# Low-Cost Indoor Air Monitor for Global Health


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## Abstract


In the last decade, quantitative epidemiological studies have been carried out in low and middle-income developing countries that attribute respiratory diseases to indoor tobacco use and burning of biomass fuels for cooking and heating purposes. Both activities are known sources of particulate matter (PM) and result in levels well beyond tolerable thresholds. We have developed a low-cost PM monitoring device that displays the current respiratory heath risk in an easy-to-interpret manner. Testing verified that individual LEDs became activated when PM levels were simulated to be within arbitrarily-defined "good," "fair," and "poor" concentration ranges.


## Background

- Poor indoor air quality (IAQ) contributes to chronic respiratory diseases such as asthma, heart disease, and lung cancer [1].
- U.S. Environmental Protection Agency (EPA) designates a standardized air quality level known as the Air Quality Index, which is a function of: CO, $NO_x$, PM and other substances [2].
- EPA standard is that indoor $PM_{2.5}$ does not exceed 35 μg/m³ in a 24-hour period; however, a study of Indian households has detected mass concentrations of more than 300 μg/m³ [3].

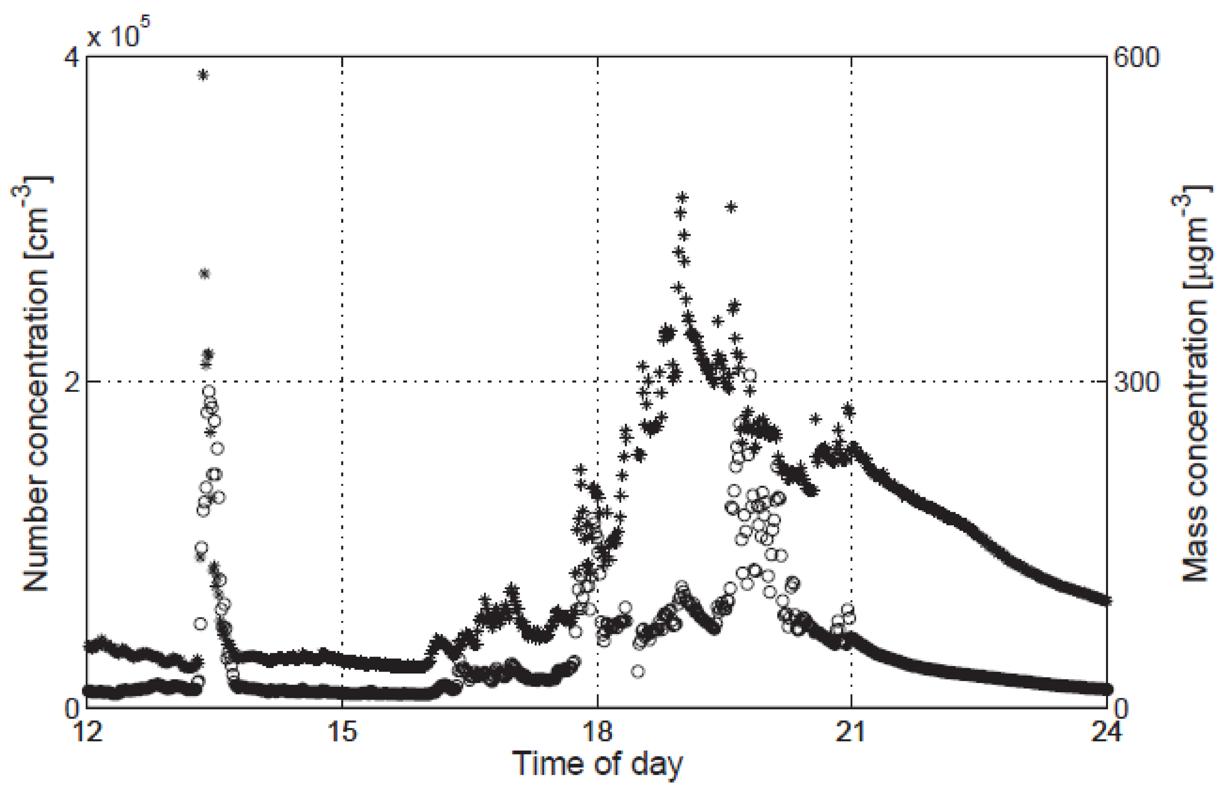


**Figure 1:** An example of excessive diurnal PM levels due to kerosene-based cooking inside an Indian household [3].

## Motivation

Poor IAQ is a major health issue worldwide resulting in millions of deaths each year. Currently, no simplistic and inexpensive device monitors air quality. Our goal was to design an educational/intervention device that will:

1. Continuously and reliably monitor airborne indoor PM levels
2. Clearly display the corresponding health risk for interpretation by a non-scientific user.

## Design Requirements

- Monitor indoor PM levels due to tobacco smoke and biomass fuel
- Indicate probable health risk in a simple fashion
- Minimize cost for wide-spread accessibility
- Maintain functionality for 1 year

## Final Design

**Figure 2:** A Shinyei® PPD42NS PM sensor is housed in a plastic case and exposed to the ambient environment via vents. LED colors correspond to PM concentration ranges based on set thresholds.

