Air Quality Monitoring

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1 Introduction

Include Short introduction, motivation- technical and social Air pollution is a serious issue in urban cities. The deteriorating air quality is a cause of a plethora of heart and lung diseases.Burning of wood/plastic waste, Metal processing plants, vehicular emissions are the major sources of air pollutants. These pollutants are referred to as "Particulate Matter" as they remain suspended in air and can enter human lungs while breathing. PM 2.5 (Particulate Matter) (2.5 microns) is categorized worldwide to be the major cause of respiratory and cardiovascular problems. Apart from this other pollutants like Carbonmonoxide (Co), Sulphur dioxide SO_2 ,PM 10 etc also affect human health when present in significant quantities.
Statistical data about the concentration of air pollutants in different parts of the city can assist in the following ways:

- Help to locate the source of emissions The policy makers of the city can impose restrictions in case it is an industry/factory to reduce emissions.
- Data driven decisions can be taken by policy makers. The correlation between the data collected about the air quality and the diseases prevalent in an area can detect early onset of diseases.
- Create awareness among citizens

The commercially available Particulate matter sensors like Dylos 1100 C Pro (Cost: 300$) and SDS 011 (Cost : 40 $) are expensive with high power consumption. On the other hand there are sensors like Samyoung DSM 501 A (Cost : 12$) and Shinyei PPD42Ns (Cost : 10$) which are claim to sense PM 2.5 using LED/photodiode arrangement with moderate accuracy. Using low cost sensors to sense PM 2.5 levels in windowed thresholds if not accurately as the commercially used ones can be a stepping stone in monitoring air quality of small regions. Battery powered sensor nodes with low cost sensors and solar charging capability will be an optimum solution to address the issue of monitoring air quality at relatively lower budget.

2 Problem definition

Design a sensor node with air quality, temperature and humidity sensors and display it on a visualization tool to interpret them. Air Quality Monitoring requires measurement of eight pollutants, viz. PM10, PM2.5, NO_2, SO_2, CO, O_3, NH_3, and Pb. However, tracking PM 2.5 levels as started by **SAFAR** Project and **breathe.org** is essential to estimate air quality. In this project we are exploring the sensing of PM2.5 and CO. We are also measuring temperature and humidity. For measurement of PM2.5 we are using DSM501

3 Requirements

3.1 Hardware Requirements

Sensor node and the central server present the major hardware requirement.

- Sensors
  - MQ-7 - Carbon monoxide (CO)
  - DSM 501A - Particulate matter (PM2.5)
  - DHT22 - Temperature and Humidity Sensor
- Controllers
  - MSP430F5529 Launchpad - for sensor node
  - Raspberry Pi (2, Model-B) - as data and web server
- Communication Module
  - CC2530 Zigbee (IEEE 802.15.4)
- Sensor Node Design
  - Stackable Headers and general purpose perforated boards
  - MOSFET switches : PSMN022-30pl (N type Enhancement mode)
  - Battery : Lithium Ion (3.7V, 2600mAH)
  - CN6009 Boost Converter (3.7V to 5V)
  - Indicator LEDs, Push-to-on switches, connectors
  - Discrete resistors

3.2 Software Requirements

- Django 1.10
- plot.ly Javascript library
- Sqlite3
- PyCharm
- Energia and Code Composer Studio

4 Real world issues and considerations / assumptions

Functionality: Inputs, outputs and constraints

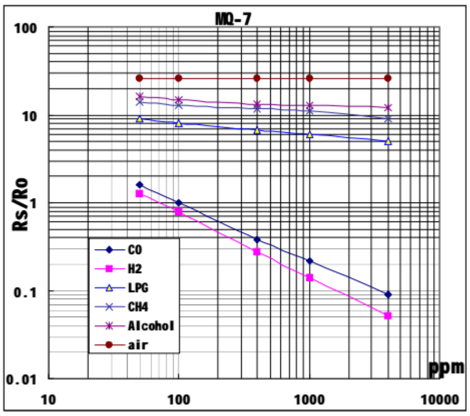

Figure 1: MQ 7 Output characteristics

4.1 Sensors : Calibration and inherent constraints

MQ-7 CO(Carbon monoxide)

4.1.1 Description

MQ-7 is a chemical sensor which is sensitive to CO, H2, alcohol and LPG. The sensor has a heater element and uses heat as a catalyst to vary the resistance of its sensing film based on gas concentration.

4.1.2 Calibration

The output of the sensor change in resistance of its sensitive film due to a change in concentration of the above mentioned gases. The figure1 below shows the resistance ratio **(RS/ Ro)** where **'RS'** is the sensor or film resistance and **'RO'** is the sensor resistance in clean air.

4.1.3 Curve fitting

The first step in calibrating the sensor was to find out the output function i.e. equation for ppm given the RS/RO ratio.

