Portland State
UNIVERSITY

MASEEH COLLEGE OF ENGINEERING

T31 Capstone Project

Open Bike Initiative: Air Quality Sensor Hub

UML Design Diagrams

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Air Quality Sensor Hub Overview

The sensor hub consists of three primary air quality sensors capable of detecting small particulate matter, large particulate matter, and carbon monoxide. It also has sensors to detect temperature, humidity, and GPS. The system is self-contained and designed to write a new line of sensor data every 2 to 3 seconds, and store the data internally on an SD card in an easy to analyze format. The records are time-stamped using a real time clock and the SD card can easily be removed from the outside of the enclosure for data analysis. The system is powered with a rechargeable battery and all components are housed inside of a small enclosure with copious amounts of airflow. An on/off switch will start and stop data collection by supplying power to the system.

The system is designed to be rugged enough for the average city bike ride and can be mounted to any bicycle with a rack. It has been designed to be capable of communication with future Open Bike Initiative "Smart-locks" (a bike sharing model with open source software and open hardware) via RS232 communication using an RJ45 connection. The smart locks will contain cellular and Wi-Fi technology which can upload the records to the cloud for open access and analysis. The hub will also be capable of passing dynamo power to the Smart-Lock via the RJ45 line.

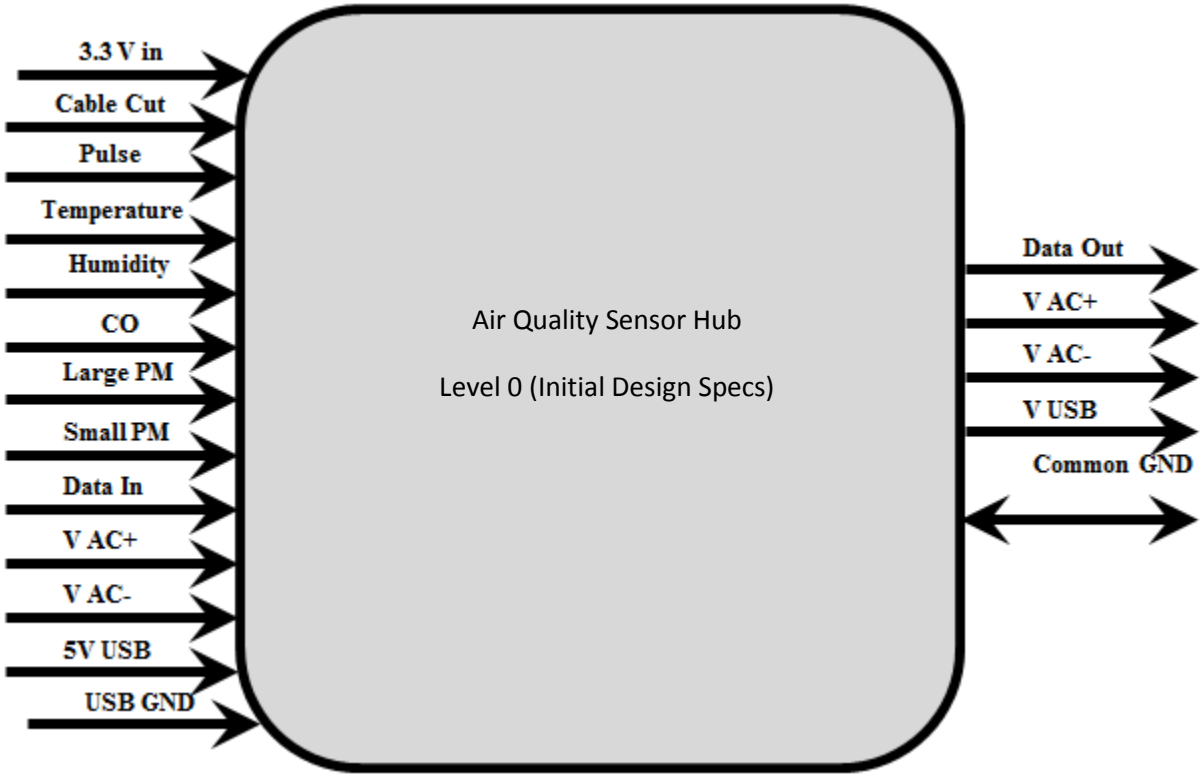
The system had different initial specifications making it dependent on the OBI Smart-Lock (outlined below in level 0). However, it has been modified to be the stand-alone system it is today as described above (outlined below in Level 1).