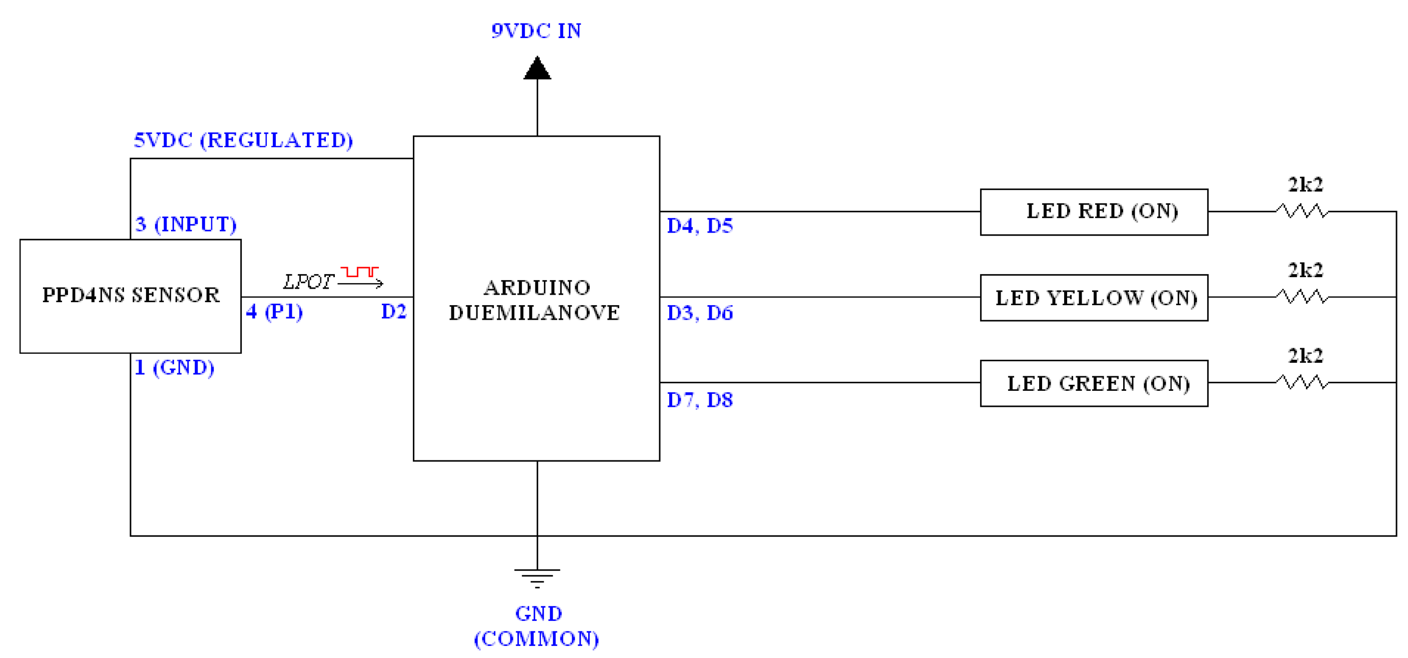


**Figure 3:** Block diagram of prototype circuitry on an Arduino microcontroller platform.

### Key Features of the Final Design:

- Shinyei® PPD42NS sensor is a self-aspirated PM sensor
- It employs a light scattering detection method to produce low and high pulse voltage outputs
- Low pulse occupancy time (LPOT) is proportional to concentration of PM over 1 μm
- Arduino microcontroller samples for 30 seconds, calculates LPOT, and powers an LED based on programmed thresholds