The concentration of CO in clean air or indoor environment is between 1-4 ppm. However our sensor has a range of 20-200 ppm. However due to our calibration or curve fitting function, it shows 1-3 ppm in indoor environment.While, computing the curve fit as assumption of 2 ppm of CO in air was taken.

4.2 DSM 501 A (Particulate Matter or Dust Sensor)

4.2.1 Description

The sensor works on counting the number of particles in the air passing through it i.e. opacity of air using Led and Photo detector module. The sensor characteristics given in the data sheet does not present the amount of granularity as required to come up with a good curve fit.

4.2.2 Calibration

The sensor gives a PWM output in response to detection of dust particles. The output goes low for a duration proportional to the concentration of dust particles. The sensor gives two outputs:
Vout2 : Gives concentration of particles above 1 µm.

Vout1 : Gives concentration of particles above 2.5 µm.
A sample PWM output from the sensor is shown in 3. The data sheet shows two interesting graphs one **Low ratio% vs particle in milligram/m3** and second one is **Low ratio% vs particles(pcs)/283ml**. After verifying experimentally and comparing with Dylos Sensor, we found that the second graph is more useful and possibly more accurate. This graph is shown in 4. According to this graph, we choose to fit the average values to a fitting function using Matlab. We got the following function for pcs/283ml vs Low ratio%.

$$f(x) = 0.02791x^2 + 614.1x + 4.921 \quad \text{where x is Low ratio\%} \tag{1}$$

The figure4 shows the plot of the fitted function versus sensor response taken from the data sheet.The pcs/283ml is equivalent to pcs/0.01 cubicfoot. The Dylos sensor against which we tried to correlate always gives the output in the same unit.

4.2.3 Interfacing

The **Vout2** and **Vout1** PWM outputs are connected to digital I/O pins on the micro controller. We check the duration of low pulse in a time window of 30 seconds to determine the Low ratio%. The computation of f(x) i.e. concentration in pcs/0.01 cubicfoot is done on the server.

