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# An Intelligent Exhaust Gas Processing System for Desktop 3D Printer

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**Abstract.** With the rapid development of 3D printing technology, desktop 3D printers have gradually become popular. The mainstream 3D printing technologies are FDM (Fused Deposition Modeling), SLA (Stereolithography), and SLS (Selective Laser Sintering). However, these 3D printing technologies will cause environmental problems during printing, and UFP (ultra-fine particles) and some harmful gases and dust will be emitted during work, which will affect human health. There is currently no treatment method for the pollution problem caused by 3D printing. In this paper, an intelligent exhaust gas processing system that can perform adsorption and catalysis is developed for desktop 3D printers such as FDM, SLA, and SLS. Using 51 single-chip microcomputers as the operation and data processing center, on the basis of manual control of the processor switches, a digital universal particle concentration sensor was adopted, and a new type of intelligent exhaust gas treatment system was designed based on the change of the internal particle concentration in the printer. In order to achieve the intelligence of the exhaust gas treatment.

## 1. Introduction

The 3D printer has brought revolutionary development to the manufacturing industry. It can generate objects of any shape directly from computer graphic data without the need of machining or molds. At present, it has become a trend that is rapidly developing and applied to all walks of life. Desktop 3D printers are gradually becoming popular. The mainstream 3D printing technologies are FDM, SLA, and SLS. However, these 3D printing technologies will cause environmental problems during printing, such as SLA (Stereo Lithography Apparatus) technology, the working principle of it is that a laser beam passes through a scanner controlled by a numerical control device and is irradiated onto a liquid photosensitive resin surface according to a designed scanning path. A layer within a specific area of the surface cures and produces a pungent smell during work. When 3D printing is performed using the FDM technique "melt deposition" technology, the heating head heats the hot melt material (ABS resin, nylon, wax, etc.) to a critical state, and UFP (ultrafine particles) and some harmful gases are emitted at this time. And dust, affect human health[1-3].

With the rapid development of control technology, intelligence has become more and more popular. Automatic control technology and sensor technology are of great significance in intelligent production. 3D printing is widely used in production. Research on how to achieve 3D printing exhaust gas



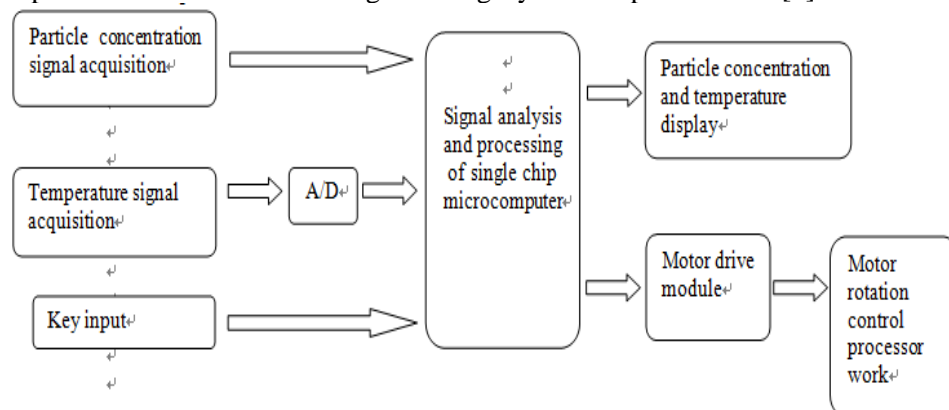
treatment control Automation and intelligence have very important practical significance and can also provide reference for the realization of other industrial intelligent control.

There is currently no treatment method for the pollution problem caused by 3D printing. In this paper, an intelligent exhaust gas processing system that can perform adsorption and catalysis is developed for desktop 3D printers. The use of 51 single-chip microcomputer for the operation and data processing center, so as to achieve the intelligent treatment of tail gas.