- LEDs organized in a stop-light manner for easy interpretation
- Wall outlet power source

***Total Product Cost:** ~$152

*Price excludes cost of shipping and unincorporated components.

## Testing

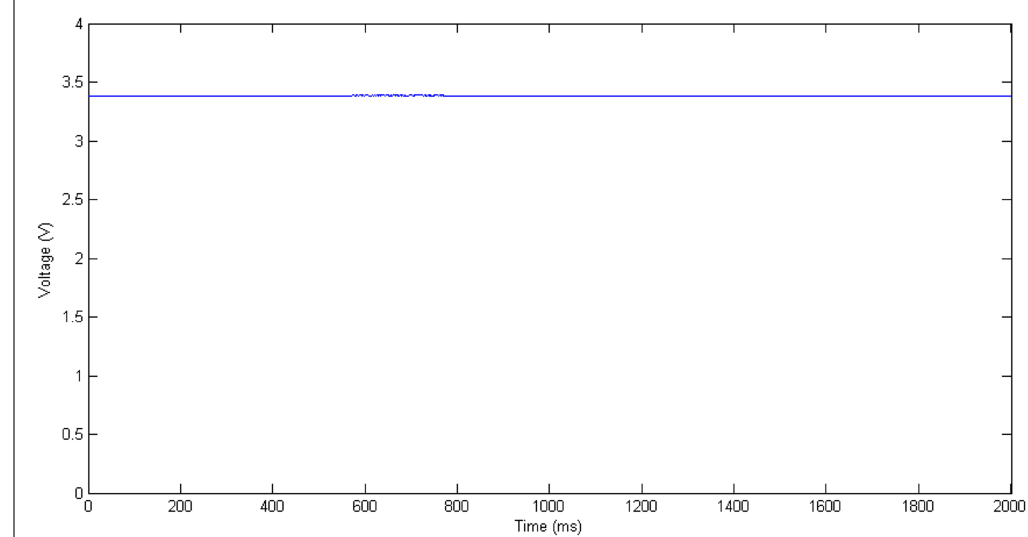

**Figure 4:** MatLab trace of sensor voltage output for normal ambient air. Low-pulse occupancy time was calculated to be 0%, resulting in lighting of the green LED (activation range set at 0%<LPOT<4%).