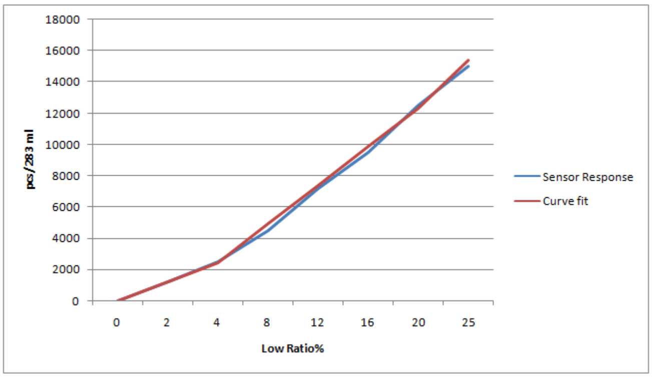

Figure 2: Curve fit

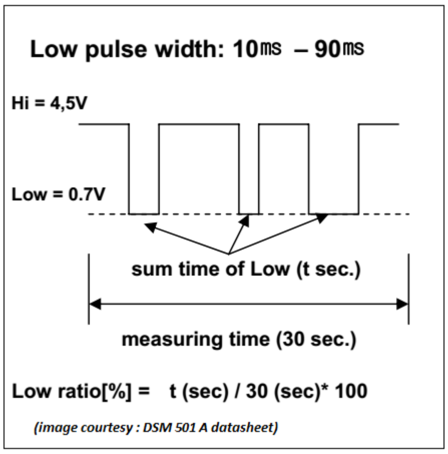

Figure 3: DSM 501 A Sample Output

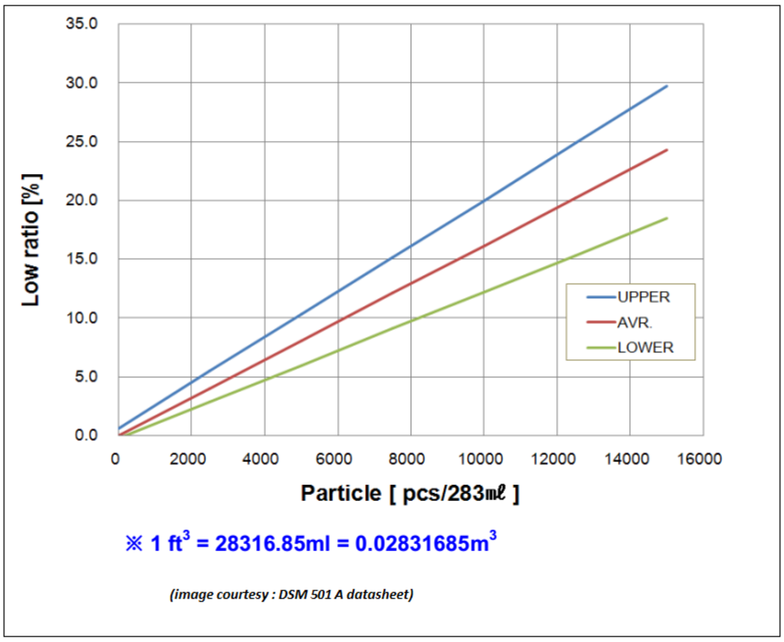

Figure 4: DSM 501 A Output Characteristics

4.3 DHT 22 (Temperature and Humidity Sensor)

4.3.1 Description

Uses capacitive humidity sensing and thermistor for temperature sensing [1]. The sensor comes precalibrated and outputs digital temperature and relative humidity percentage on a single wire.

4.3.2 Calibration

Since the sensor comes precalibrated, we decided to test its performance against another precalibrated weather monitoring station (Netatmo).
The figure *5* shows the plot of temperatures sensed by the two over a span of three hours. We provided a step input by turning ON the air conditioner at around 4:20 am. From the plot, it can be seen that DHT22 is sluggish and has a higher response time as compared to Netatmo. However, DHT22 catches up with Netatmo as soon as temperature becomes relatively stable.

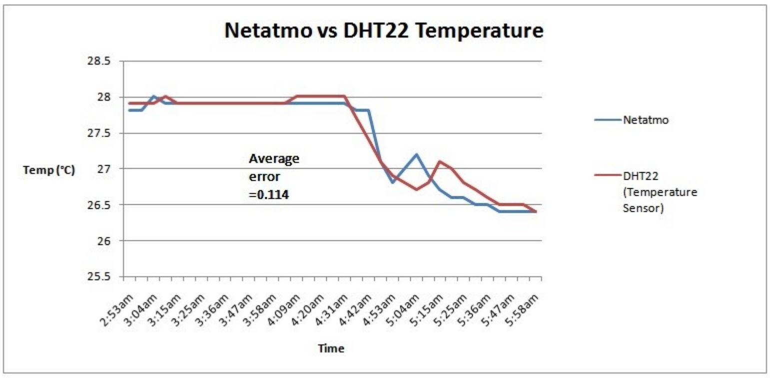

Figure 5: DHT22 Temperature vs Netatmo

Next, we compared the humidity readings between the two. As it can be seen from the plot 6 DHT22 is more sensitive to humidity changes and shows an average error or difference of 3.648%. Surprisingly the humidity levels do not go down when air conditioner is switched ON.

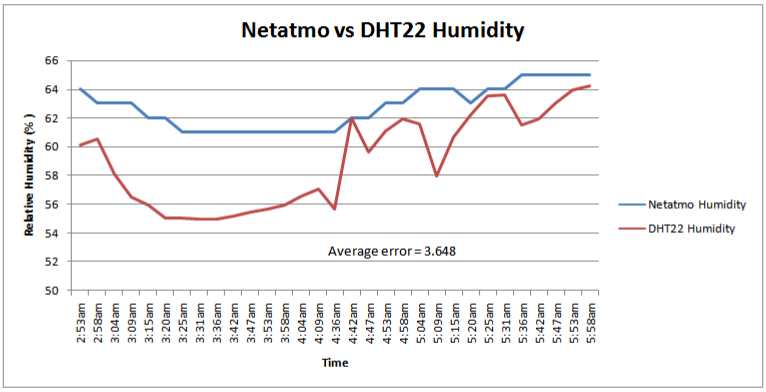

Figure 6: DHT22 Humidity vs Netatmo

4.4 Challenges Faced

- Low Power Optimization: Initial objective of project was to make the whole system low power and make it sustain itself on a 3.3V battery. However the CO sensor we used required a heater operating at 5V. This heater consumed substantial amount of current during battery operation.

  Resolution:

- Zigbee Communication

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5 Test results

We developed both the software and hardware modules simultaneously. During the initial stages of the project as we don't have the real time data, we generated the random data using python. Later we decided to change the way the random data is generated. This is because the data is generated randomly irrespective of the time stamp i.e., temperature at 2 PM can even be 10 degree centigrade(considering climate at IIT Bombay) which is not the correct way. Later we moved to other way of generating the random data i.e., through XL sheet. This generates the data depending on the time stamp which is a good idea to proceed with. We finally tested the web application using this generated data.

5.1 Testing CO sensor

The resistance measured from this sensor varied with exposure to candle. The ppm output showed some changes, but not precise as such a small CO concentration is outside its measurement range.

5.2 Testing DHT22 (Temperature and Humidity)

The readings from DHT22 were compared against a precalibrated Netatmo sensor. The results are included in our presentation.

5.3 Testing DSM 501 A Particulate matter sensor

We tried to see the correlation between our dust sensor and the commercially available Dylos 1100C Pro Sensor.