Terms Used

- RTC: Real time clock.
- MCU: Micro-controller unit.
- PM: Particulate matter.
- CO: Carbon monoxide.
- OBI: Open Bike Initiative.

System Overview

(Level 0 -- Initial Design)



Module: • Air Quality Sensor Hub
Inputs: • **3.3V In:** 3.3V power input from OBI Smart-Lock (part of RJ45) • **Cable Cut:** A security signal that will activate an alarm if the lock cable is cut (part of RJ45) • **Pulse:** Users heart-rate • **Temperature:** Ambient temperature • **Humidity:** Ambient percent humidity • **CO:** Carbon monoxide in the surrounding air • **Large PM:** Large particulate matter particles in the surrounding air • **Small PM:** Small particulate matter particles in the surrounding air • **Data In:** Input data from OBI Smart-Lock (part of RJ45) • **V AC+:** Hub dynamo AC + power generated • **V AC-:** Hub dynamo AC – power generated • **5V USB:** 5V of power that will be supplied with a USB battery pack connected to micro-USB • **USB GND:** Ground connection from the USB battery pack connected to micro-USB
Outputs: • **Data Out:** The data to be transmitted to the OBI Smart-Lock (Part of RJ45) • **V AC+:** Hub dynamo AC + power to be passed to OBI Smart-Lock (part of RJ45)

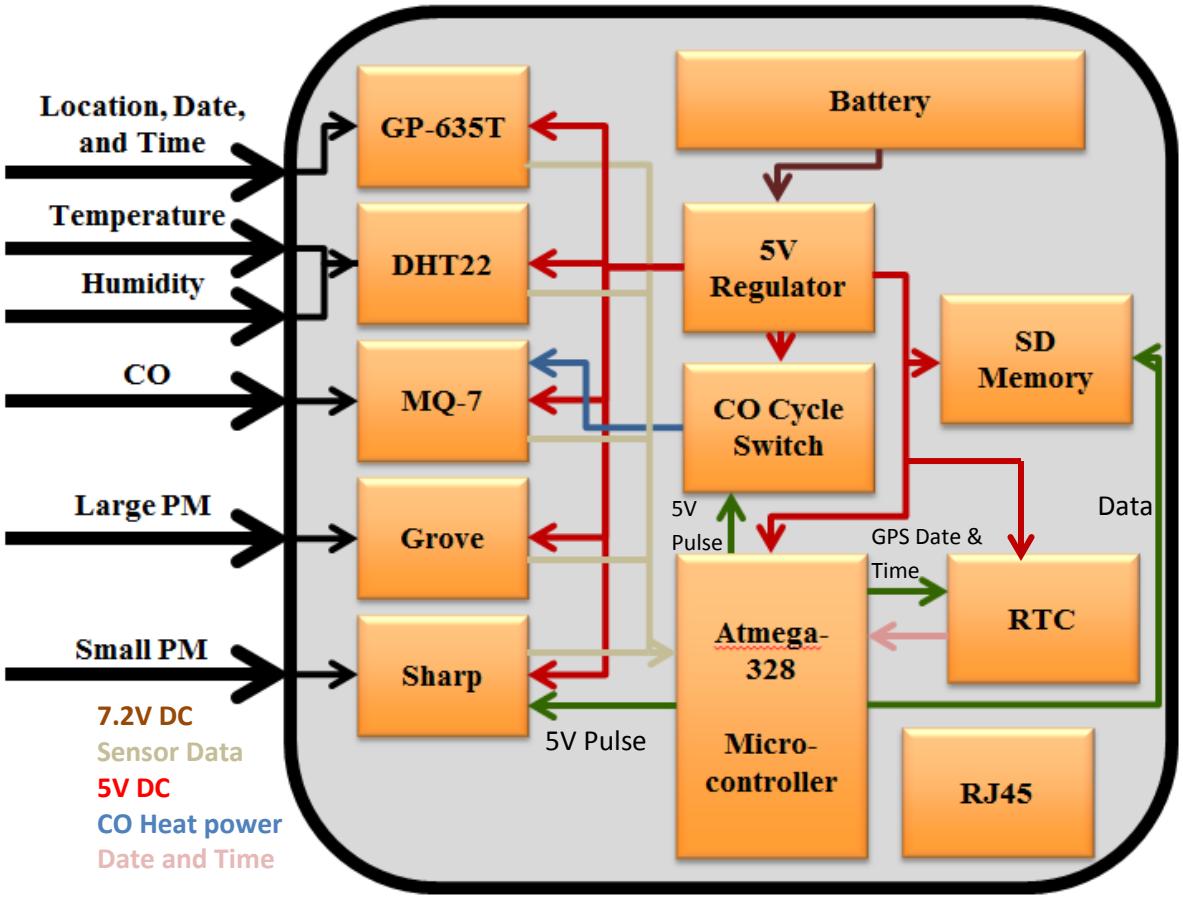
- **V AC-:** Hub dynamo AC – power to be passed to OBI Smart-Lock (part of RJ45)
- **V USB:** 5V USB line to be passed to OBI Smart-Lock for charging the battery (Part of RJ45)
- **Common GND:** Common ground signal between all power signals between OBI system and sensor hub