## 2. Design of control system

### 2.1. Selecting a Template

The system consists of a digital universal particle concentration sensor, a microcontroller, and a DC motor. This system chooses AT89C51 one-chip computer as the main control chip, AT89C51 one-chip computer has the characteristic such as low power consumption, high performance, low price, make the development cost of the system lower, the operation of the system is more reliable. The system uses a digital particle concentration sensor and uses laser scattering to achieve accurate measurements. The digital particle concentration sensor has the advantages of six-sided omnidirectional shielding and stronger anti-interference performance, and its minimum resolution particle size is  $0.3 \mu\text{m}$ . The system uses a modular design to achieve control functions, control system overall design diagram shown in Figure 1, the main components of the microcontroller main control module, button control module, display module, particulate concentration acquisition module, motor control module, temperature module. Maintaining the Integrity of the Specifications[4].



**Figure 1.** General design block diagram of control system

### 2.2. Hardware circuit design

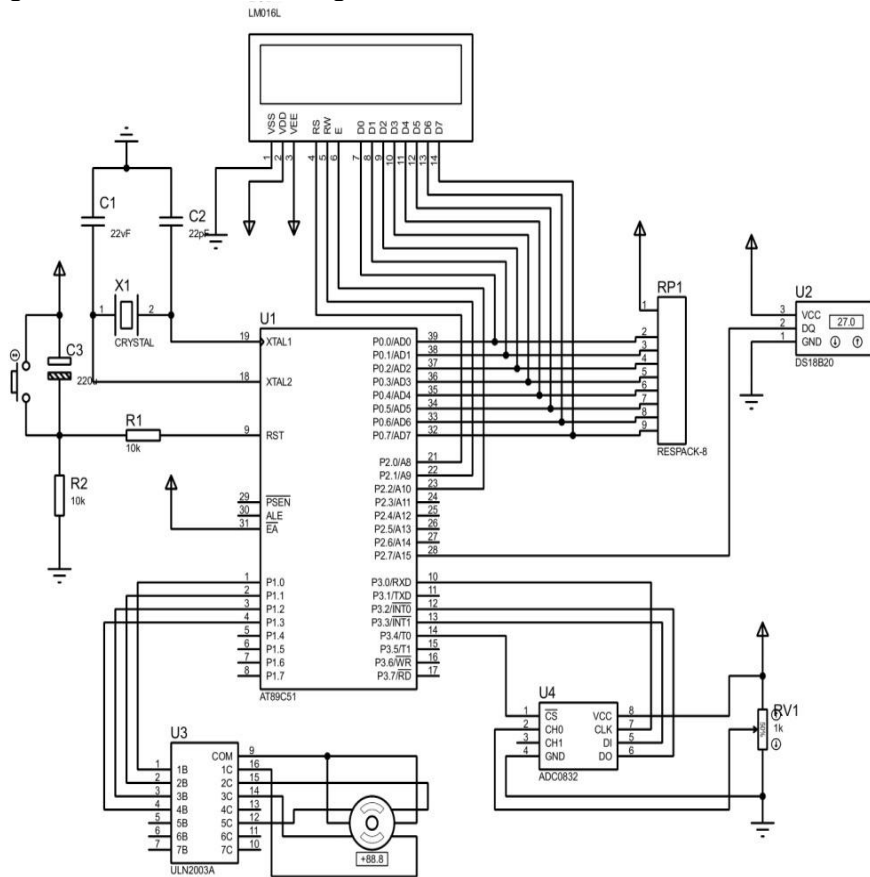
The hardware circuit is mainly composed of a crystal oscillator circuit, a reset circuit, a data acquisition circuit, a display circuit, and a power transmission module. Control system hardware circuit shown in Figure 2. Among them, the power supply part through the external socket input AC 24V or DC 12V voltage supply, after the three-terminal integrated regulator voltage output 5V voltage to provide power for the display circuit, the use of 2 regular batteries to provide DC power.

