A Low-cost Sensor Module for In-Building Monitoring and Threat Detection

Interim Report for 4B25 Embedded Systems

1 Overview

This interim report aims to provide a detailed progress update for the in-building monitoring and threat detection system project.

1.1 Aims and objectives revisit

The aims and objectives for this project remain largely unchanged [1] and are listed as follows.

The project aims to develop a low-cost hardware system, which is capable of providing environmental monitoring, safety sensing and security threat detection functionalities, suitable for in-building deployment [1].

In order to achieve the aim, the following objectives are identified:

- To design a hardware prototype to provide temperature, humidity, sound and motion sensing data as well as smoke detecting capability.
- To develop a low-cost *in-situ* means to display and report sensed data and important messages to end-users [1].
- To test and evaluate the system in a building at the University of Cambridge, Cambridge, UK [1].

1.2 Benefits analysis

Having a scalable, low-cost in-building monitoring system deployed can potentially help identify the environmental performance levels of the buildings, which is one of the most popular sustainable energy and development research topics. In the mean-time, due to its low-cost and ease of implementation properties, such a system would be commercially attractive for a broader use-case for ordinary households.

Several benefits, research and commercial-wise, of having such an in-building monitoring system are identified as follows:

- Acquire data and knowledge of sustainability and energy matters.
- Based on the understanding of building environment, potentially lead to better building design and daily operation strategy.
- Lower cost products potentially lead to a higher deployment rate with a wider use-case.

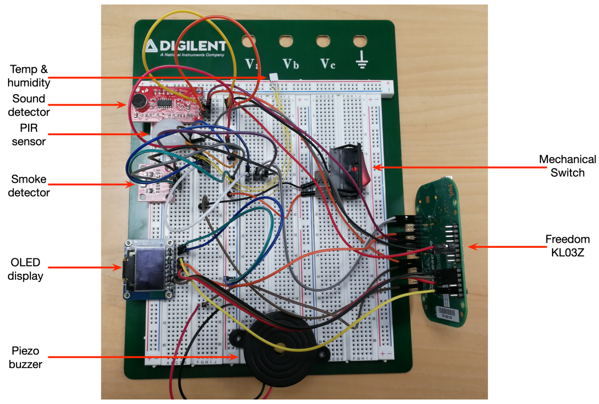

Figure 1: Picture of the prototype on breadboard.

2 Resource and components analysis

Due to the availability of components and considering the ease of implementation, several minor changes have been made in terms of component selection. The electronic and mechanical resources needed are listed in Table 1. All the necessary components have been ordered through online component distribution suppliers, including Onecall and Amazon, for next day deliveries. The wires, jumpers and headers are available via Division's workshop and Physical Computation Laboratory. Through-hole capacitors, which will be used for integrated circuit (IC) decoupling, are available in the Dyson Centre. The underlying firmware is available from Github and has already been used for several coursework deliverables throughout the term.

Table 1: The resource list for the in-building monitoring system

Component	Part number	Supplier	Status and Remarks
Freedom development board	FRDM-KL03Z	NXP Semiconductors	In house
OLED breakout	INA219	Adafruit	In house
Piezo buzzer	KPEG-350	Kingstate	Delivered
PIR motion sensor	EKMC1603111	Panasomic	Delivered
Temp, Humidity Sensor	HIH8120-021	Honeywell	Delivered
Smoke sensor breakout	SEN-14045	Sparkfun	Delivered
Sound detector breakout	SEN-12642	Sparkfun	Delivered
Mechanical rocker switch	C1353ATNAN	Arcolectric	Delivered
Through-hole capacitor	0.1 uF		Available Dyson centre
Jumpers and headers			In house
Wires			In house
Breadboard			In house

3 Current project progress overview

To date, the project progression has followed the timeline shown in the project proposal [1]. However, changes to the plan have also been made. The hardware design was conducted before writing up the firmware for the system, and the first-stage hardware setup is shown in Figure 1. The schematic of the system is shown in Figure 2.

Given the limited project time and resource available, the previously proposed smoke detector and sound sensor using SMT technologies have been replaced by two commercial-off-the-self (COTS) breakout boards provided by Sparkfun. The smoke detection unit comprises a MAX30105 particle sensor. The sound detection unit uses a 9.7mm microphone with LMV324 general purpose ampli-

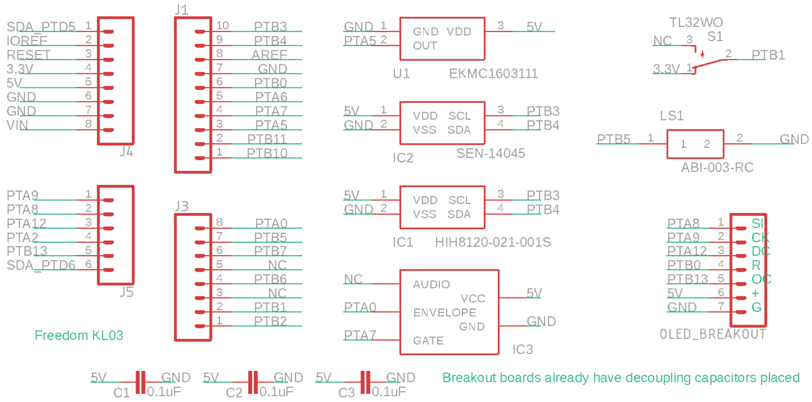

Figure 2: The schematic diagram of the system showing the interconnections as well as component setups. The Freedom KL03 board is shown on the left as a group of four on-board header connections.

fier. All the components have been ordered and successfully delivered. Moreover, a sensor data processing strategy has been designed and shown as a block diagram in Figure 3. A mechanical switch will be used to toggle two scenarios, namely the threat-detection scenario where passive infrared (PIR) motion sensor and sound detector will be turned on, and the normal monitoring scenario where the two sensors will not operate. An initial breadboard assembly was completed as of writing this interim report. As for firmware development, all the sensor datasheets have been collected and read.

