Accurately Measuring Particulate Matter

Detecting Airborne Particulates

Particulate Matter, abbreviated as 'PM', is a mixture of airborne solid particles and liquid droplets that can be inhaled and may cause serious health problems. Particulate matter is distinguished based on the aerodynamic diameter of the particles. The different size-based categories are reported under the nomenclature **"PMx"**, where x is the diameter of the particle size on average in micrometers. In the past, particles around PM2.5 and PM10 were most important to be monitored as their harmful effects are well documented. However, as more studies are being conducted, the importance of monitoring particles on the smaller end of the spectrum is coming to light. Particles greater than 100 nanometers (or PM0.1) in diameter and under 1 micrometer (or PM1.0) in diameter are called Sub-micron particles, and to monitor these is of great importance. These particles are so small that they can penetrate the skin directly and enter the bloodstream, and the more toxic ones can be potentially fatal. Air quality monitoring companies are now constantly attempting to better their particulate detection and analysis to provide richer and more accurate information which would determine the appropriate course of action. The World Health Organization (WHO) reports airborne particulate matter (particulate from 0.1-10 micrometer in size) as a Group 1 carcinogen and as the biggest environmental risk to health, with responsibility for about one in every nine deaths annually.

The most accurate way to measure PM values has been the gravimetric method which determines the particulate pollution in "mass concentration" i.e. the mass of particulate matter in 1 cubic meter of air. A filter of known weight would be deployed to collect particulates of the desired size (this would depend on how fine the mesh of the filter used is) over a 24-hour period. A known volume of air would be passed through the filter per hour. At the end of the 24-hour period the filter would be weighed once more. The filter would be heavier because of the accumulated particulate, and this added weight would be divided by the total volume of air passed through the filter to yield the "**mass concentration**" of PMx in $\mu g/m^3$, i.e. micrograms of particulate per cubic meter of air.

This method comes with its limitations. The setup is bulky, expensive, usually one specific PM level data can be obtained averaged over 24-hours. It requires multiple setups running simultaneously to get the distribution of the particulate pollution in various PM levels, which is far from being cost-effective. Also, the method is not for real-time monitoring, inapplicable for tracking changes in air quality affected by many factors such as humidity, temperature, air currents, traffic, etc. throughout the day.

Therefore, real-time optical particle counters (OPCs or dust sensors) have become the standard means for measuring air quality as they are the most cost-effective and are easy to use. Moreover, these sensors are quite small, which makes integrating them into other air-treatment appliances such as air purifiers and air conditioners easy. These sensors are usually based on the principle of light scattering. There is an air chamber in the sensor module takes in ambient air containing particulates, and they are subjected to a light beam (Infrared, or laser). A photodiode converts scattered light scattered by the particulates (photon packets) into a voltage signal, which can be translated into meaningful data. However, the low-cost light scattering type particulate sensors are using LPO (Low-Pulse Occupancy) time measurement technology, effectively measuring opacity of particles in a certain sampling time rather than counting individual particles. The manufacturers rely heavily on algorithms to estimate various sized particulate concentration (usually just PM2.5 and PM10) with questionable accuracy and yet, it is not enough to overcome the inherent limitations of hardware itself.

Piera Systems Technology

Our Intelligent Particle Sensor Module, **"Piera-1"** is an optoelectrical sensor also based on laser scattering. For processing Piera-1 utilizes our **"PCIC"** (Particle Counting Integrated Circuit), a derivation of an ASIC originally developed for photon-counting live X-ray image data processing (3 granted US patents). The working principle is identical in a sense that the microchip is capable of processing tiny currents resulting from scattered photons off of obstacles whether they are airborne particles or organic materials. The PCIC can identify different sized particles and their concentration by directly counting pulses of different levels of photon energy, featuring superior accuracy, resolution and true real-time data acquisition compared to existing sensors based on the LPO technique.

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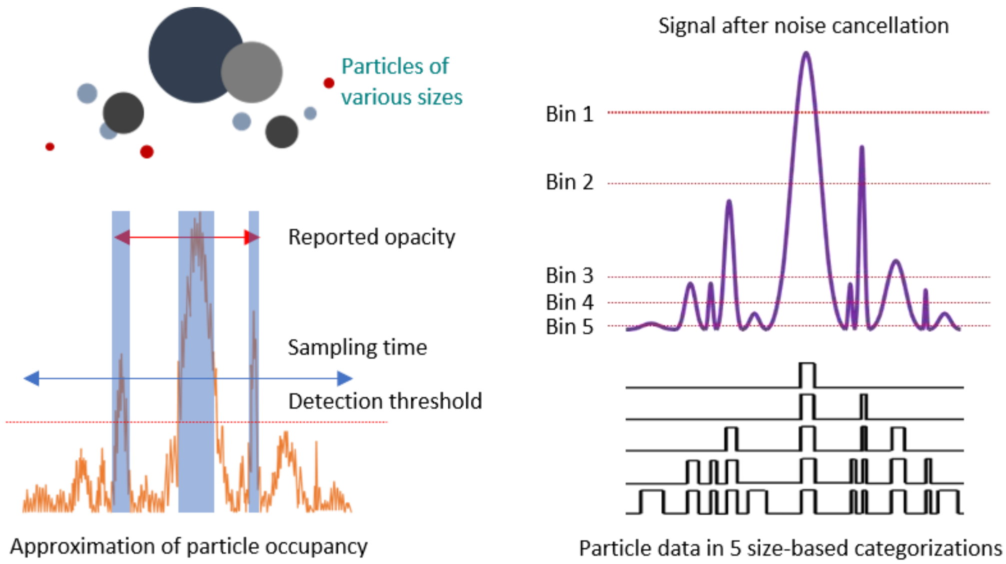