Test-1: We only took the **Vout2** i.e. particle concentration above 1 µm. The location was KReSIT terrace.

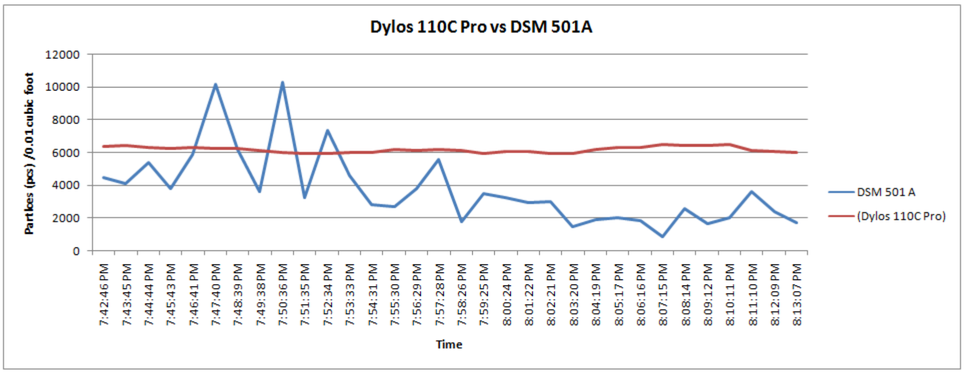

Figure 7: Test-1 Results

Test-2 : Since we did not see much correlation, we took both the **Vout1** and **Vout2** readings subtracted them as the result should theoretically give PM 2.5 µm levels. The location for the test was Gulmohar hotel compound just besides a moderately busy road.The peak in levels of Dylos between 8:20 to 8:30 pm shown in 8 was due to a procession with many people along with trucks passing by.

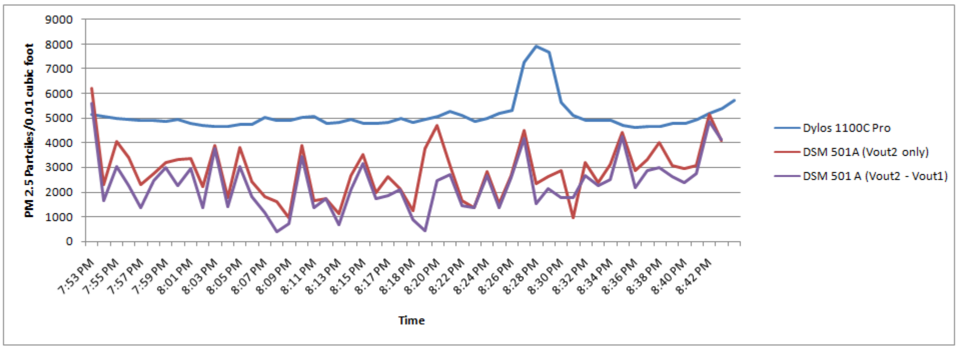

Figure 8: Test-2 Results

Test-3 : For this test, we placed both the Dylos and our dust sensor indoors where the levels of particulate matter are low and do not change much.The results of the test is plotted in 9. [!ht]
Miscellaneous : As per the Air quality standards (AQI) in India, the PM 2.5 levels are specified in µg/m3. The University of Montana's Center for Environmental Health Sciences came up with a conversion function for translating pcs/0.01 cubic foot to µg/m3. Using this function, we have plotted PM 2.5 levels from the data accumulated in Test-2.
Test Results : We found that DSM 501 A is quite noisy. However, if we use a simple 3 point moving average filter as shown in 10 we can reduce noise to some extent. If we look at the plot in 10 carefully, the trend of DSM 501 A readings starts increasing at 8:30, but at slower pace as compared to Dylos. Also in all the graphs, we see that there is an offset of the order of 1000 pcs/0.01 cubic foot or 10µg/m3.
In all these tests, the reading were taken at 1 minute intervals for about an hour. Now if we take hourly average of the values obtained (Since hourly averages are mostly displayed on air quality monitoring sites) Test-2 : Dylos 1100C Pro 1 Hour average : 5082 pcs/0.01 cubicfoot DSM 1 Hour average : 2447 pcs/0.01 cubicfoot

Test-3 : Dylos 1100C Pro 1 Hour average : 3783 pcs/0.01 cubicfoot DSM 501 A 1 Hour average : 2802 pcs/0.01 cubicfoot

