Citizen Air Quality Sensor

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Introduction

A replicable device that uses multiple air quality sensors for local data collection.

- Emphasis on community atmospheric science
- Easily replicable
  - Thorough documentation
  - Relatively cost-effective
- Modular
  - Solar cell rechargeable on-board battery pack, or direct AC power
  - Use Wi-Fi or 4G
- Wireless data collection
- On-board and server storage
- Data encryption

Defining the Problem

Poor air quality can cause:

- Inhospitable environments
- Health risks such as heart disease and lung cancer.

Phones and PC’s can give generalized data

- Not very accurate, averaged over regions

There needs to be a way for local air quality data to be tested cheaply and easily.

Solution to the Problem

- The Air Quality Device will use modular sensors to measure the specific pollutants in its’ surrounding area
  - Gives user options for what pollutant they would like to detect
- Remote/manual access
- Specified Pollutants:
  - Carbon Dioxide
  - Sulfur Dioxide
  - Nitrogen Dioxide
  - Ozone
  - Methane
  - Particulate Matter

Standards & Regulations

Environmental Considerations:

- National Electrical Code benchmark for electrical design to avoid harming people, property, and the environment [1]
- ANSI/ASHRAE Standard 62.1-2016: Ventilation for Acceptable Indoor Air Quality for sensor detection in ppm (Parts Per Million) concentration indoors. [2]
- IP34 (Resistance to small objects and resistance to rain on all sides) [3]
- NFPA 70E (Health risk assessment protocols) [4]
- TCP/IP & associated Web standards [5]
- IEEE 802.11 (Wireless connections) [6]

Design

Power

Function:
Provide modular power options with battery, mains, and or solar

Constraints:
- Ability to provide 1.686 W to account for maximum current usage
- Battery capacity of at least 39.89 Wh to allow device to run for the 48 hour minimum

Analysis
- Chosen battery has a capacity of 92.5 Wh and can output 15 W

Microcontroller

Function:
Sample sensor data, log onto local storage, and send to Communication subsystem.

Constraints:
- Sufficient memory for operating code. Estimated 165 kB (+-5%)
- Support USB flash drives.

Analysis:
- Arduino Mega will come with 265 kB flash and ample pins.
- Arduino Host Shield provides USB capabilities.

Communication

Function:
Transfer data wirelessly to Google Sheets for logging.

Constraints:
- Grant ability to send/receive data on the Internet.
- Utilize either Wi-Fi or 4G

Analysis:
- ESP8266 can provide Internet access and has good reviews.
- Widely used and field tested for Wi-Fi abilities.

Design

Sensors

Function:

- Observes outside data and transfers through Interface within sampling interrupts.

Constraints:

- Sensor must detect at least 1 pollutant within the selected list.
- Max sampling rate of 10Hz.

Analysis:

- The MIKROE-2767 is analog voltage O3 sensor that can sample in range.
- The SEN0377 is digital NO2 sensor that can take 3.3-5V.

Interface

Function:

- Conditions a chosen set of analog voltage and analog current output ranges before entering the ADC

Constraints:

- Scale signals to 0 - 5 volts
- Convert a current signal 0 to 5 V

Analysis:

- Interface uses a combination of op amps, 2 and 3 resistor circuits to scale or convert signal ranges

Web & Wireless

Function:

- Provide easy access to logged data via a website or spreadsheet.

Constraints:

- Must be able to log at least 1 month of data. 50 MB.
- Provide public or private data access

Analysis:

- A Google Script connected to a Google Sheets.
- Google services are easy to use and available

Implementation

Sensors

- Air quality sensors were substituted with other types to simulate the input/output of sensors.
- Current sensors include: distance, temperature, gyroscopic, acceleration

Web and Wireless

- A Google Script has been written to automatically update a Google Sheet when given a set of data. This Google Script updates data dynamically and may optionally be linked to a Google Site.

Interface

- The interface was implemented as planned with 4 different circuits soldered onto different areas of a perfboard.

