 1. Simplified block diagram for altitude Controller on a Quadcopter using ICM-20789

Change of 1 Pa = 8.5 cm in height at sea level. A 10 Pa change can cause 90 cm (3ft) change in height that would cause the drone to hit the ceiling or the floor depending on decrease or increase in pressure and lose complete control.

Figure 2 illustrates the pressure changes observed in a room when opening a door. For the above experiment the pressure sensor data was captured using ICM-20789 placed stationary in a room while the door was opened/closed 6 times. The pressure changed from 101288 to 101300 which ~ 12 Pa. The pressure sensor is filtered for illustration.

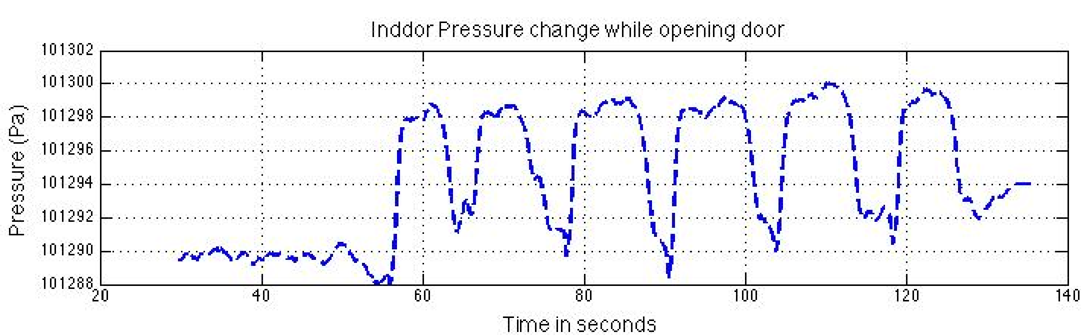

Figure 2. Pressure data from ICM-20789 placed in stationary in a room

3 SOLUTION

Provide a second pressure sensor (P-stationary) which is stable in height, not attached to the drone and is witnessing the same environment as the drone. Have a method to communicate in real time to the drone the measured value of the environment pressure that will be used to subtract from the pressure seen by the first pressure sensor (P-drone) which is attached to the drone. The difference pressure (P-system) is then used for altitude hold in the drone system.

P-system = (P-drone) – (P-stationary)

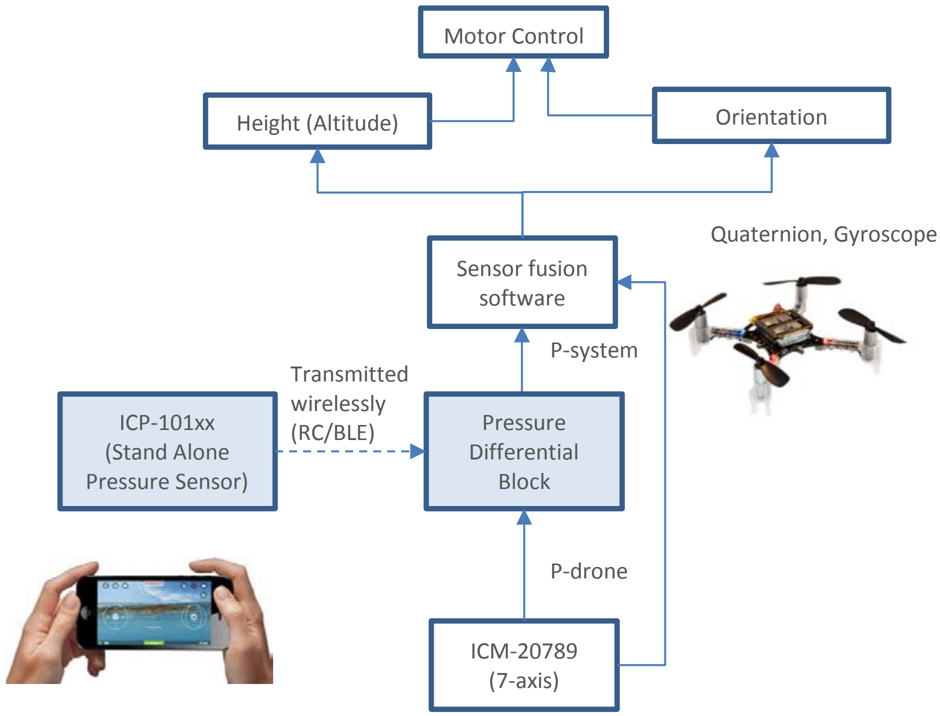

Figure 3. Simplified diagram for differential pressure concept

Controller: The system can be imagined as two parts. The controller and the drone. The controller could be RC or a phone with pressure sensor capability and a way to communicate the pressure sensor data to the drone. A single axis stand-alone pressure sensor, ICP-101xx, is sufficient on the controller. The P-stationary can be generated using the RC/Phone or similar controller communicating with the drone. Other ground station / telemetry method can be used as well.

Drone: The drone can get the ambient pressure data and compare it with the pressure data seen by the drone itself. In the drone's control loop for height stabilization the assumption of constant pressure (P-drone) is made and any change in pressure is attributed to change in height rather than change in environmental pressure. This leads the drone to compensate the height as it is tasked to do and creating altitude-hold. A compensated pressure (P-System) would be perfect as any change in pressure is now associated with change in drone height rather than ambient pressure.

