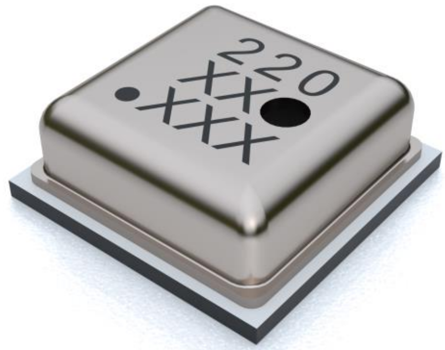
ScioSense



ENS220

Application note

Indoor Event Detection by ENS220

ENS220 application note: Indoor Event Detection

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Content Guide

1 Introduction

Gaining insights about indoor environments holds vast potential for a wide range of applications. From optimizing environmental control systems like heating, air conditioning, and lighting to enhancing security measures and occupancy detection, the possibilities are extensive.

The ENS220 provides precise barometric pressure measurements with high resolution and sampling rate at low power consumption. Events like opening and closing doors and windows create small and fast changes in air pressure. These changes can be clearly measured using the ENS220, owing to its high resolution and sample rate.

2 Setup

Plan of the office where the pressure sensors are placed is shown in **Figure 1**. Three ENS220 pressure sensors are placed in kitchen and offices labelled as H and G. For this plot a conversion time of 2 milliseconds (ms) and oversampling factor (OVSP) of 32 is used, resulting in sampling period of close to 64 ms or 15.6 sample /seconds[1]. ***Table 1*** shows an overview of ENS220 settings.

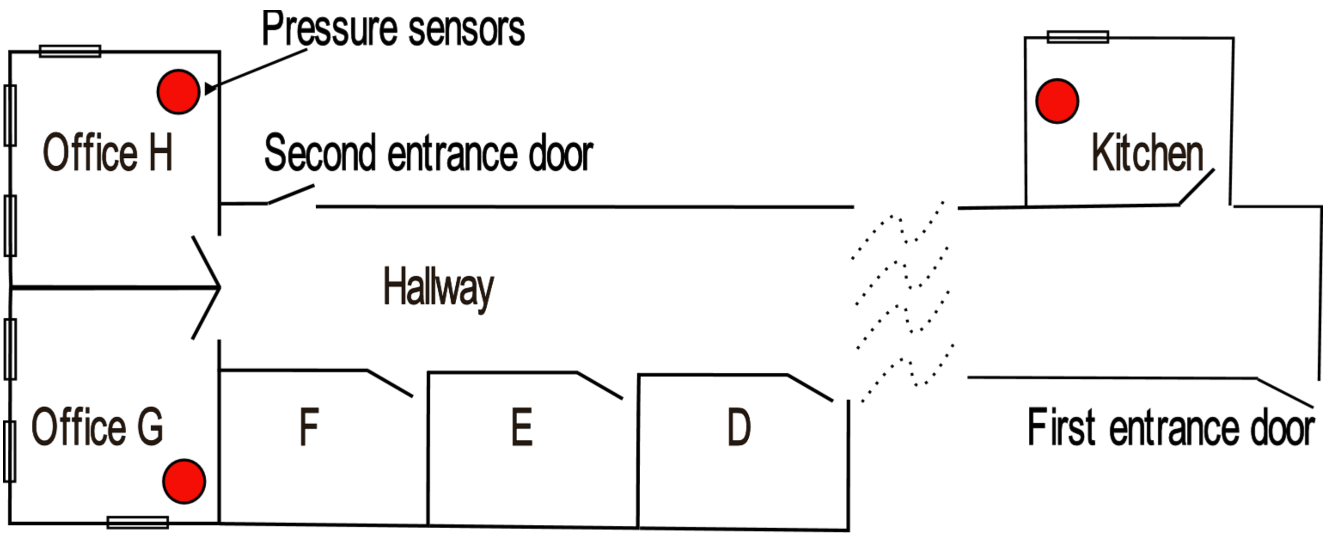

Figure 1. A map of the office where the pressure sensors are placed.

Table 1: ENS220 settings

HP	P_CONV	PT_RATE	STBY_T	OVSP	OVST
1	2 ms	4:1	0 ms (continuous)	32x	4x

[1] A conversion time (P_CONV) of 2ms with an oversampling of pressure (OVSP) of 32, oversampling of temperature (OSST) of 4, and PT-rate of 4 will require in total 269ms to measure 4 pressure samples, producing an acquisition rate of 14.9 samples/s. The sensor takes 3ms to change between pressure and temperature sensing, and can only read one parameter at the same time. Please, refer to ENS220 datasheet for complete explanation and possible values for parameters.

