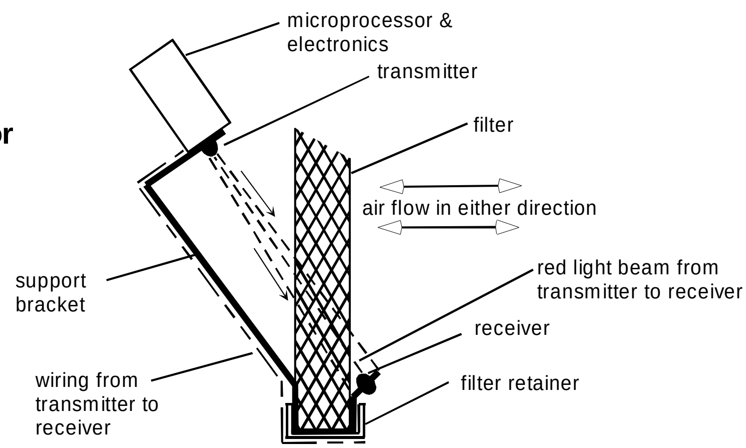
Abstract:
The FilterPulse$_{TM}$ is an optical sensor system for HVAC air filters. FILTERPULSE$_{TM}$ provides a positive indication when an air filter is sufficiently clogged that it should be replaced. The sensor illuminates a portion of an HVAC air filter and monitors the light transmitted through the filter. An initial light transmission measurement is recorded after inserting a clean filter across the sensor. Subsequent measurements are compared with the initial measurement and an alarm is activated after a preset optical density threshold is exceeded. This optical clogging threshold can be adjusted in the field by the user to fit their requirements and various brands of filters. The FILTERPULSE$_{TM}$ operates independently of HVAC blower speeds and resulting pressure fluctuations. Graphic plots are shown of sensors tested under actual operating conditions. Redstone Arsenal housing, Huntsville, Al, Beacon Property Management, Ft. Walton, FL, G. W. Jones & Sons Properties, Huntsville, AL, and others currently field these sensors. The sensor is U.S. manufactured using automated surface mount technology.

How it Works:
The FILTERPULSE$_{TM}$ is a heating and air-conditioning dust filter sensor. The FILTERPULSE$_{TM}$ indicates when an air filter should be replaced. In Fig. 1, FILTERPULSE$_{TM}$ shines a light beam through a HVAC dust filter and detects the light that passes through the filter. An initial light measurement is made after inserting a clean filter and resetting the sensor. Later measurements are compared with the initial "clean" measurement. The alarm indicates when the measured light drops below a trip point[1]. Unlike typical pressure sensors, the FILTERPULSE$_{TM}$ operates regardless of the HVAC blower speed.

Fig.1 FILTERPULSE$_{TM}$ Clogged Dust Filter Sensor



How to Mount:

The FILTERPULSE$_{TM}$ mounts in the dust filter track (Fig. 2). The "U" shaped mounting bracket is available in several widths. They will accommodate most filters[2].

1. The FILTERPULSE$_{TM}$ trip point sets how clogged the filter must be before the alarm goes off.
2. FILTERPULSE$_{TM}$ accommodates 1", 2" and 4" filters. It also works with filters fitting behind return air grills

(Fig. 2a) and filters sliding (Fig. 2b) into air handlers or ducts.

