(12) INNOVATION PATENT (11) Application No. **AU 2019101181 A4**
(19) AUSTRALIAN PATENT OFFICE

(54) Title
Dust Concentration Detection System in Factory Workshop

(51) International Patent Classification(s)
G01N 15/06 (2006.01) ***G01N 21/53*** (2006.01)

(21) Application No: **2019101181** (22) Date of Filing: **2019.10.02**

(45) Publication Date: **2020.01.16**
(45) Publication Journal Date: **2020.01.16**
(45) Granted Journal Date: **2020.01.16**

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20191011181 05 Dec 2019

ABSTRACT

During the production and manufacture of factory workshops, a large amount of dust can be produced, which poses a serious threat to the workers' life and health, especially lung and respiratory diseases. Aiming at reducing the effect of dust in workshop, this paper designs a dust concentration detection system based on controller with local area network bus. The system can use the detector to continuously and real-time detect the dust concentration in each node of the workshop. When the threshold value is reached, the ventilation system of each node can be triggered automatically, or the sound and light alarm can be carried out. The main components of the system include the computer, dust sensor and Arduino single chip microcomputer.

2019101181 05 Dec 2019

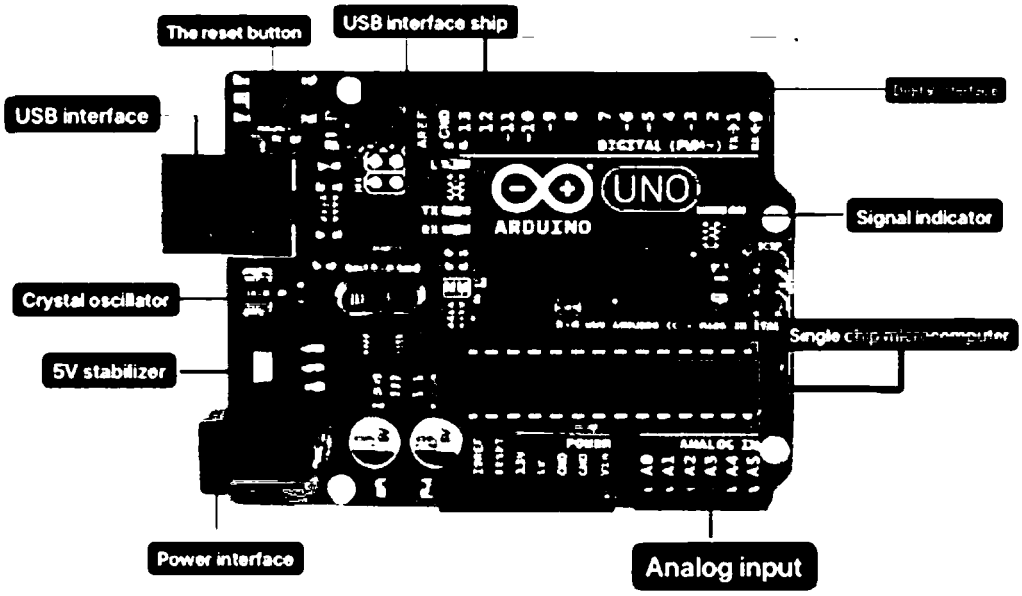
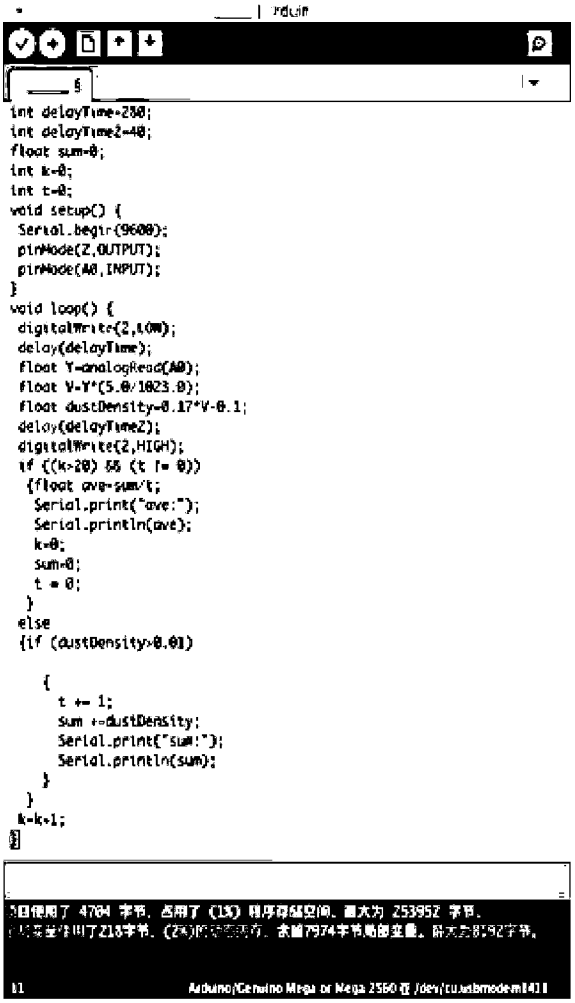


Figure 1



```
int delayTime=250;
int delayTime2=40;
float sum=0;
int k=0;
int t=0;
void setup() {
 Serial.begin(9600);
 pinMode(2,OUTPUT);
 pinMode(A0,INPUT);
}
void loop() {
 digitalWrite(2,LOW);
 delay(delayTime);
 float V=analogRead(A0);
 float V=V*(5.0/1023.0);
 float dustDensity=0.17*V-0.1;
 delay(delayTime2);
 digitalWrite(2,HIGH);
 if ((k>20) && (t != 0))
  {float ave=sum/t;
   Serial.print("ave:");
   Serial.println(ave);
   k=0;
   sum=0;
   t = 0;
  }
 else
 {if (dustDensity>0.01)

    {
      t += 1;
      sum +=dustDensity;
      Serial.print("sum:");
      Serial.println(sum);
    }
  }
 k=k+1;
}
```

Figure 2

2019101181 05 Dec 2019

TITLE

Dust Concentration Detection System in Factory Workshop

FIELD OF INVENTION

The invention belongs to the field of atmospheric monitoring, and is used for real-time monitoring of dust concentration in air and initiating countermeasures.