3 Indoor event detection

Figure 2 shows the absolute pressure measured in office H.

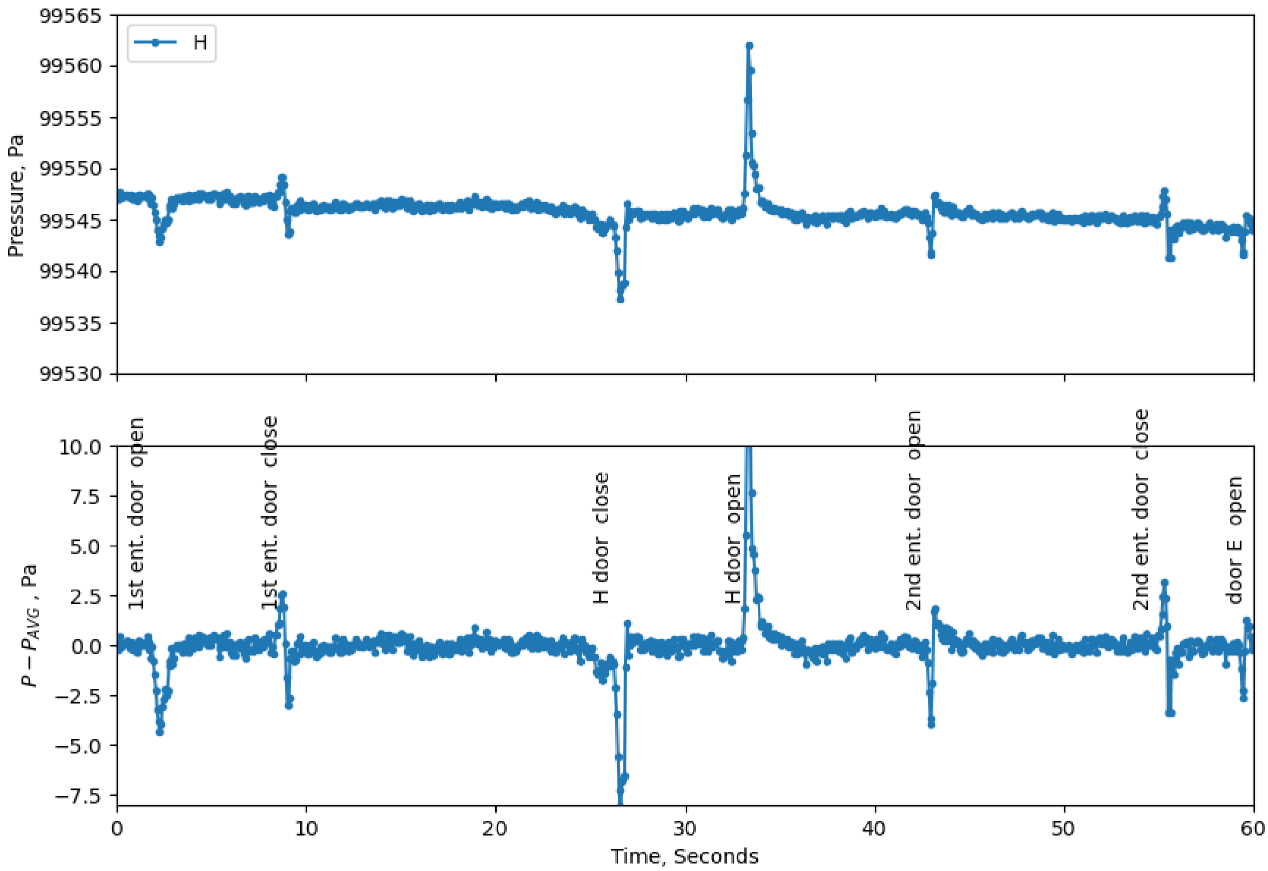

Figure 2. Change of pressure in reaction to various indoor events in the same office and outside this office. Top: The absolute pressure reading of the ENS220 in Pascal. Bottom: pressure change with respect to average pressure.

Various doors were opened or closed during the measurement period. The top plot of figure 2 shows the absolute pressure signal of the sensor in office H. Pressure changes caused by the office door, the main entrance door in ca. 5m distance, and even the door in the hallway in 10m distance are clearly above the sensor's noise floor and typical ambient pressure variations.

