

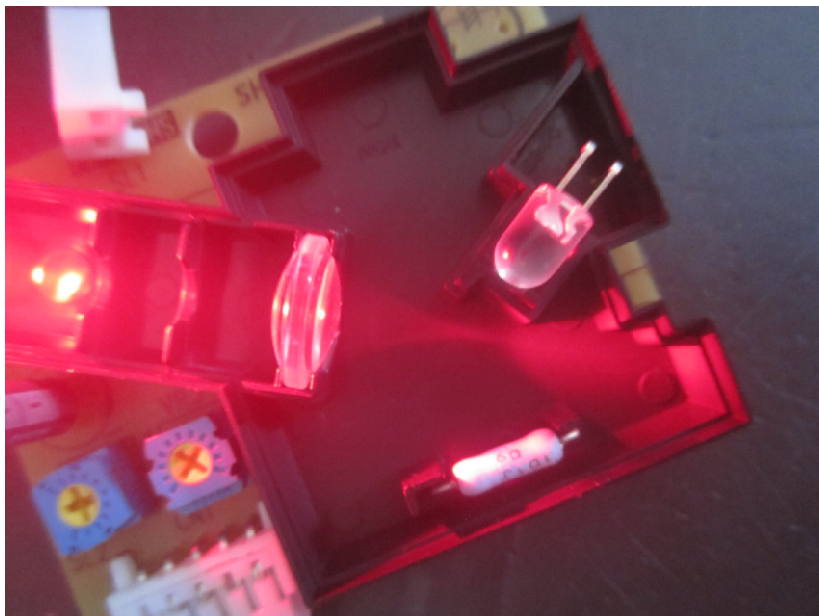
De-construction of the Shinyei PPD42NS dust sensor.

I reverse engineered the circuit of the PPD42NS, two samples, date code 2/2002. Please refer to http://www.shinyei.co.jp/stc/optical/main_dust_e.html for the manufacturer's description. See in particular at the bottom of that page an animation of the operating principle. My motivation for doing this is to understand better how the signal is processed internally. It is an clever device, but what is it really measuring? These observations should not be construed in any way as official word from Shinyei Technology. I make no warranty that my observations are correct. Caveat emptor!

The PPD42 entrains particles in a thermal plume provided by a 100Ω resistor, driven at $5V * 50mA = 0.25W$. Particles convect up through an light beam provided by the infrared led, LED1. Light scattered by particles at a forward angle of about 45° is picked up by PIC1, photodiode. The light path is baffled to avoid stray light pickup, and a lens in front of the photodiode focuses into a detection region in the air flow and close to the LED light portal.



The shield can be unsoldered from the circuit board and removed, and then a tab on the end releases the plastic top cover to reveal the interior.



In this photo a bright red LED is placed at the position of the photodiode, and artificial smoke is sprayed into the detection area in order to help to visualize the focal point of the lens. The cone of light can be clearly seen as it comes down to a focal point directly in front of the opening behind which sits the infrared LED. Turning it around, light from the IR LED, scattered by particles in that same area, would be focused in reverse up onto the photodiode.

Circuit description:

LED1 is in series with the 5V power supply and 110Ω of resistance, provided by $3 \times 330\Omega$ in parallel. The forward voltage of the diode was measured as 1.41V and the diode current was 33mA continuous. Note that the 5V power supply applied at the input connector should be well filtered, because fluctuations in power supply voltage will translate directly to fluctuations in light output from the LED, which will be indistinguishable from actual signal. In the devices tested, large supply filter capacitor C8 was not installed on the circuit board. C10 is a much smaller ceramic type.

Power to the photodiode is filtered by resistor R1, diode D1 and $100\mu\text{F}$ capacitor C1. I am assuming that PIC1 is a standard photodiode, rather than an integrated circuit. The name, PIC1, is puzzling. It has a forward voltage of 0.7V and its position in the circuit is consistent with it being a standard photodiode. The photodiode is reverse biased and is in series with a variable resistance comprised of R2, R16 and VR3. In the two that I tested, VR3 was set close to $50\text{k}\Omega$, and R16 was not installed on the circuit board.

Changes in light cause changes in current from the photodiode, and that develops changes in voltage across the combined resistance of R2, R16 and VR3. Adjusting VR3 to a higher resistance would increase the sensitivity. Capacitor C15 is in parallel with the photodiode and slows down and integrates the response on a time scale of a millisecond or so, and that time constant increases along with increases in the sensitivity adjustment.