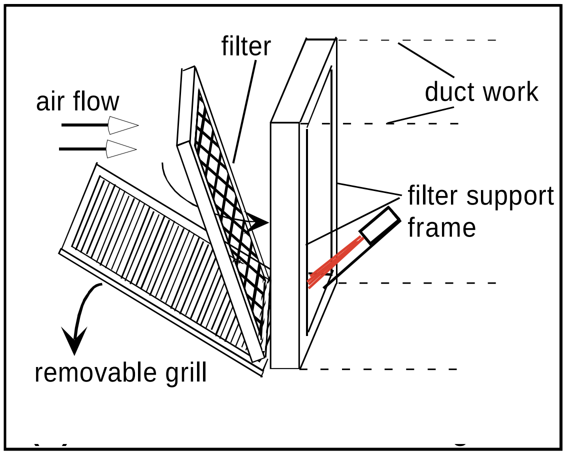


Fig. 2a Filter behind return air grill

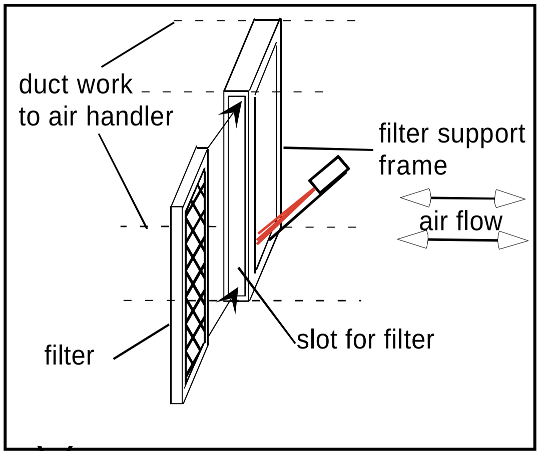


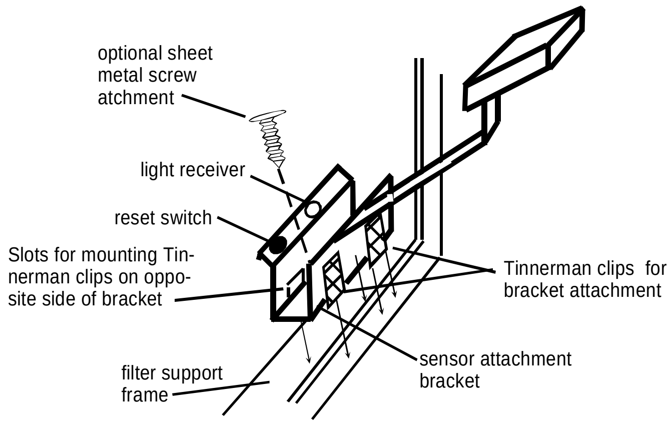
Fig. 2b Filter slides in side of duct

In Fig. 3, the FilterPulse mounts to the filter retainer with either Tinnerman type "Z" clips or a sheet metal screw.

Fig. 3 FILTERPULSE™ Bracket Clips onto Filter Support Frame

Tinnerman type "Z" clips fit on either side of the sensor attachment bracket. Optionally, sensor is attached with a sheet metal screw.

FILTERPULSE™ is permanently installed and remains in place during filter replacement.



Electrical Hookup:

The AC version of the sensor operates from 24+/-8 volts AC

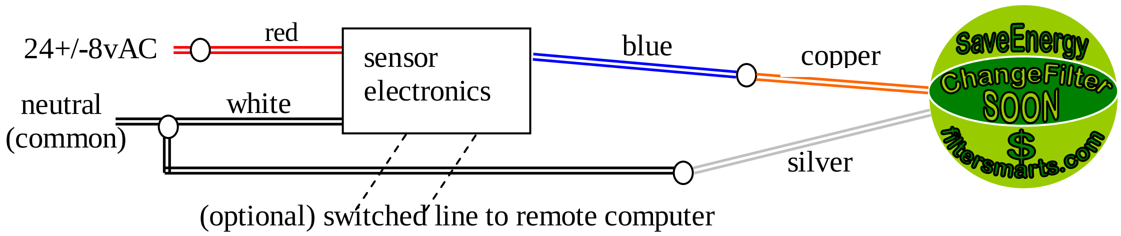


Fig. 4 Electrical Hookup

A switched line can be connected to a remote monitor. This line is programmed to either:
1) switch from open to closed (or vice-versa) when the trip point is reached
2) switch at a frequency of one hertz (clean filter) varying to three hertz (very dirty filter).