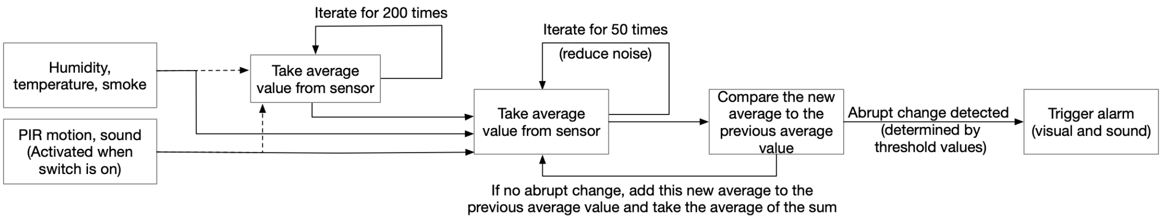

Figure 3: A block diagram to demonstrate the process of the system.

4 Changes of the project plan

The previously proposed mechanical design which requires the use of 3D modelling and 3D printing will no longer be considered due to the limited amount of time available. It should also be noted that the system prototype will be breadboard-based, with a provision of carrying out strip-board designs. Therefore no printed circuit boards (PCB) will be created for the project. The focus will be to integrate the set of sensors using headers and wires and to set up a user-friendly sound and vision alerting human-interface. The cost of constructing such a system is high at this prototyping stage since sensor breakout boards that are of higher cost were purchased due to the limited resources and time available.

The updated Gantt chart for this project is shown below.

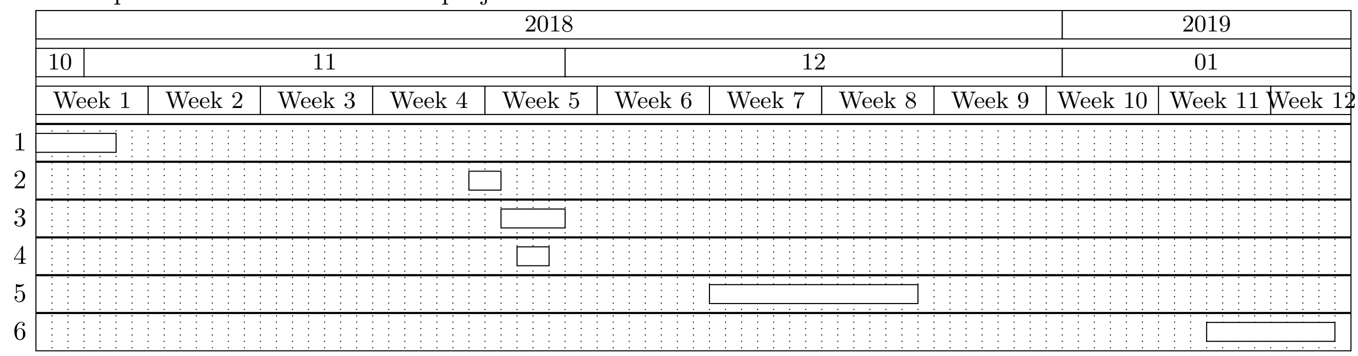

Figure 3. The updated Gantt chart for the project showing proposed timeline with indication of dates and weeks.

The specific tasks, which in total sum up to 24 hours, are listed as follows. 1: Components selection and high-level design (2 hrs). 2: Components ordering and schematic design (2 hrs). 3: Interim report writing (4 hrs). 4: Hardware wiring and setup (1 hr). 5: System construction, both hardware and software (10 hrs). 6: Final report writing and demo preparation (5 hrs).

5 Feasibility analysis

The piezo buzzer requires the least amount of work. As planned, this buzzer will be directly connected to one of the Timer/PWM (PTB5) pins on the Freedom development board. I have had experience in controlling a piezo buzzer to play music using a microcontroller from Microchip. If the PWM pin did not work as planned, an alternative solution is to directly use the pin as digital output and control the toggling pattern of this pin to control the piezo buzzer's output frequency.

Depending on the workload and actual project progress, it is possible that one or two of the currently deployed sensors will not be activated due to the limited time to write up the drivers for these sensors, in specific the sound sensor breakout, since it requires the most amount of time for the firmware development.

It is estimated that two-thirds of the remaining time will be spent on writing up the drivers for the deployed sensors and the software for sensor data processing. The sensors modules that will be used are all I2C-enabled, and the configuration setups are analogous to the INA219 current sensor used for coursework 4. Therefore, it is anticipated that a maximum of 1.5 hours will be used for the configuration of each sensor (6 hours overall). Based on the previous experience in implementing software algorithms, communicating with I2C devices and developing microcontroller firmware, the coding work can be done within the six-hour framework. Depending on the remaining working hours left, the organic light-emitting diode (OLED) display module will be configured either only to display icons when the alarm is triggered or to display the collected sensor data continuously on site.

6 Conclusion

In general, it is believed that the project will be completed in the 24-hour framework. The current project status has been reviewed throughout this report, with high-level hardware and software design completed and prototype assembled. The next stage will be system firmware development as illustrated in the updated Gantt chart.

References

[1] Y. Wang, "A Low-cost Sensor Module for In-Building Monitoring and Threat Detection Project Proposal for 4B25 Embedded Systems," tech. rep., Cambridge, 2018.