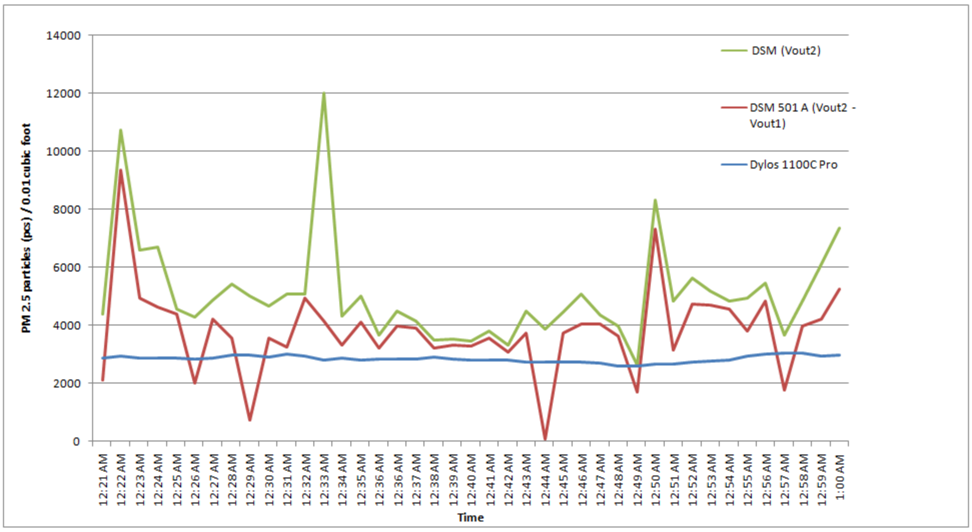

Figure 9: Test-3 Results

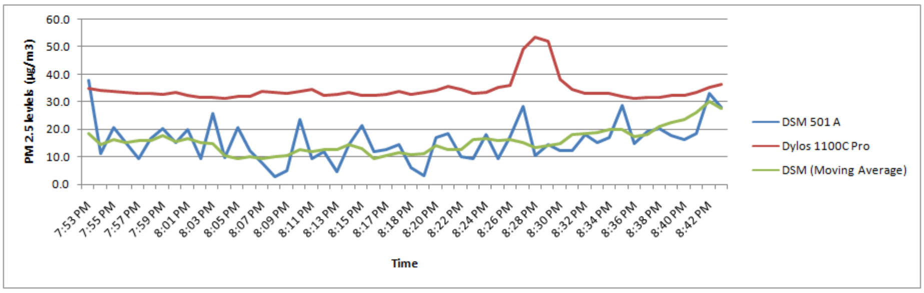

Figure 10: PM 2.5 levels in µg/m3

6 Conclusion

Conclusion- [2]

Clearly mention your set goals for the project and mention how the above sections (4, 5 and 6) has affected the final outcome. Also include your comments on final test results of the system.

References

[1] Aosong Electronics Co.Ltd. Dht22 datasheet. `https://www.sparkfun.com/datasheets/Sensors/Temperature/DHT22.pdf`. [Online; accessed April 23, 2017].

[2] E. C. Ifeachor and B.W. Jervis. *Digital Signal Processing*. Pearson Education Ltd., New Jersey, 2002.

A Appendix

Circuit Connections

A.0.1 DHT 22 Connections

Figure 11 shows connection for DHT22 (Temperature and Humidity sensor). Sensor has 3 pins viz. Ground, V_{cc} and Signal(V_o). Sensor is powered on 3.3V voltage rail. Sensor provided a digital output on single wire. Signal pin is connected to Port2 pin 0 of micro-controller as shown in Figure 13.

