SYSTEM AND METHOD TO DETECT OPTO-SENSORS POWDER DIRTINESS LEVEL IN 3D PRINTERS

HP INC
Title

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Abstract

Some 3D printer technologies are based on using powder material that is processed to create 3D printed parts. In general, this powder material is very fine and a small portion of it tends to get dispersed within the printer environment. This powder can become a problem for optical sensors in the printer as the powder can deposit on the emitter and the sensor can lose effectiveness. This disclosure shares an idea to be able to proactively detect that the sensor is getting dirty, so the user can be warned before the user starts malfunction and some maintenance can be done.

Hints (problems solved)

Fine powder may become airborne within parts of a 3D printer. This is specially a challenge if optical sensors are used to detect the status of some of the elements of the printer, like carriage position flags, platform position flags, sieve closed detection. Let’s understand first how a regular operation of the sensor is to see what the problem of the sensor in powder environment is.

Sensor regular operation:

The opto-sensors are a very economical option for switches. Their principle of operation shown in Figure 2. The sensor consists of an LED (emitter) which emits a light beam and a phototransistor (receiver) that senses the light received, being the output of the sensor dependent on the amount of light received, creating two different states (open or closed) in case the light beam is interrupted or not. The circuitry used generally to drive this sensor is showed in Figure 3.

Figure 1. Opto-sensor construction

Figure 2. Opto-sensor emitter light beam representation for open(a) and close(b) state
The output is generally read by a digital input, so the different states of the sensor can be determined. An example of waveforms can be seen on Figure 4, where we can see how the output signal changes from a low voltage ('0' digital) to a high voltage ('1' digital) when the sensor is blocked.

**Sensor on a powdery environment:**

Being this a two-state switch, whenever powder starts building on the emitter and the receiver side, less light gets from the emitter to the receiver to a point that the sensor reacts the same way being open or closed.
See Figure 6 for an example of the waveforms evolution in a powdery environment, as the sensor gets dirty with time. The low-level depends on the how well the photo-transistor is polarized based on the amount of light received from the emitter. If the amount of light is reduced, the output of the sensor will be degraded to a point that the signal starts getting into the uncertainty zone for digital chips and the value can be misread. In this situation, it is difficult to know if the sensor is dirty or it is not working and needs to be replaced (when the LED is not emitting light at all). This behavior has been seen in some of the sensors that get very dirty.

**Hints (prior solutions)**

In general, the approach is reporting when the sensor is acting bad and not being able to detect the ‘open’ position. No proactive action is done.

**Hints (description)**

A better control of the level of dirtiness on an opto-sensor can be done by connecting the sensor output to an ADC type of input and creating a customized transition threshold that gives more margin to the system, independent of GPIOs $V_{IH}$ and $V_{IL}$ restrictions.
By doing this, the sensor returns an analog value all the time and the information can be interpreted. In general, the two voltages of transition can be obtained for every transition and the level of dirtiness can be assessed based on the difference between the two voltages. With this information, the threshold can be adjusted based on the level of dirtiness of the sensor or can be kept to a higher value and the level of dirtiness can be monitored to request from maintenance when the margin is getting low. See in Figure 7 and example of how the dirtiness margin would be obtained for every transition, how a new fixed threshold level could be set between open and close state, and a region selection where the customer would be warned that maintenance would be needed (when margin is too low to be detected reliably).

![Figure 7. Opto-sensor with dirtiness margin detection](image)

**Hints (advantages)**

The system become more robust to powder dirtiness as the system threshold can be reset to most optimum voltage level based on a dirty sensor case. Taking into account that is the lower level that gets degraded, it is desired to have a threshold closer to the higher voltage level to get more margin. For the fact of using ADC reading, you are not linked to the 0.8V limitation set by digital chips $V_{IL}$ values.

As you are reading analog voltage all the time, you can assess the level of dirtiness at all time, knowing if you are getting out of margin, being able to warn the customer in case some maintenance is being required. In general, you can check the margin before starting the job so you can guarantee that the build will be able to finish. In case of the traditional digital reading of sensor, that is not possible. The sensor could be in a marginal state at the beginning of the build and fail in the middle of a job as you only have a pass-fail response.

With this method, it is very easy to distinguish a broken sensor than a dirty sensor as the output analog voltage are very different.

*Disclosed by Marina Ferran, Luis Garcia and David Soriano, HP Inc.*