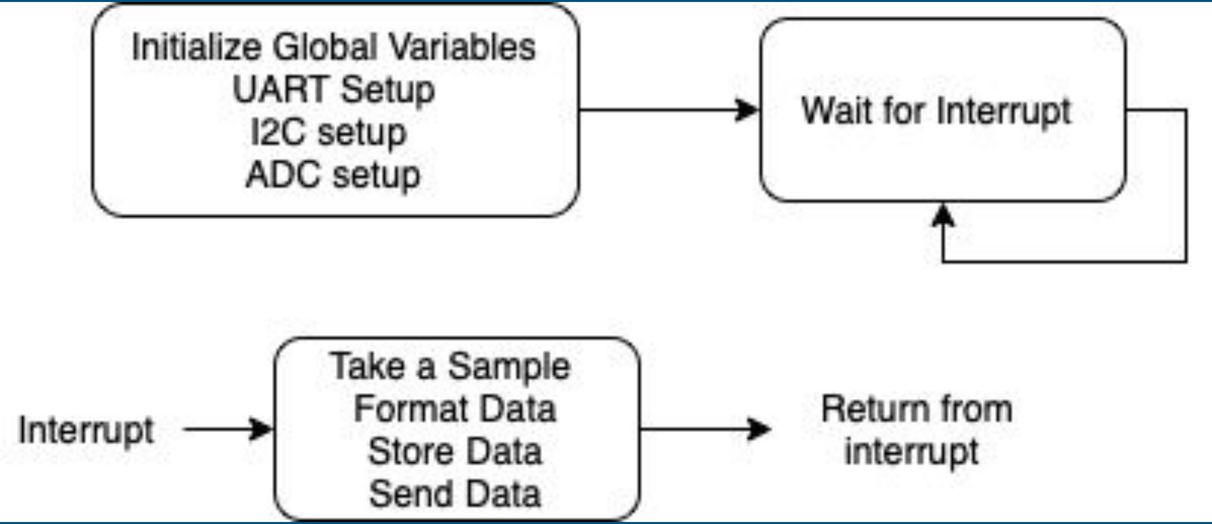
Communication

- 4G dropped out of scope. Internet access and data exchange was implemented with Wi-Fi.

Power

- Solar powered battery was implemented and has an operation time of 21.8 days. This far exceeds our expectations and needs.

Software


Initialize Global Variables
UART Setup
I2C setup
ADC setup
Wait for Interrupt
Interrupt
Take a Sample
Format Data
Store Data
Send Data
Return from
interrupt

Software cont.

Achieved	Not Achieved
Dynamic usage of USB flash drive.	Current error handling.
Master-Slave communication from Arduino to ESP.	Battery monitoring capabilities.
Wi-Fi accessed and utilizing HTTPS for data transfer.	Power saving options and emergency deep sleep mode.
Interrupt driven sampling.	Hot swapping digital sensors.
Local logging of data onto USB flash drive.	Temporary data buffers for larger payload transmissions during logging.
Wireless logging of data onto Google Sheets.	Wireless connection timeout and connection self-diagnosis.
Successfully read from at least 3 Digital and/or Analog sensors.	Security measures such as encryption, GPS, or psychical trauma.

What Went Wrong...

Pitfalls:

- Due to ordering delays and disruption, the team did not receive air quality sensors and the use of other sensor types to simulate data was required.
- The original plan was for a deployable server to encompass the Web & Wireless subsystem. Difficulties in making the code run and easy to use resulted in the idea being discarded.
- Time management was poor with features taking much longer to implement than anticipated.
- Faulty components were received and required repurchasing.
- Authorization to use an Internet Access Point on campus took six weeks longer than expected.

Experimentation

Interface

- The Sharp 2Y0A21 distance sensor was connected to the interface and the voltage was read from the ADC at varying distances between 10 - 80 cm.

Power

- Measured an average current draw for the system of 228 mA
- Using solar panel extends operational time to 524 hours