**2.2.1. Particle concentration acquisition module.** Particle concentration sensor detects whether the concentration of particulates in the desktop 3D printer exceeds the lowest critical value harmful to the human body. The concentration of the detected particulates is compared with the preset concentration limits by the circuit. If the concentration exceeds the upper limit, the motor is turned on; if less than The lower limit, the motor is closed, if the user needs manual intervention and adjustment in special circumstances, can be manually controlled through an external switch to achieve air processor switch.

**2.2.2. Temperature Acquisition Circuit Module.** Through the circuit diagram shown in the figure below, real-time monitoring of the internal temperature of the 3D printer.

**2.2.3. Display circuit module.** In this paper, the display module uses LMO16L LCD display, which controls the lighting of that point by giving each level different levels to display the graphics or text in combination.

**2.2.4. Motor Control Circuit Module.** The motor control module mainly realizes the drive of the DC motor. The ULN2003A chip is used as the core of the drive circuit in this module. Due to the poor load capacity of the single chip microcomputer, this chip provides the power supply control of the motor through the single-chip microcomputer and allows the ULN2003A to assist the single-chip output high current. The motor voltage is satisfied to drive the motor.

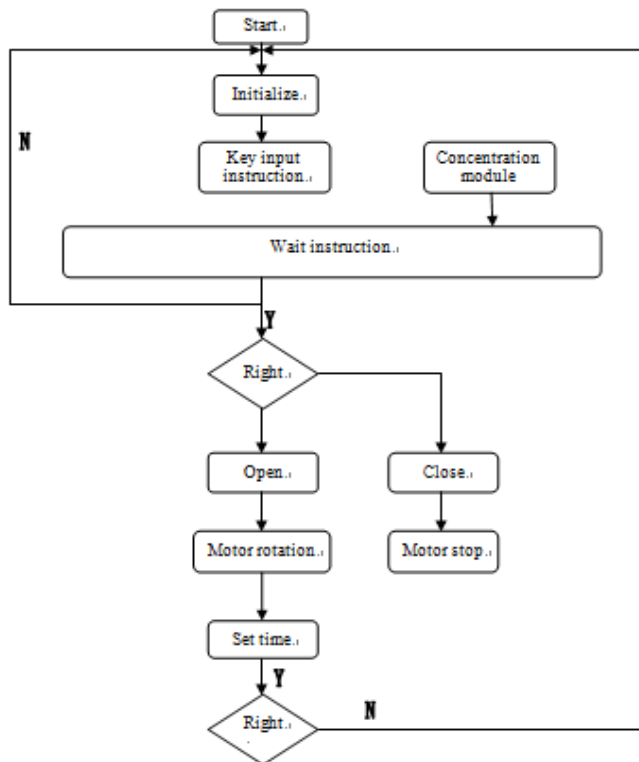


**Figure 2.** Control system hardware circuit diagram

### 3. System software design

The main task of the microcontroller microprocessor in this system is to complete the control and processing of the data collected by the particle concentration acquisition module and compare it with the preset standard value. When the value is greater than the standard value, the control motor is turned on.

The main program first completes the initialization, and then starts the particle concentration acquisition module and performs the corresponding output operation. The system flow chart is shown below. System software flow is mainly divided into system initialization, data acquisition, data processing three parts.



**Figure 3.** System overall software flow chart

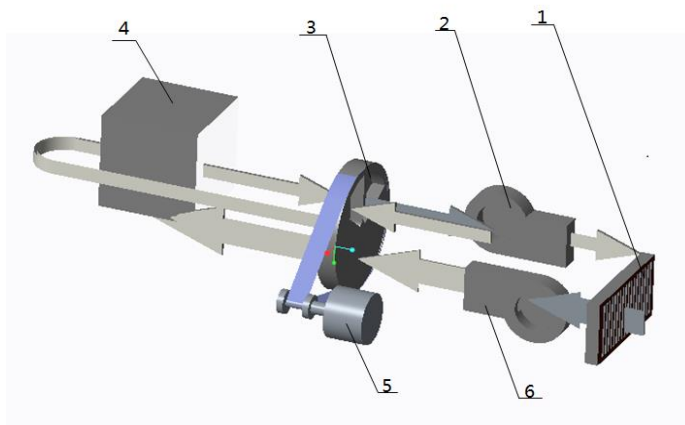
#### 4. Structure design of desktop 3D printer intelligent exhaust processor