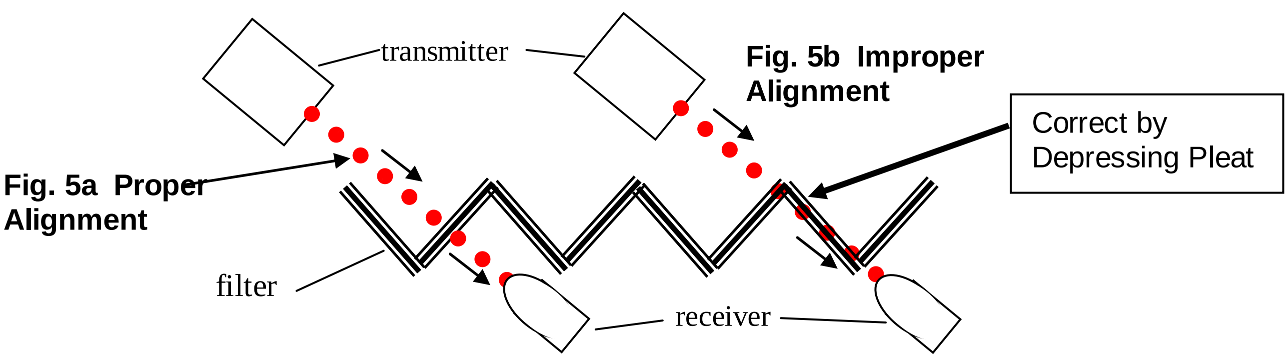
Normal Operation:

Once a clean filter is installed, pressing the reset switch starts the unit. This reset action forces FILTERPULSE™ to store an initial measurement with the clean filter. After pressing the switch, a 30 second delay occurs. This is followed by either:

1) Three slow flashes of the orange indicator signal a successful reset.
2) Ten rapid flashes signal a reset failure.

If ten rapid flashes occur, the optical transmitter/receiver path is partially blocked. An adjustment of the filter or sensor is made to eliminate the blockage.

a) The cardboard trim or support structure may obstruct the (red) light path and require movement of the filter or sensor.
b) The red light may be beamed along the edge of the filter material of a pleated filter and not reach the receiver. See Fig 5a & b. The filter may be rotated 180° (or 90°) and the reset switch pressed again to correct this problem. Optionally, the pleat at the sensor can be depressed.



Transmitter/receiver alignment:

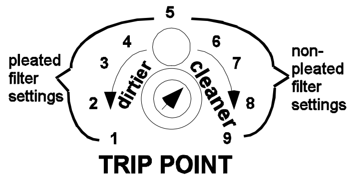
The broad transmitter beam allows for some misalignment. The visible red beam allows the installer to check for proper beam alignment at the receiver. Alignment can be checked by inserting a small sheet of paper into the red beam path at the receiver.

Sensitivity Adjustment:

The factory set trip point is midway and designed for both filter types. A rotatable shaft allows the installer to adjust the trip point for his custom application.

1) Non-pleated filters: Most of the dust accumulates on the filter upstream surface and blocks the light beamed through the filter at this location. Higher trip points are generally desirable.
2) Pleated filters: The light may transmit through several pleats and becomes blocked on the upstream surface of more than one pleat. Lower trip points are generally desirable.

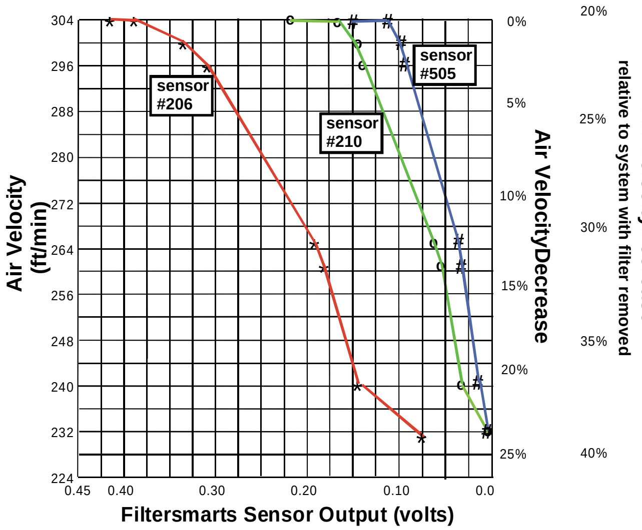
Fig. 6 Setting of the Trip Point



Evaluation:

The principle criterion for changing HVAC dust filters has typically been either 1) observation of the filter and changing it when it appears "dirty", or 2) scheduled change. For commercial establishments airflow velocity decrease through the filter, sometimes monitored via differential pressure sensors, can be used as the filter change criterion. The FILTERPULSE$_{TM}$ is designed to monitor the dirt accumulation within the filter, a quantitative measure of 1) above, and also relatable to decreased airflow through the filter. Figures 7 and 8 depict filter optical clogging (FILTERPULSE$_{TM}$ electrical output) as airflow velocity is reduced for clogging pleated dust filters in home and office environments. The outputs for the individual sensors, delineated by the different curves, follow similar trends. Thus the trip point threshold level can be selected for the sensor/filter combination. The change-filter alarm will then activate at a similar optical density level; i.e., flow velocity deficit level. Figure 9 provides similar data plotted for a non-pleated filter.

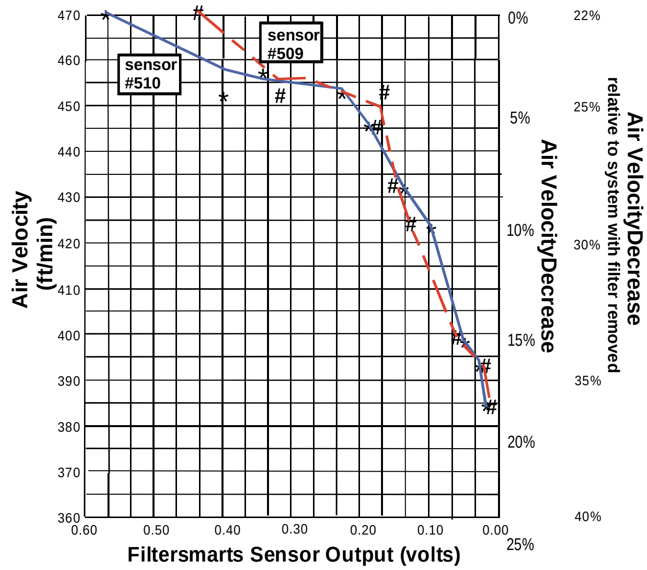
Figure 7: Air Velocity vs. FILTERPULSE Output for Pleated Filter in Home Environment



Note: 1) Curves connect median flow speeds monitored by an UEi DAFM2 thermo-anemometer (ueitest.com).
2) Airhandler: Carrier 58MPV-060 furnace (max static pressure 0.5")
3) Filter: Pleated 20x20x1"; MERV8
4) Filter is wall grill mounted ~6" above the floor and over kitchen tile ~15' from stove; unit covers ~1250sqft with 1/3 carpet and the remainder tile.
5) Velocity measurements taken at grill upstream surface at same location each time.

25 Feb. 04

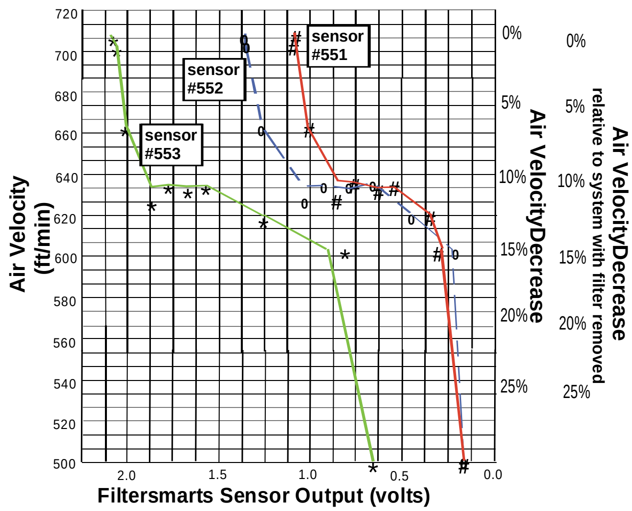
Figure 8: Air Velocity vs. FILTERPULSE Output for Pleated Filter in Office Environment