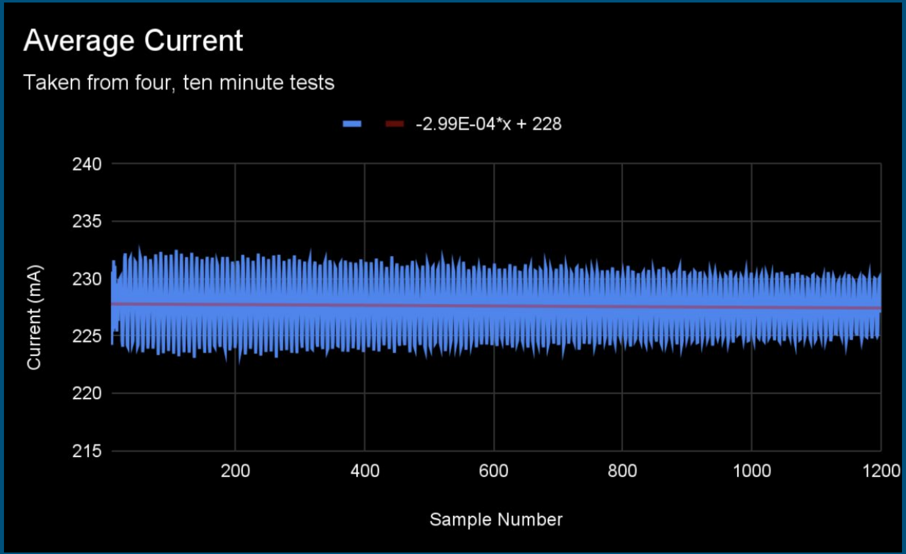
Microcontroller

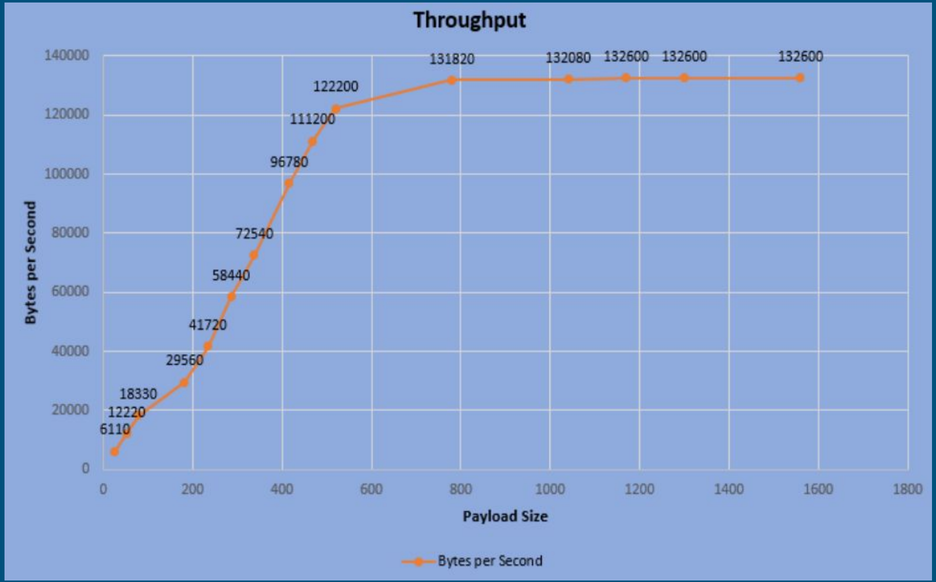
- Data is able to be written at 64 KB/s and read at 169 KB/s
- Flash storage storage needs at most 4 ms to access.

Communications

- Max throughput is 132,600 KB/s at 1000 KB payload size
- Reliable connection distance from Internet access point is 70 ft.

Experimentation cont.





Budget

Options	Major components	Total
1	Solar, Battery, Wi-Fi, USB	$77.38
2	Solar, Battery, 4G, USB	$181.18
3	Mains, Wi-Fi, USB	$89.37
4	Mains, 4G, USB	$146.18
5	Mains, USB	$73.39

Note: All options not enumerated

Lessons Learned

1. Take deadlines more seriously
2. Fully explore and research all available options before you make final decisions
3. Better communication between team members
4. Better communication between supervisors and customers.
5. More accountability between team members
6. Scheduled group work times

References

1. National Fire Protection Association, International Fire Safety Protocol Institute, "National Electrical Code," https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=70
2. The National Institute for Occupational Safety and Health (NIOSH) "Indoor Environmental Quality" https://www.cdc.gov/niosh/topics/indoorenv/hvac.html
3. Rainford Solutions "Ingress Protection Rating" https://rainfordsolutions.com/products/ingress-protection-ip-rated-enclosures/ip-enclosure-ratings-standards-explained/#:~:text=IP34,water%20spray%20from%20any%20direction
4. National Fire Protection Association "Standard for Electrical Safety in the Workplace" https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=70E
5. International Business Machine Corporation (IBM), "Socket Programming," https://www.ibm.com/docs/en/i/7.1?topic=communications-socket-programming
6. IEEE 802 "IEEE 802.11TM WIRELESS LOCAL AREA NETWORKS" https://www.ieee802.org/11/