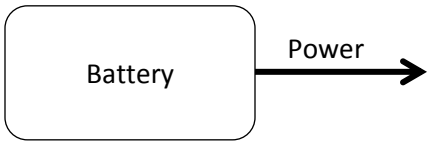
Functionality:

- Collect time stamped records of CO and particulate matter levels in the air, temperature, percent humidity, and riders' pulse.
- System will be housed in a small enclosure that allows copious amounts of airflow.
- System will be capable of transmitting sensor data to the main OBI Smart-Lock.
- System will be capable of passing power to the main OBI Smart-Lock from a dynamo for charging the battery.
- System will be powered via a 3.3V line from the main OBI Smart-Lock which will activate the system.
- System will connect with the main OBI Smart-Lock via an RJ45 connection to receive 3.3V power, data, and security cable cut signal; it will also transmit data, dynamo power, 5V USB power, and share a common ground.
- System will be capable of time-stamping the data using an RTC.
- System must be cost-efficient.
- System will collect sensor data every few seconds.

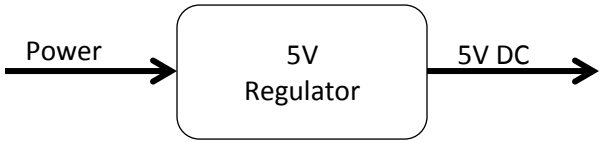
System Overview

(Level 1--Implemented Design)

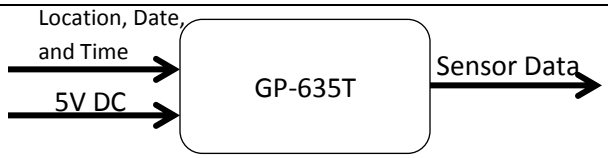


Module: Battery	

Inputs: None
Output: • **Power:** 7.2V DC
Functionality: • Supply power to the 5V linear regulator to power the system • A switch connects/disconnects the output signal to power the system on/off • Rechargeable 3300mAh Ni-MH battery

Module: 5V Regulator	

Inputs: • **Power:** 7.2V DC
Output: • **5V DC:** Regulated 5V DC signal
Functionality: • The input signal enters a 7.2V to 5V linear DC to DC voltage regulator. • The signal is smoothed using >= 10uF capacitors on the input and output. • The signal is then fed to all powered components of the system.

Module: GP-635T	

Inputs: • **Location, Date, and Time:** Satellite signal containing Location, Date, and Time. • **5V DC:** Power for the sensor
Output: • **Sensor Data:** NEMA codes supplied by the GPS to indicate the Location, Date, and Time to the microcontroller.
Functionality: • When connections to satellites are made, the GPS module receives the location, date, and time. • The sensor translates the signals to NEMA codes which are translated to strings using the microcontroller. • The module is powered with a 5V signal.

Module: DHT22	

Inputs:

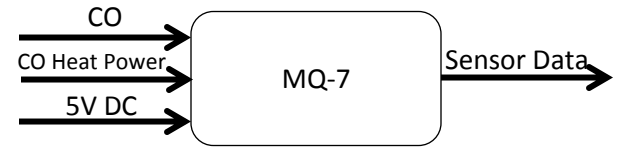
- **Temp & Humidity:** The ambient temperature and ambient humidity in the air are detected by the sensor.
- **5V DC:** The sensor is powered with a 5V signal.

Output:

- **Sensor Data:** The sensor outputs the evaluated temperature and percent humidity to the microcontroller for processing.