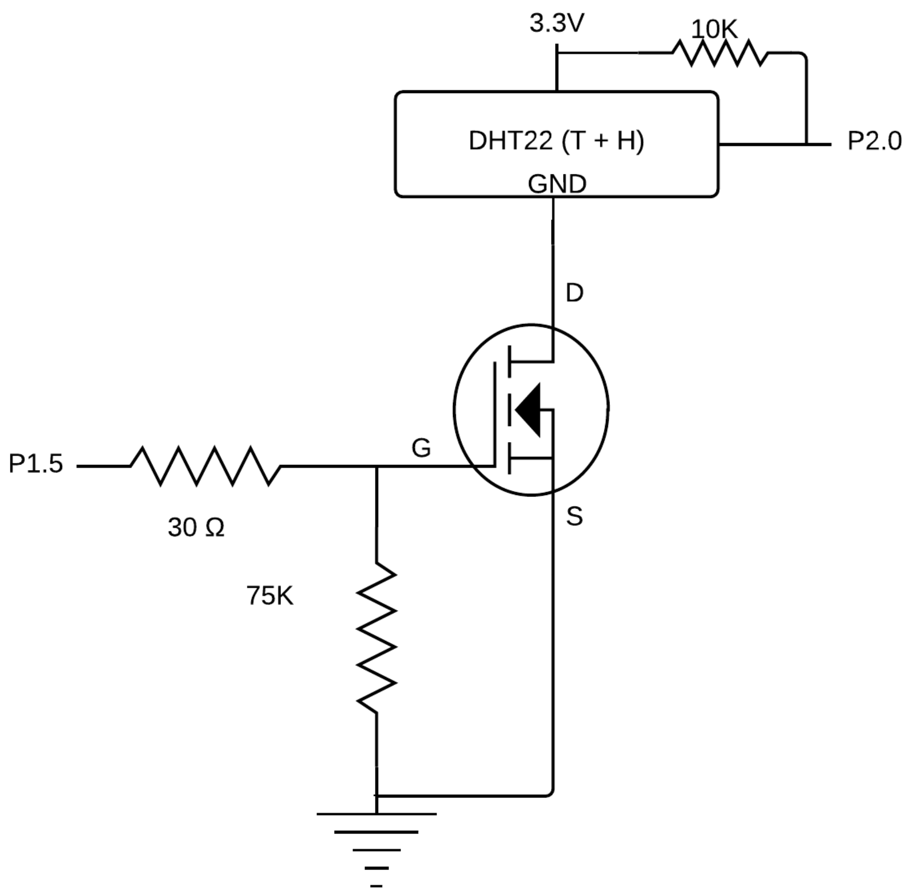

Figure 11: DHT22 (Temp. and Humidity) sensor connections

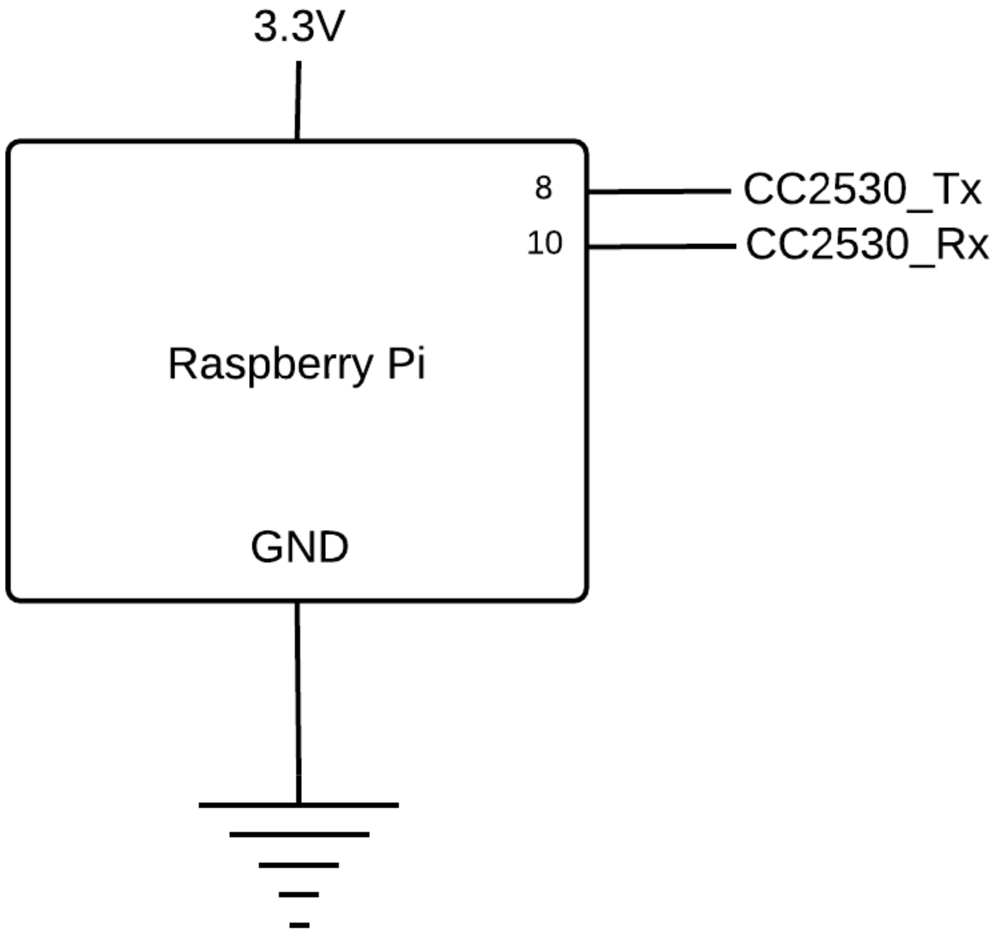

Figure 12: Raspberry Pi connections

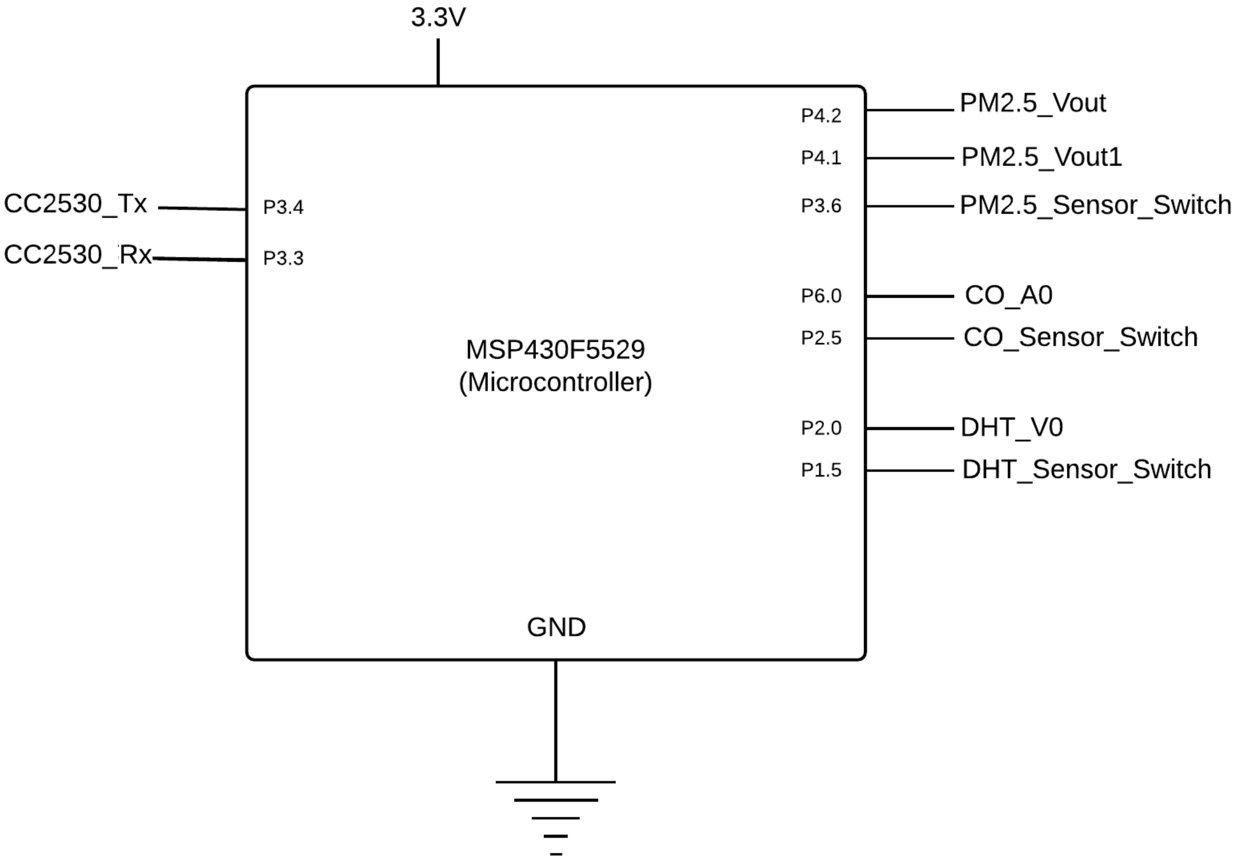