Figure 1. conventional LPO Time measurement technology (left) vs. direct particle-counting technology (right) of Piera Systems

PCIC

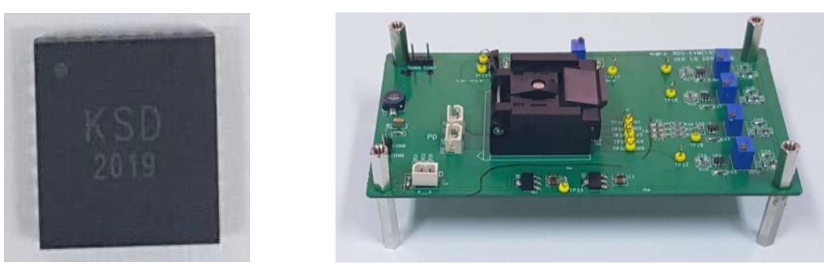

Figure 2. 2nd generation PCIC (QFN – 32 pins 5mm x 5mm) and its test board

Our state-of-the-art ASIC is capable of sampling and processing a much smaller signal from the photodiode at least 1,000 times faster (in a given time frame) than the existing sensors' which operate at less than 1kHz. Such high-speed sampling is essential to ensure minimal meaningful data loss. Unlike any other sensor's processor, the PCIC has been designed to have extremely high SNR (Signal-to-Noise Ratio), effectively cancelling out common noise by using zero-bias differential amps – capable of correctly detecting small signals otherwise hidden in the noise. Moreover, the PCIC determines particulates based on 3 distinct pieces of information: width, absolute amplitude, and number of signals. The resulting data goes to 5 programmable discriminators (bins) for a size & count based categorization of the particulates (future versions will support up to 9). Compared to the LPO time measurement that relies only on pulse width information, the PCIC can deliver at least 100% more accurate and reliable particulate count data with more than 2 times faster overall speed.

The PCIC has 16-bit parallel digital outputs for 5 different sized particulate count data, and an analog output directly from the analog front-end. The chip is manufactured on a mixed-signal 180nm standard process with 1-poly 8-metal at a leading semiconductor foundry (Global Foundries). It is small (5mm x 5mm) and can easily be integrated with existing sensor modules.

IPS: Piera-1

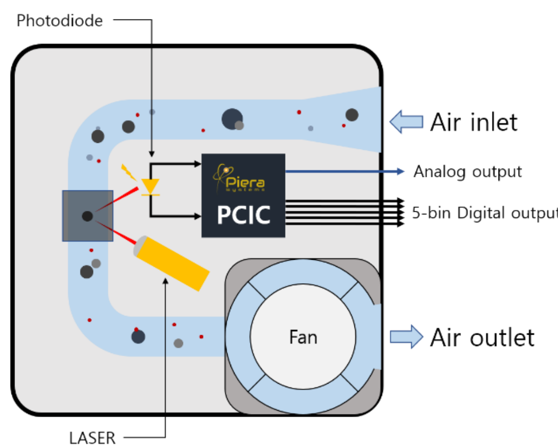

Figure 3. Piera-1 (4.1cm x 1.4cm) and its block diagram

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Air flows through the air chamber as the particulate matter travels through it and out the other side. The particles pass through the laser beam which is angled appropriately so that the scattered photons are received by the photomultiplier (or photodiode). It is then converted to a mass/number concentration through PCIC and algorithms proprietary to Piera Systems. Each of the 5 programmable bins of PCIC can be customized and calibrated to simultaneously output 5 different types of number/mass concentration data within a desired range, anywhere from <0.1 μm -10μm. PCIC, a fully integrated chip makes the Piera-1's circuit board much smaller compared to other sensors that use discrete components (more than 8 passive components and 3-5 active components). Using PCIC on Piera-1 provides huge advantages in terms of manufacturing cost due to drastically reduced number of required through-holes on the PCB. By eliminating most of the discrete components, Piera-1 has better noise immunity – much less susceptible to error induced by parasitic resistance and capacitance (overall noise reduction: 20-30%), and features low power consumption (~20mA compared to >65mA).

Piera-1 operates on 5V, and supports UART and I2C communication. Applicable to air quality monitoring, vape/smoke detection, spectrum analyzer for noxious gases and more.

Summary of Technology

1. Intuitive direct-particle counting methodology – more than 100% faster overall performance
2. High resolution and minimal data loss due to at least 1,000x faster sampling, noise cancellation circuitry
3. Extremely accurate real-time particulate data available in 5 simultaneous size-based categorizations
4. Low manufacturing cost, high reliability, ultra low power consumption

Together PCIC and Piera-1 ensure users have the power to monitor whatever PM levels they need with the highest accuracy and resolution in real-time. The data can be used in a variety of digital health applications to monitor air quality, improve it and identify unique combinations.

An example is **"Canāree"**, our first Digital Health product which leverages Piera-1 and can identify uniquely vape and cigarette smoke. Lab Analysis of the data captured by Canāree resulted in an Algorithm that can detect and uniquely identify vape and smoke, accurately detect its presence, mass concentration and persistence (how long it remains in the air). Here is a video demonstration. Currently a proof of concept, it shows the types of products that can developed to leverage Piera Systems technology.

In Summary, Piera Systems breakthrough technology delivers accurate, complete real-time data about Particulate Matter in a low cost, programmable platform. This will lead to a range of new applications in the emerging field of Digital Health (Air Purifiers, Air Quality Monitors, etc.). Companies interested in evaluating our products can contact us via email or at +1.647.447.7919.