Throughout this period, various events occurred which are distinctly visible in the top plot, showcasing the sensitivity of our pressure measurement capabilities. As a result, these events can be reliably detected with a high level of confidence.

The following main factors lead to a change in pressure:

- When a door or window is opened or closed the air is compressed in the area where the door or window moves inward, momentarily increasing the pressure within that room. Simultaneously, the pressure in the area that the door is moved outward is decreased. This change sensed by sensor depends on the size of the room, the distance of sensor to the window or door, and the speed the door or window is moved.

- In buildings with air conditioning, the inside pressure may differ from outside pressure. When a window or door is opened, the air link to the outside equalizes the outside and inside pressures. This results in a fast change of the pressure in the room which is sensed by the pressure sensor.

4 Indoor event localisation

To enhance the specificity of event detection, multiple pressure sensors can be deployed. In Figure 3 we show the measured pressure at two locations: office labelled as 'G' and next office labelled 'H'. Notably, the sensor in office 'H' exhibits a significantly more pronounced response to events within its vicinity when compared to the sensor in the adjacent office. In contrast, both sensors register events from the main door and an office in the hallway with equal magnitude. We see that employing multiple pressure sensors improves event detection and allows event localization.

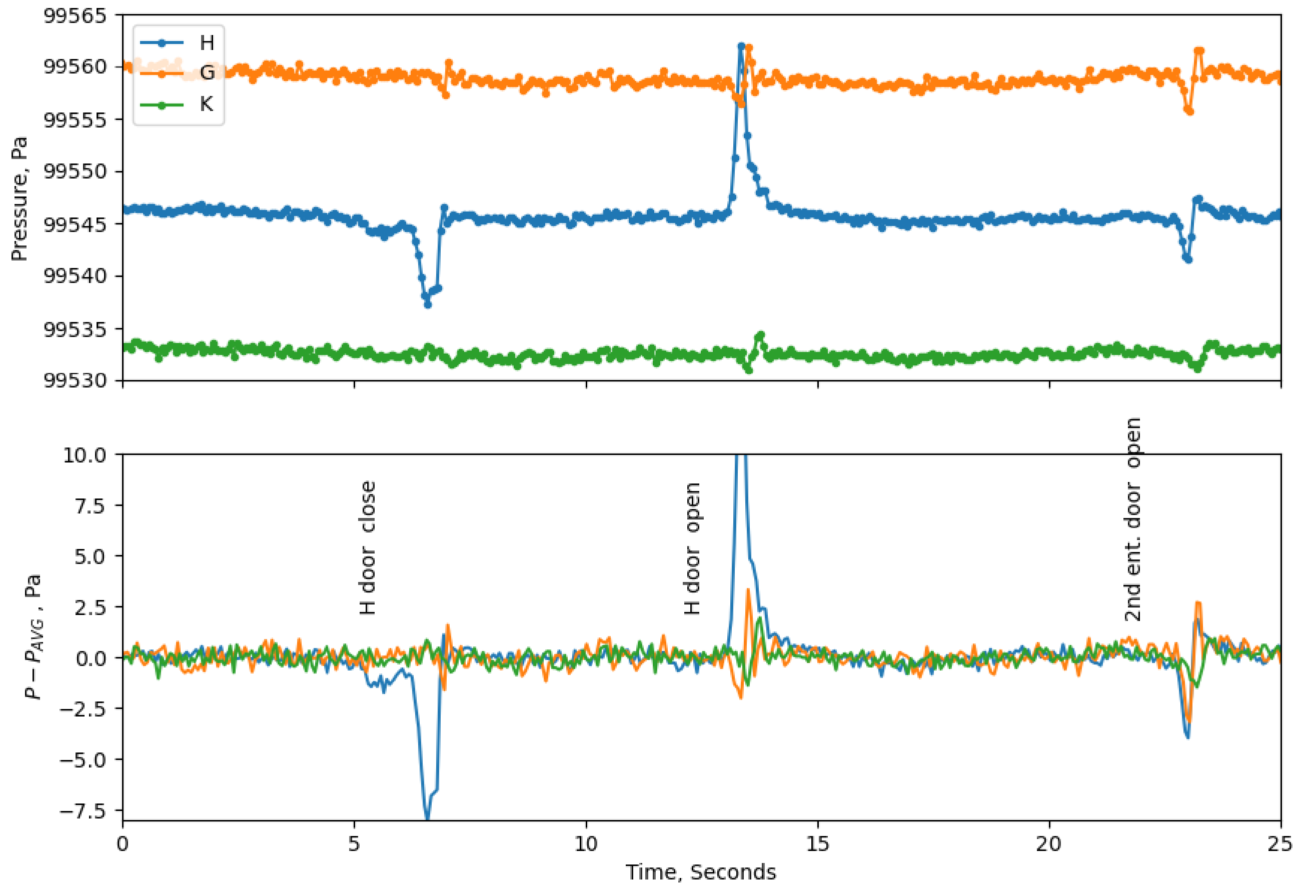

Figure 3. Change of pressure in three locations (Kitchen, Office H, and G) in reaction to various indoor events. Top: Absolute pressure. Bottom: pressure change with respect to average pressure.

The high sample rate of ENS220 enables another possible method for event localization using the difference in time that the events are sensed at different locations. A timing synchronization in the order of few milliseconds between sensor nodes is required. Figure 4 shows the measured pressure signals when the kitchen window is opened and closed. The sensor in the kitchen measures the strongest signal and registers the event first.

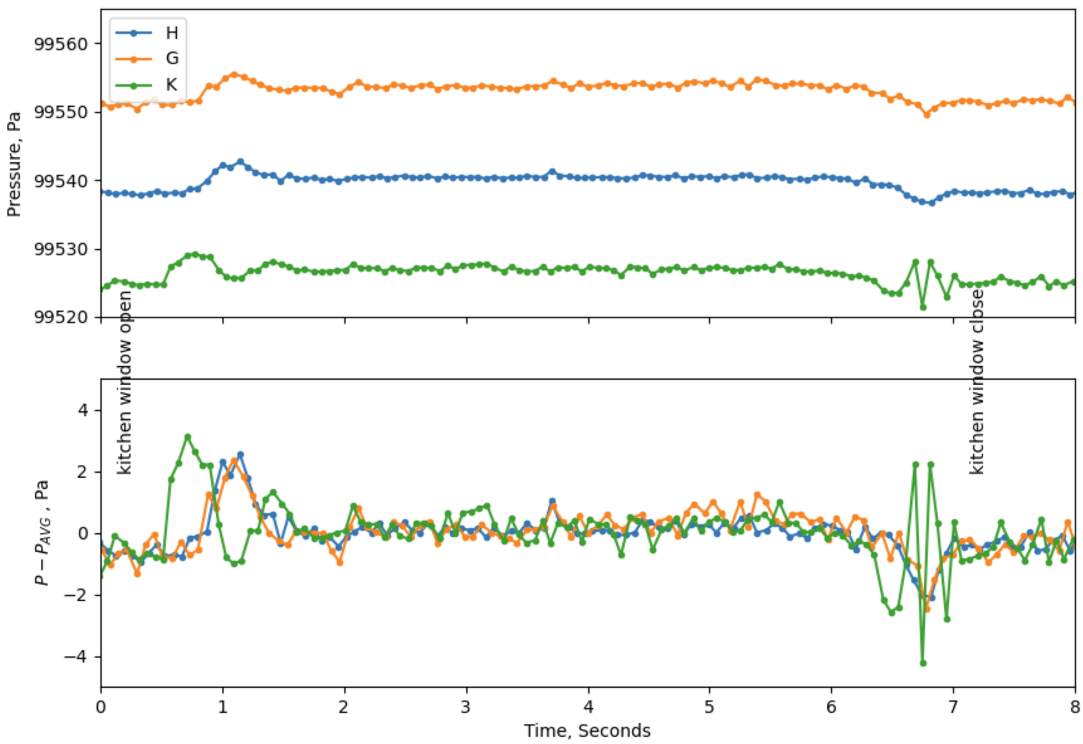

Figure 4. Time difference between sensed events at different locations. The sensor in the kitchen registers the opening and closing of the kitchen window earliest. The sensors in H and G offices register the events in the kitchen at the same time.

5 Event detection algorithm

The changes induced by the events surpass the fluctuations in ambient pressure within short time intervals, as illustrated in Figure 3. In contrast, the variations in ambient pressure over an extended period exceed the signal generated by the events, as depicted in Figure 5.