Figure 13: MSP430F5529 connections

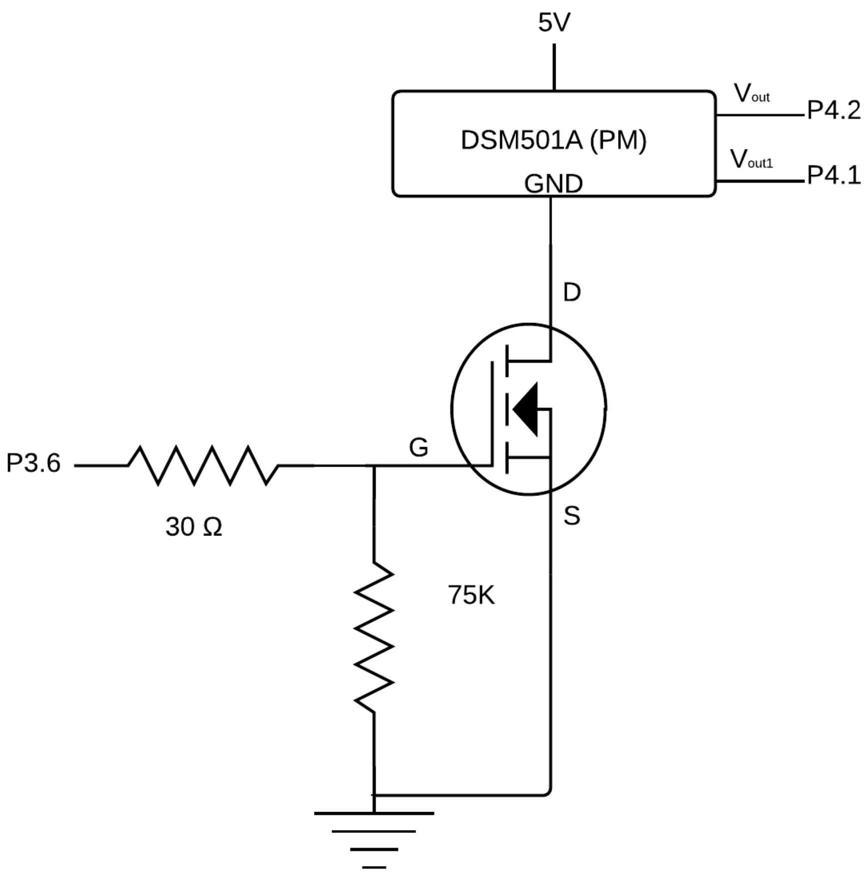

Figure 14: DSM501A (PM-2.5) sensor connections

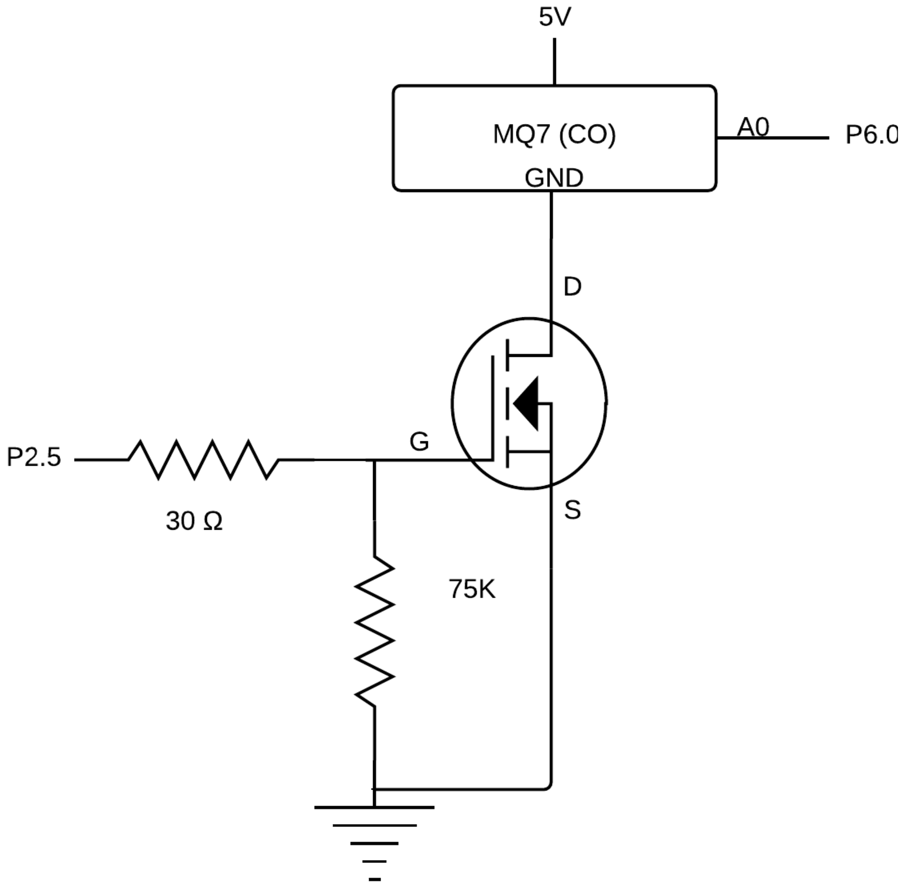