Functionality:

- The sensor detects the ambient temperature and humidity in the surrounding air.
- The sensor sends the data to the microcontroller for processing and evaluation.
- The module is powered with a 5V signal.

Module: MQ-7	

Inputs:

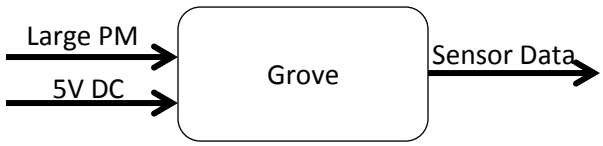
- **CO:** The levels of CO in the surrounding air are detected by the sensor.
- **CO Heat Power:** 5V or 1.4V power for the heater coil for the sensor.
- **5V DC:** The sensor is powered with a 5V signal.

Output:

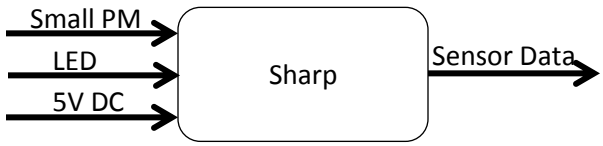
- **Sensor Data:** The sensor outputs an analog voltage to the microcontroller representing the relative amount of CO in the atmosphere.

Functionality:

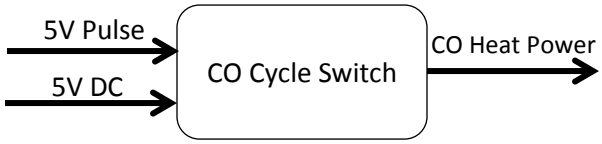
- The sensor receives 5V as a reference for data communication with the microcontroller.
- The sensor has a coil which provides a resistance used to detect CO. This coil has two power cycles. As CO builds up on the coil, a 5V burn off (cleaning) phase is used at approximately 150mA for approximately 60s. After this phase a 1.4V phase is used for detection for approximately 90s. The cycles continually repeat.
- The sensors output is relative. In order to correlate the voltage with actual PPM values, certain tedious calibration techniques are necessary outlined in the datasheet.

Module: Grove	

Inputs: • **Large PM:** Larger PM (>= 1um) is detected by the Grove sensor. • **5V DC:** The sensor is powered with a 5V signal.
Output: • **Sensor Data:** The concentration of PM in the surrounding air is detected by the sensor and transmitted to the microcontroller.
Functionality: • The sensor outputs a digital signal proportional to the PM concentration (1um or larger) in the air. • The sensor sends the data to the microcontroller for processing and evaluation. • The module is powered with a 5V signal.

Module: Sharp	

Inputs: • **Small PM:** very fine PM is detected by the sharp sensor. • **LED:** Signal from microcontroller to turn the LED in the sensor on and off. • **5V DC:** The sensor is powered with a 5V signal.
Output: • **Sensor Data:** The dust density in the air is detected by the sensor and transmitted to the microcontroller for processing.
Functionality: • An infrared emitting diode and a phototransistor are used to detect the reflected light of very fine dust particles in the air. • The sensor sends an analog voltage proportional to the very fine dust particles in the air to the microcontroller. • To save power, an LED is turned on and off when detection takes place. • The system is powered with a 5V signal.

Module: CO Cycle Switch	

Inputs:

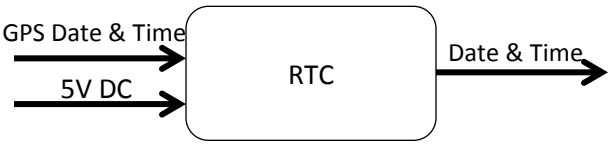
- **5V Pulse:** a 5V pulse from the microcontroller that controls the CO sensor power cycle. It is high for 90s (1.4V detection phase) and low for 60s (5V burn-off phase).
- **5V DC:** The switch regulates the 5V signal to a 1.4V DC.

Output:

- **CO Heat Power:** The switch either passes the 5V signal to the MQ-7 directly, or passes the regulated 1.4V signal.

Functionality:

- The MQ-7 heat cycle is controlled using this module.
- The module regulates the 5V signal to 1.4V.
- A transistor network uses a 5V pulse that stays high for 90s and low for 60s.
- When the pulse is low, the 5V DC input is passed to the MQ-7 heater coil for the burn-off phase, when the pulse is low, the regulated 1.4V signal is passed to the MQ-7 heater coil for the detection phase.