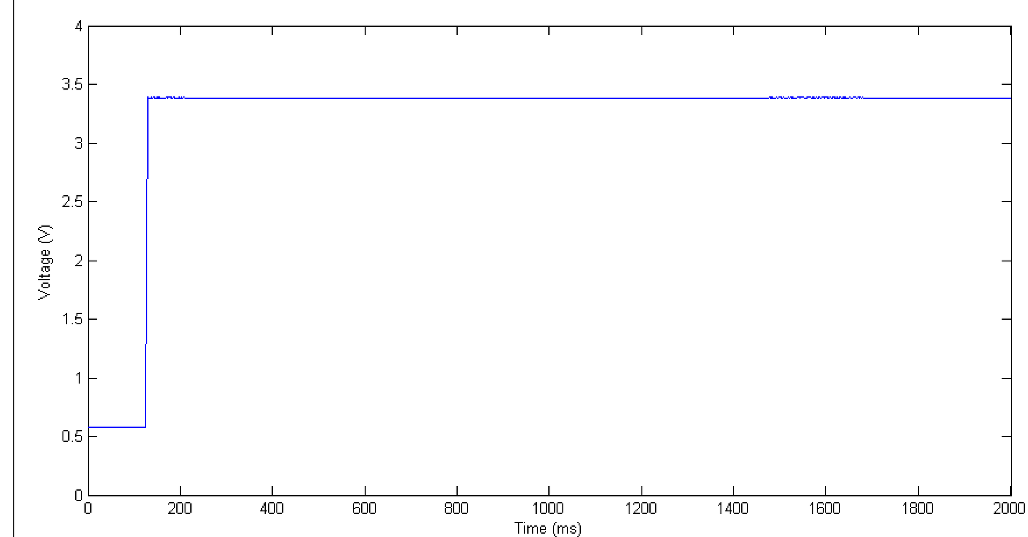

**Figure 5:** MatLab trace of sensor voltage output for slightly-obstructed ambient air. Low-pulse occupancy time was calculated to be 6.3%, resulting in lighting of the yellow LED (activation range set at 4%≤LPOT<8%).

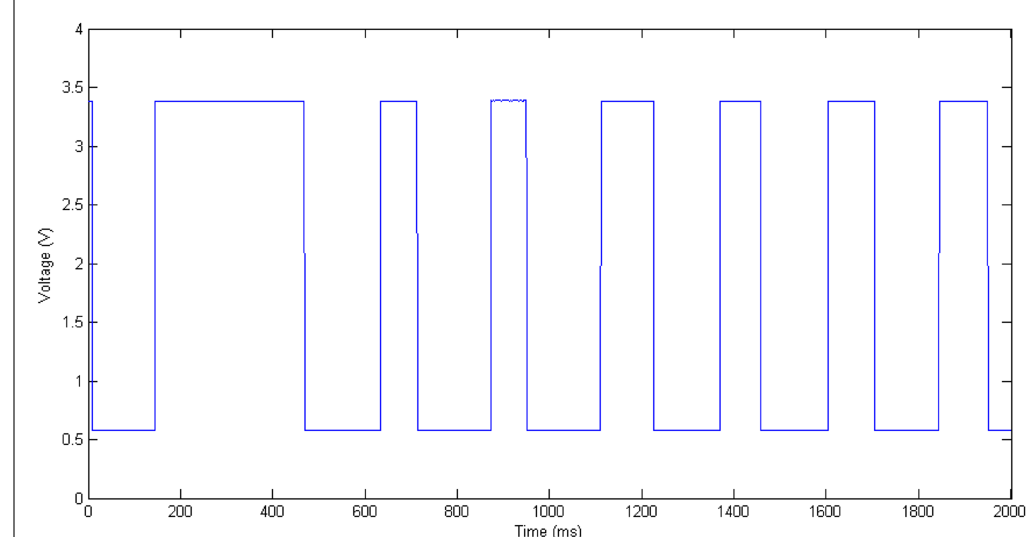

**Figure 6:** MatLab trace of sensor voltage output for highly-obstructed ambient air. Low-pulse occupancy time was calculated to be 55.1%, resulting in lighting of the red LED (activation range set at LPOT≥8%).

## Future Work

- Determination and calibration of threshold PM concentrations
- Sense other air pollutants (e.g. CO, $NO_x$) and display a weighted proxy of air quality
- Integrate data logging mechanism for research implications
- Allow for the uploading of field data in a wireless manner
- Incorporate power backup mechanism

## References


1. Kim, S, Paulos E. *inAir: Measuring and Visualizing Indoor Air Quality. UbiComp. 2009.*

2. Choi S, Kim N, Cha H, Ha R. Micro sensor node for air pollutant monitoring: hardware and software issues. *Sensors. 2009. 9, 7970-7987.*

3. Monkkonen P, Pai P, Maynard A, Lehtinen KEJ, Hameri K, Rechkemmer P, Ramachandran G, Prasad B, Kulmala M. Fine particle number and mass concentration measurements in urban Indian households. *Science of the Total Environment. 2005. 347, 131-147.*