##### 4.1. Desktop 3D printer exhaust components

The mainstream application technology of 3D printing is FDM, and its market share is relatively high. When 3D printing is performed using FDM technology, "fusion deposition" technology, the heating head heats the hot melt material (ABS resin, nylon, wax, etc.) to a critical state, and UFP (ultrafine particles) and some harmful gases are emitted at this time. And dust, affect human health.

##### 4.2. Tail gas treatment equipment

For the exhaust of the desktop 3D printer working process, due to its higher temperature, the adsorption equilibrium constant is small, that is, the adsorption volume per unit volume of adsorbent material is small, the required adsorption material is more, and the economy is poor. Therefore, It must be cooled before adsorption. After heating the desorption concentrated exhaust gas to a certain temperature, it catalyzes carbon dioxide and water, and discharges after cooling. The exhaust gas treatment equipment mainly includes an adsorption-desorption device and a catalytic burner. The main structure and function of the adsorption-desorption device are shown in Figure 4.



**Figure 4.** Tail gas treatment equipment structure diagram

1. Filter, 2, Fan (1), 3, Adsorption turntable, 4, Heater, 5, Motor, 6, Fan (2)

**4.2.1. Cycling adsorption turntable.** Adsorption pad 3 is filled with a shaped adsorbent, and the continuous operation can be realized by the pulley traction, adsorption zone, desorption zone and cooling zone.

**4.2.2. Adsorption zone.** Adsorption disc 3 VOCs-containing exhaust gas passes through the turntable to this zone for adsorption purification.

**4.2.3. Desorption zone.** The small amount of hot air blows through the desorption zone of the adsorption turntable 3, the VOCs adsorbed on the adsorption turntable are forcibly desorbed, and the adsorbent is regenerated.

**4.2.4. Sorbent cooling zone.** The desorption of the adsorbent is cooled with a small amount of low-temperature airflow to ensure the effect of adsorption of the adsorption zone in the turntable 3.

The main function of the catalytic combustion device is to catalytically combust the desulfurized high-concentration tail gas to produce harmless carbon dioxide and water vapor. The choice of catalyst plays an important role in catalytic combustion. In this project, honeycomb ceramics loaded with noble metals Pd and Pt are used as catalysts, cordierite is the first carrier, and alumina is the second carrier. The catalyst has the advantages of high activity, wide application, low ignition temperature, low poisoning, long service life, and the like. In order to reach the catalyst activation temperature, the honeycomb catalyst was installed in a silicon carbide electric heater to form an adsorption-catalytic combustion composite reactor. In order to avoid the "heat island effect" caused by the high-temperature gas after catalytic combustion on the external environment, an efficient plate-fin heat exchanger is installed behind the composite reactor to reduce the temperature of the burned gas to the atmosphere.

## 5. Conclusion

The exhaust gas produced by the desktop 3D working process contains solid particles and harmful gases, which will cause some damage to the environment and people. Although it is suitable for FDM desktop 3D printers, this paper can also be used on other desktop 3D printers such as SLA and SLS, and develop an adsorption and catalytic combustion composite reactor based on 51 single-chip microcomputer based intelligent coupling adsorption desorption and catalytic combustion, which can realize 3D printing. The harmless treatment of exhaust gas fills the blank of 3D printing waste gas treatment, and greatly expands the application of desktop 3D printer.

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