Figure 15: MQ7 (Carbon Monoxide) sensor connections

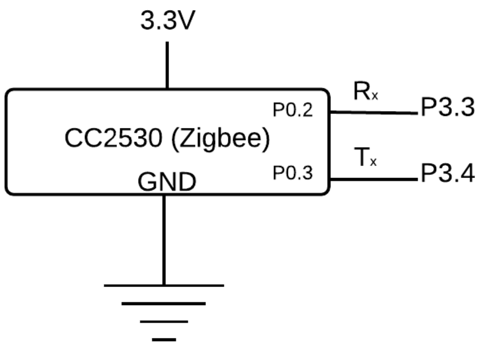

Figure 16: CC2530 (Zigbee Module) connections

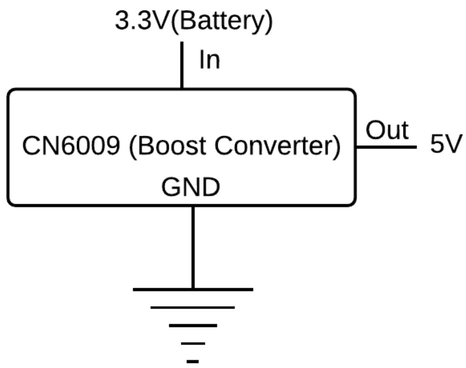

Figure 17: 3.3V to 5V boost converter connections