Note: 1) Curves approximately connect median flow speeds monitored by an UEi DAFM2 thermo-anemometer (ueitest.com).
2) Airhandler: Rheem RHQA 2020J, 1/2HP blower motor (ext. static presure 0.2" w.c.)
3) Filter: Pleated 25x25x1"; MERV8
4) Filter is wall grill mounted ~6" above the floor and over commercial carpet in office hallway.
5) Velocity measurements taken at grill upstream surface at same location each time.

25 Feb. 04

Monitoring the flow speed at an output register and physically blocking the return air grill by 0%, 25%, 50%, 75% and 100% has provided similarly shaped plots to those of the figure. As the physical blockage increases, the flow remains relatively constant until a blockage (or clogging) threshold is exceeded. Then the flow speed can drop dramatically.



Note: 1) Curves connect median flow speeds monitored by an UEi DAFM2 thermo-anemometer (ueitest.com).
2) Airhandler: Rheem RHQA 2020J, 1/2HP blower motor (ext. static presure 0.2" w.c.)
3) Filter: nonpleated 25x25x1"
4) Filter is wall grill mounted ~6" above the floor and over commercial carpet in office hallway with ~30% of return from vinyl tiled electronics lab and ~70% from interior carpeted office space .
5) Velocity measurements taken at grill upstream surface at same location each time. 26Feb04

Figure 9: Air Velocity vs. FILTERPULSE Output for Non-Pleated Filter in Office Environment

For the non-pleated filter of Fig. 9, as the dust loads, velocity initially decreases ~10%. This flow velocity is then approximately flat as the filter further loads with dust. As the dust load increases and a threshold is exceeded, the velocity drops significantly. This differs from Figures 7 and 8 where flow velocity decreases slightly initially. It then drops more rapidly in a more or less linear fashion as the dust builds in the pleated filter. As noted below the figures, data are acquired in facilities that are approximately a) 100% carpeted, b) 30% tiled and c) 66% tiled.

In addition to the above plotted data, FILTERPULSE$_{TM}$ have been tested at several other locations.

a) Beachside condominium tests in Florida, over the last year, have lead to design improvements in sensor attachment within the filter retention slot and in sensor operation.
b) Sensors installed at Redstone Arsenal Housing, with utilities provided at no costs to the occupant, have led to occupant awareness of the need to change the filter. This has been followed by, not only energy savings, but also improved HVAC system cleanliness leading to fewer service calls and increased unit life.
c) Testing of FILTERPULSE$_{TM}$ at a Georgia restaurant with dual in-line dust filters required a very sensitive sensor for the filters in the ceiling of the restaurant; these filters were customer visible and changing was cosmetic related. Less sensitivity was suitable for the rooftop mounted filter sensors.
d) Fifteen sensors were installed in a local office building in late October. For this building, FILTERPULSE$_{TM}$ outputs replaced non-functioning differential pressure sensor outputs. These fifteen sensors are interfaced to a central control computer.

All of the above sensors are functioning according to design.

Authors: Wilson, David J., Xtec Inc, 2707 Churchill Dr, Huntsville, AL 35801, djwilson@FilterPulse.com; Dr. William Eberle, Eberle Associates, 9604 Todd Mill Rd., Huntsville, AL 35803, weberle@bellsouth.net; Douglas Morris and Ralph Glapion, Alpha Beta Technology, 3411C Triana Blvd, Huntsville, AL 35805; douglasm@alphabetatech.com and rglapion@alphabetatech.com. Douglas House of Huntsville is recognized for design of the mechanical support bracket and electrical housing of the FILTERPULSE sensor.