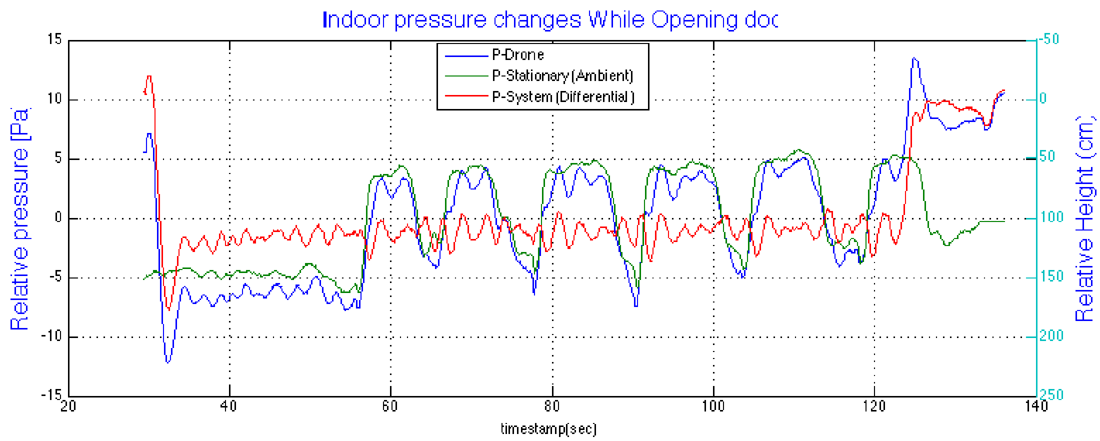

Figure 4. Differential pressure sensor graph

Figure 4 shows differential pressure measurements being used in a drone system. To simplify the problem, one needs to look at only relative pressure changes and bring both P-stationary and P-drone to same relative number which is close to zero. This action can be achieved before take-off to zero out the offsets. The P-System is a differential measurement of the pressure sensor data from the room pressure sensor and the one experienced by the drone. The P-System is more reliable than the P-drone and can maintain excellent altitude hold in fluctuating environmental pressure conditions. The above diagram and figure are simplified, improved results can be achieved by including filter blocks to reduce the noise level and as well adjust the PID loop to accommodate the increased common noise.

ICM-20789 has pressure noise as low as 0.4 Pa RMS, and relative accuracy performance of 1 Pa which enables excellent altitude hold in drone applications for both single or differential pressure drone systems.

4 EXPERIMENTAL SETUP

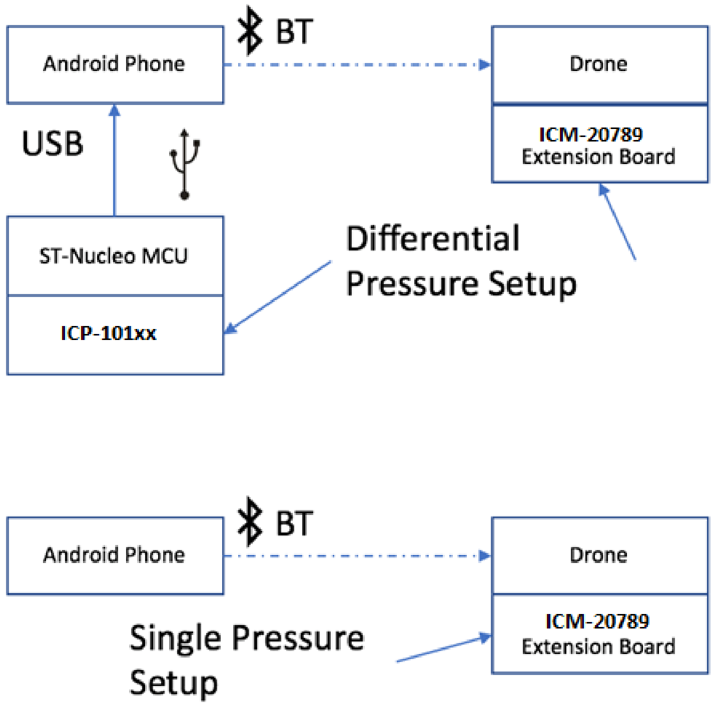

Figure 5. Experiment setup

1. **Drone**: Crazyflie 2.0 fitted with ICM-20789 extension board [3] . Crazyflie software is modified to accommodate the extension board and make provision for single vs differential mode of working.
2. **Controller**: Android Phone with external ICP-101xx on ST-Nucleo board via USB is connected to the phone. Android app was modified to take the external pressure sensor via USB peripheral. The ST-Nucleo board was used to mount the ICP-101xx to communicate the pressure Via USB to the phone.

The data, code base for the android app, Crazyflie drone, ST-Nucleo setup is not covered in the scope of the document.

Experiment: Two drones are flown simultaneously with one having only the single pressure (P-drone=P-System) altitude-hold software and the second drone uses differential (P-system = P-drone minus P-Stationary) output for altitude hold. The door leading from outside to the room is opened and closed to see the effect of the pressure variation and height control of the drone. In this experiment once launched the throttle is not updated and only the pitch/roll is controlled to limit the horizontal drift.

Results: The Video link here shows the concept in action and the above data graphs are excerpts from the differential experiments.

5 CONCLUSION

Differential Pressure sensing using an external pressure sensor that is at a static altitude delivers excellent altitude hold performance in harsh environmental pressure changes, commonly experienced indoors. Figure 4 and the video shows the benefits of the differential pressure sensing system.

6 REFERENCES

1. ICM-20789, https://www.invensense.com/products/motion-tracking/7-axis/
   Contact us for more: *sales@invensense.com*
2. ICP-101xx, https://www.invensense.com/products
   Contact us for more: *sales@invensense.com*
3. Crazyflie 2.0 Specification: https://www.bitcraze.io/crazyflie-2/
4. Crazyflie 2.0 Source Code: https://github.com/bitcraze/crazyflie-firmware
5. Video link for differential drone: https://youtu.be/ka3aWVNyosA

7 REVISION HISTORY

DATE	REVISION	DESCRIPTION
02/13/17	1.0	Initial Release
10/04/17	1.1	Updated part numbers, content