Fluctuations in voltage are coupled through capacitor C2 and R3 into section **a** of the op-amp, which provides non-inverting low frequency voltage gain of $\times 77.5$. Low frequency here means everything above 0.5 Hz. C13 in the feedback path provides AC stability as it compensates for the input capacitor C15.

Fluctuations at the output of section **a**, are fed through capacitor C3 and R6 to section **b** of the op-amp, and this section provides adjustable DC gain from $\times 12$ to $\times 50$ with VR1 in combination with R8 and R9. In the two that I measured, VR1 was set at near $50\text{k}\Omega$, for a second stage gain of $\times 22$. The combination of C3 with R6 attenuates frequencies below 8Hz.

The output of section **b** feeds into a first order lowpass filter, R7 and C4. This section attenuates frequencies above 4Hz. The result of the combined high-pass C3:R6 and low-pass C4:R7 suggests that frequencies around 6 Hz are the least attenuated, and that pulses of a certain length and frequency are more apt to pass through to the output. This needs further analysis and experiment.

Sections **c** and **d** of the op-amp are set up as comparators to provide output pulses for the P1 and P2 outputs at the connector. Voltage divider R10 and R11 determine a threshold of 1.09V for P1. Similarly, R12 and R13 determine a threshold of 2.5V for P2, P1 and/or P2 will pulse low so long as the input voltage exceeds their respective thresholds. Note that any time the signal is high enough to activate P2, P1 will be active also. Applying an additional resistor or a voltage to the external threshold input could adjust the P2 threshold either up or down.

There are a number of test point TP1...TP16 scattered around the circuit board, and most of those are also marked on the schematic. Note that there are not official test points at the op-amp outputs at the corners of the 14-pin package, but the op-amp outputs are probably the best place for monitoring the circuit performance.

The op-amp is a generic NJM2902, which is essentially the same as the ubiquitous LM324. The circuit is very straightforward, as you can see, and does not involve tricks except for the clever heat pump and the nice optical chamber. There is no fancy large scale integrated circuit or microprocessor. Quite the contrary, and all the electronic parts are standard issue.

The PPD42 power drain is determined almost completely by the combination of the heater RH1, 50mA and LED1, 33mA.

The connector appears to be JST series EH. Specifically:

crimp terminal: SEH-001T-P0.6 \$0.03 each

housing: EHR-5 \$0.10 each

side entry header (as on the Shinyei): S5B-EH

top entry header: B5B-EH-A

These are in stock at major suppliers, Digikey, Future, Newark.

Shinyei literature and other communications suggest that pulses at the P1 output correspond to 1 μ m particles, and pulses at the P2 output correspond to 2.5 μ m particles. That would seem to compare with the 1V and 2.5V thresholds set on the comparator inputs. There is presumably a calibration adjustment made to the sensitivity and gain trimmers in order to adjust the calibration to a standard maintained at Shinyei. Calibration would be necessary if only to account for variations in the components, and especially to adjust for the LED output and photodiode sensitivity. We should be skeptical though about any quantitative link to real particles in all their variety. The usual issues in interpretation of optical scattering apply here. Optical scattering properties of aerosols vary widely among different classes of particles. Also there is great variation within a heterogenous aerosol of one type or from one source dependent on a host of factors and over the course of time. The electronics suggest that the response is an average of clouds of many smaller or fewer larger particle that pass through the detection area in a sustained concentration large enough to push one or both of the outputs over their thresholds to give a pulse at the P1 or P2 outputs. It is not a particle counter in the sense of the Dylos, which does in fact count the pulses caused by individual particles, nor is it a photometer, that quantifies the an overall level of light scattering in a larger volume. It is a hybrid. The response of this sensor to specific aerosols will have to come from experiments and from co-locations with standard instruments.

Possible to do on the hardware side:

- measure temperature of the heater resistor above ambient.
 - measure resulting air velocity or volume movement of the convection current.
 - measure/analyze frequency and pulse response of the stages of the amplifier/comparator.
- Does the pulse response match up with the residence time of particles in the beam?
- experiments, hacks. tap off the raw signal and process differently.
 - Replace the heater with a Murata piezo blower or Sunon miniature fan.

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