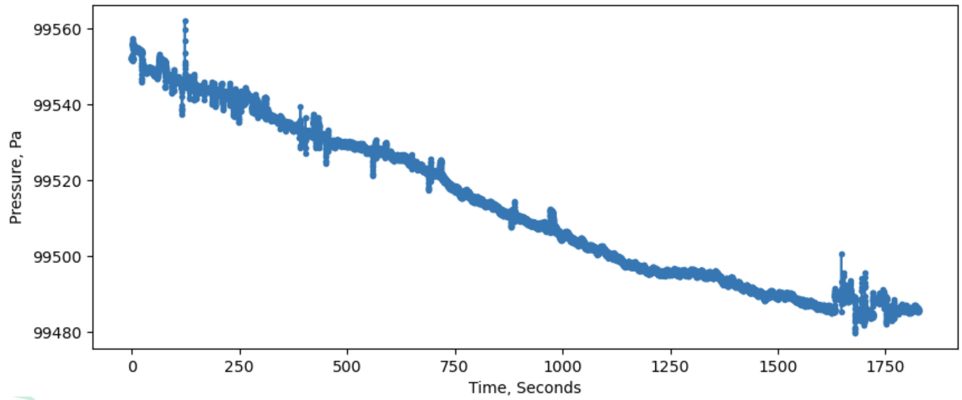

Figure 5. Ambient pressure in office in 30 minutes. We see that the natural change in pressure exceeds the amplitude of the events.

To eliminate ambient variations and identify the events, several methods can be employed:

- Using a moving average to compare the current pressure with the average.
- Using a short time window and compare the pressure with median or mean pressure.
- Given our interest in rapid pressure changes in any direction, employing the first or second derivative of the pressure as the signal.

Here, we opt for the third method due to its simplicity and superior performance.

Figure 6 shows diagram of a proposed algorithm for event detection. Firstly, the derivative is calculated by dividing the pressure difference by the time difference. Then a low-pass filter is used to reduce the noise. The bandwidth should be large enough to pass the events lasting from one to a few seconds. For the sample rate of the 15.6 sample/second, employed in data collection, a 2nd or 3rd order digital Butterworth filter with normalized bandwidth of 0.1 to 0.2 yields satisfactory results. The filter output is compared to an average variation like mean absolute deviation or standard deviation. If the filter output exceeds the average variation by a factor of 'm' then an event is detected. By changing 'm' the false alarm rate and sensitivity of event detection can be tuned. Typical values for m are in the range of 3 to 5.

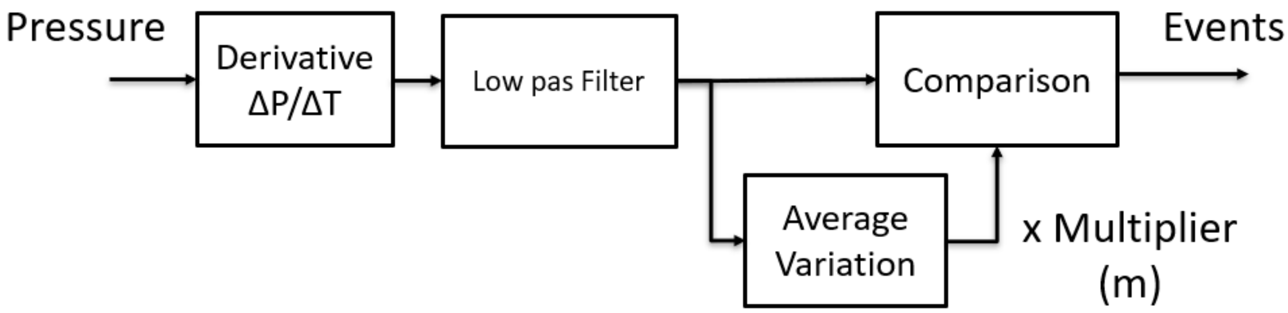

Figure 6. Block diagram of event detection algorithm using first order derivative of the pressure signal.

Figure 7 shows the output of the lowpass filter and the detected events by the three sensors in H, G, and K locations. We see that most events are detected by all sensors. Some events however are only detected by the sensor that is closes to the event.