Module: RTC (Real-Time Clock)	

Inputs:

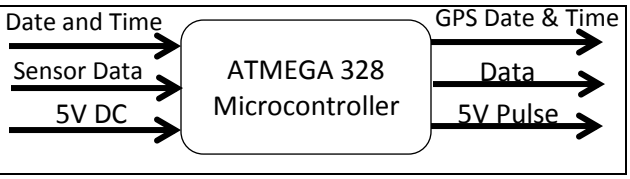
- **GPS Date & Time:** The microcontroller uses the obtained GPS date and time to set the RTC.
- **5V DC:** The RTC is powered using a 5V DC signal.

Output:

- **Date & Time:** The date and time are read by the microcontroller and written with each record.

Functionality:

- The module is independently powered using a CR2032 3.3V battery to maintain the date and time.
- The module uses I2C protocol to communicate with the microcontroller.
- The module has an independent 32.766 kHz crystal.
- The module is powered using a 5V DC signal.

Module: ATMEGA 328 Microcontroller	

Inputs:

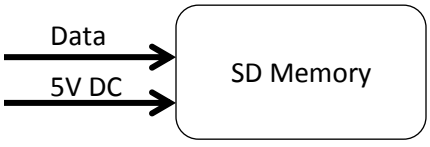
- **Date and Time:** The date and time is read from the RTC.
- **Sensor Data:** The CO, PM, temperature and humidity, and GPS data is read from the sensors.
- **5V DC:** The sensor is powered with a 5V signal.

Output:

- **GPS Date & Time:** The GPS date and time is used to set the RTC.
- **Data:** The processed sensor data is sent to the SD memory shield for storage.
- **5V Pulse:** 5V pulses are used to adjust turn on and off the LED for the sharp sensor, and to adjust the heating phase of the MQ-7.

Functionality:

- The microcontroller is powered using a 5V DC signal.
- The microcontroller is flashed with the Arduino boot loader and is programmed using the C based Arduino environment and language.
- The microcontroller is programmed to send a 5V pulse to set the CO sensor heat phase using a 5V pulse.
- The microcontroller is programmed to turn the sharp sensor LED on and off using a 5V pulse.
- The microcontroller is programmed to poll the sensor data approximately every 3 seconds, and organizes the data in an easy to analyze format.
- The microcontroller correlates the environmental data to GPS location as well as the date and time from the RTC.
- The microcontroller sends the data to the SD shield to store in an easy to analyze format in a .txt file.

Module: SD Memory	

Inputs:

- **Data:** The data is sent to the SD memory shield and written to an SD card in a .txt file.
- **5V DC:** The module is powered with a 5V DC signal.

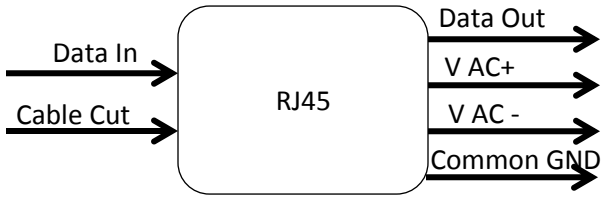
Output:

None

Functionality:

- The SD memory is used to store records.
- The records are written to a .txt file by the microcontroller.
- The SD card can easily be removed and inserted from the outside of the enclosure to the shield.
- The shield is powered using a 5V DC signal.

The RJ45 is not currently used by the system. In the future, it will be capable of connecting to the OBI Smart-locks and communicating via RS232 to transmit and receive data and pass dynamo power. The module will function as outlined below.

Module:	
RJ45	

Inputs:

- **Data In:** The RJ45 will be able to take data input from the OBI Smart Lock which will be sent to the microcontroller.
- **Cable Cut:** This line is grounded, and if the cable is cut it will result in an alarm and a siren sounding.

Output:

- **Data Out:** The microcontroller will send data output to the RJ45 for transmission to the OBI Smart Lock.
- **V AC+:** AC+ signal from the dynamo hub to be transferred to the OBI Smart Lock for charging the battery.
- **V AC-**: AC- signal from the dynamo hub to be transferred to the OBI Smart Lock for charging the battery.
- **Common GND:** Shared Common GND signal.

Functionality:

- The module will function as a connector between the air quality hub and the OBI Smart Lock.
- It will be capable of receiving data to be sent to the microcontroller.
- It will have a cable cut signal in case of theft.
- It will be able to send data to the OBI Smart Lock which can be transferred to the cloud.
- It will be capable of transmitting Dynamo power.