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A Novel IoT System for Highly-specific Gas Sensing Applied to Health Monitoring at Home

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Summary:

We introduce a novel low-power IoT system for highly-specific gas sensing applied to home health monitoring. The system integrates environmental sensors and one-pixel colorimetric gas sensors to detect indoor pollutants like CO2 and formaldehyde. These colorimetric sensors, based on dyes, enable precise gas measurements. The system offers real-time data collection and transmission, providing a scalable, non-intrusive solution for continuous monitoring. Although focused on health applications, the system's design is versatile, allowing integration into a variety of IoT-based contexts.

Keywords: IoT system, colorimetric sensors, gas sensing, low-power, home health monitoring

Introduction

In this work, we introduce a low-power IoT system designed for highly-specific gas sensing applied to home health monitoring. We leveraged compact, energy-efficient components, including one-pixel colorimetric gas sensors, environmental sensors, and an ESP32 microcontroller. Our system aimed to provide continuous real-time monitoring of indoor pollutants, such as CO2 and formaldehyde, to assist healthcare providers in remote health assessments[1]. We focused on minimizing power consumption while ensuring precise and reliable measurements, making the system suitable for deployment in home environments.

System Architecture

Our system was built around the MAX86916 OnePixel sensors, which are photo-diode sensors with red, green, blue, and infrared LED illuminations. Such photonic devices had provided good results for the colorimetric readout of gasometric dyes[2] in the past [3]. These sensors were paired with the well-known BME680 sensors, capable of measuring air quality, temperature, humidity, and pressure. Following these, our system integrated several key components, mainly the ESP32 microcontroller, a low-power, dual-core microcontroller with integrated Wi-Fi and Bluetooth capabilities. Next, we used the CP2102N USB-to-UART controller for USB communication and the MCP73831T lithium-ion battery charging IC for battery management. For data storage, we incorporated a standard microSD card slot. Time synchronization and accurate time-keeping were handled by the PCF8523TS RTC module. The device also featured a RPi A-compliant socket for connecting a screen, enabling user interaction and feedback. To ensure optimal gasflow near to the colirimetric dyes, the system included MAX6650 IC-based fan control circuitry. Fig. 1 shows the designed placement for the system in a board. Finally, the system was designed to connected by a REST API to a health monitoring at home cloud [4].

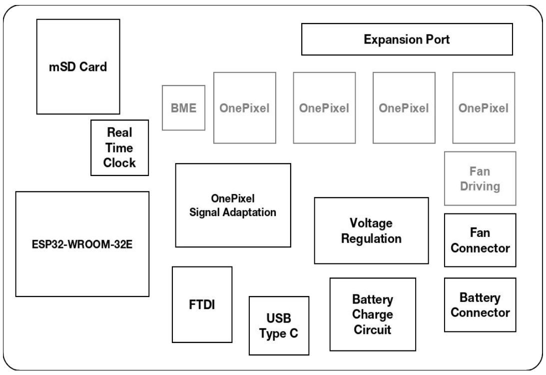

Fig. 1. The design of our IoT-system for highly-specific gas sensing. Black/gray colors represent different layers of PCB placement.

Results

We iterated the board design twice, addressing specific design improvements with each version. Fig. 2 and Fig. 3 presents a Dolfins Board (rev1.1) from the last fabrication batch, which is the size of a credit card, e.g. 3+3⁄8 in × 2+1⁄8 in, or approx. 8.5 cm × 5.4 cm.

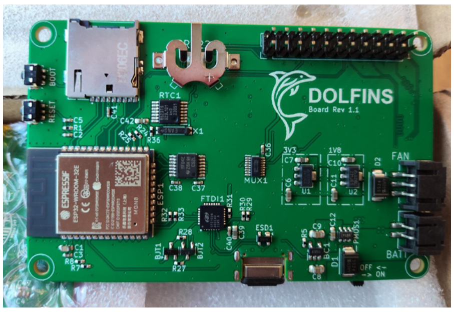

Fig. 2. Front of the fabricated board of the system (DOLFINS Board rev1.1), displaying several components of the board, such as the ESP32 microcontroller, the SD card, the RTC subsystem and all the power and communication subsystems.

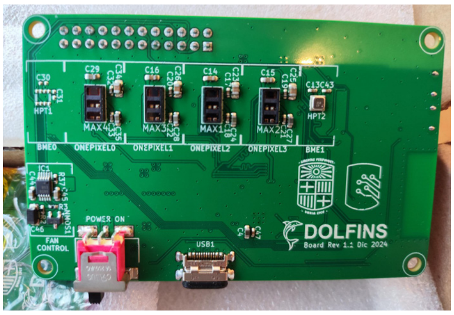

Fig. 3. Back of the fabricated board of the system (DOLFINS Board rev1.1), displaying several components of the board, such as the four MAX86916 One-Pixel sensors, one soldered BME680 environmental sensor and the fan control subsystem.

As power consumption was a key focus for us, over these last version of our system boards we measured the system's power draw in various operating modes, including sensor readings, Wi-Fi transmission, and idle states. The results, shown in the provided power consumption graph (Fig. 4), demonstrated the system's ability to operate efficiently with minimal energy. The minimal consume was found, as expected, when the device was configured in an IDLE state, a wake-up by RTC stage, where the device presented only a consumption around 100mW. Environmental and optical sensors displayed a consumption in the range of 300-400mW. Finally, usage during sensor and Wi-Fi communication activities revealed distinct peaks, around 750mW, when the device is communicating, but returning to the 350mW expected for working mode of the device, indicating efficient power management. Measurements were performed using a Dolfins 1.1 board powered by an Agilent B2912A SMU, which also recorded current and voltage through SCPI-controlled Python scripts. Instantaneous power was calculated and averaged with a 100-point rolling mean, synchronizing device activity using a custom firmware fork to isolate each functional mode.

All in all, the system has demonstrated a cost-effective, low-consumption approach for gas sensing at home. Further results will include obtaining laboratory data from the gasometric dyes in lab environments [2] and 'real data' in a simulated home environment with actors performing routine actions simulating a home-living scenario.

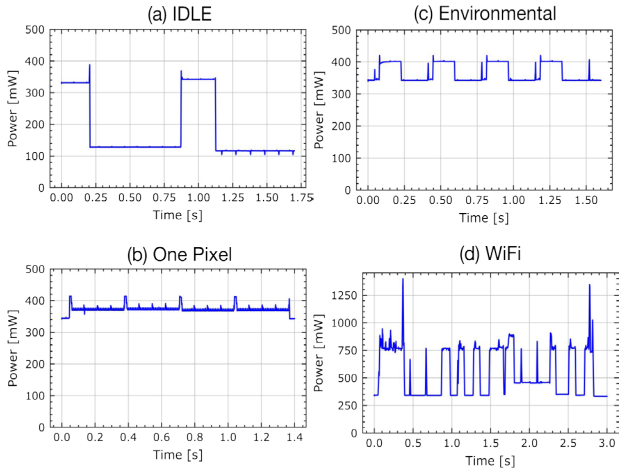

Fig. 4. Power consumption profiles for the Dolfins Board (rev1.1) under different operational modes: (a) Idle mode, (b) One-pixel sensor activity, (c) Environmental sensor activity, (d) Wi-Fi communication. The plots show the variation in power consumption over time for each mode.

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