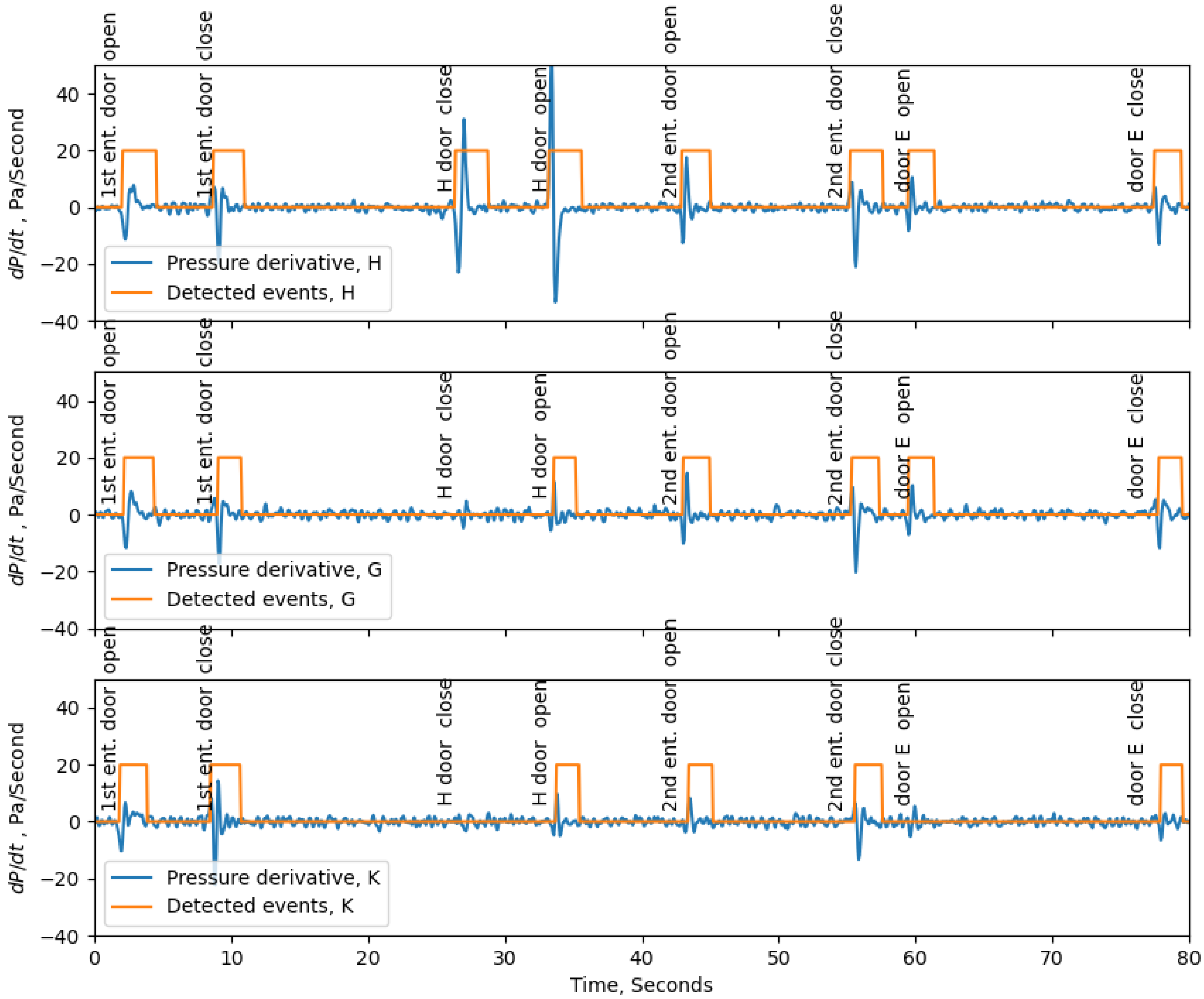

Figure 7. Filtered pressure derivative and the resulting detected events.

6 Advantages and limitations

Advantages:
One pressure sensor can be used to detect events associated with several windows and doors in one room or even adjacent rooms.
Challenges:
If doors and windows are opened too slowly, there is a risk of events being missed. In buildings equipped with climate control, this probability is reduced for connections to outside. This is because the opening of a window leads to an equilibrium between external and internal pressures, causing a detectable pressure change which is registered by the pressure sensor.

7 Example implementation

An example implementation can be found at:

Find code resources and drivers on: https://github.com/sciosense/ens220-arduino

8 Copyrights & Disclaimer

9 Revision information

Table 2: Revision history

Revision	Date	Comment	Pages
1.0	2023-12-14	• First version	10

Note(s) and/or Footnote(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
1. Correction of typographical errors is not explicitly mentioned.

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