BACKGROUND

In recent years, the scale of industrialization in China has been expanding. A large number of dust particles will be produced in the factory workshop during production and manufacturing, which are small in size, light in weight and suspended in the air. These dust particles are a great potential safety hazard to human beings and workshop production. Working in the environment with small floating particles is easy to cause upper respiratory infections such as rhinitis, pharyngitis, bronchitis, and serious pneumoconiosis. According to the data released by the Ministry of Health, from 1949 to 2015, 60,7570 cases of pneumoconiosis were reported in China, of which more than 140,000 died, the mortality was over 20%, and more than 470,000 surviving patients were reported. In recent years, the incidence of pneumoconiosis has not declined significantly. Every year, 10,000 new cases of pneumoconiosis occur. In 2010, 23,812 cases of pneumoconiosis were reported, accounting for 87.42% of the total number of occupational diseases in 2010. It seriously damages the health of workshop staff. In addition, if the monitoring of dust is not enough, it may lead to the combustion and explosion of dust, seriously harming the lives and safety of workers, bringing huge losses of life and property. Some of the existing dust concentration detection equipment used in factory workshops in the market is complex, bulky and does not have continuous real-time detection function. In this paper, a dust concentration monitoring system based on controller LAN bus is designed. The data of dust concentration in air are collected by GP2Y1010AU sensor and connected to the computer. When the dust concentration reaches this threshold, a series of measures are taken to control the ventilation system through the controller LAN bus. It is used for continuous and real-time monitoring of dust concentration and timely response.

SUMMARY

In our experiment, the dust monitor is composed of Arduino software, Arduino Mega 2560 single chip microcomputer, SHARP GP2Y1010AU dust sensor, computer and USB cable. The dust sensor can collect the information of dust from surroundings and transfer the information to Arduino single chip computer though USB cable. The detected

2019101181 05 Dec 2019

information and statistics will be analysed through the program which is uploaded to the Arduino single chip computer, transferred to computer and output on the screen of computer. The monitor can be fixed in factory and connected with ventilation system. The data will be collected and uploaded to the computer for adjusting the ventilation system automatically.

I Operating Principle:

1. Arduino Mega 2560 single chip microcomputer:
   This sort of single chip microcomputers has 54 ports for input and output, including 15 ports for PWM. It supports 3 methods of charging while we use USB charge only in our experiment.
2. SHARP GP2Y1010AU dust sensor:
   Infrared light-emitting diodes and photo transistors can identify the dust lager than 0.8μm. The receiver can catch the reflected light and output the corresponding information. The output voltage has the function relationship with the concentration of dust. Thus, the concentration of dust can be gained through measuring the output voltage in an amplifying circuit. In one power cycle period, the total delay time is 0.32ms. We receive the data at 0.28ms based on the characteristics of the dust sensor for relative precise results.
3. CAN Bus:
   The ventilation system combines the dust sensor which is based on Arduino software and hardware with CAN bus, transferring real time data. In addition, the system ensures the effectiveness and veracity of data and the normal operation of the ventilation system. For the linkage, we need to create SPI ports to contact with CAN bus node for transferring data. At last, the data will be uploaded to the CAN bus, connecting to computer.

II Operating Procedure:

1. Assembling:
   To begin with, the six pins of the dust sensor have to be inserted into corresponding ports. From left to right, the 1st pin and the 6th pin have to be connected to 5V power source on Arduino single chip microcomputer with a 150Ω resistance in series for limiting the electric current and avoiding burning the single chip computer. Then, linking the 2nd pin and the 4th pin to the GND ports. Afterwards, let the 3rd pin connecting with the PWM 2 port and the 5th pin linking to the A0 port, which provide power to infrared LED and let it transfers information to the single chip microcomputer. Meanwhile, for better powering, a 220μF capacitance is used between the positive poles and negative poles of the infrared LED. Finally, when the

2019101181 05 Dec 2019

circuit is checked, the system can be connected to computer using USB cable for experiment. For linking Arduino system with CAN bus, the nine to twelve ports in Arduino are used to form SPI ports and connect with CAN bus node (including MCP2510 chip and TJA1050 transceiver), realizing the communication of the system.

2. Programming:
   Using Arduino software to transfer the information in single chip computer to readable information for human beings. Based on the characteristics of the dust sensor, the total delay time is set to 0.32ms and the time of collecting statistics is set to 0.28ms. The software can alternate the 0~1023 information into digital signal, voltage, and use functions which identifies the relationship between dust concentration and output voltage for calculating the concentration of dust. One experiment data consists the mean value of valid values from 20 detected statistics to reducing the influence of measurement error.

III Advantages and Disadvantages:

1. Advantages:
   The equipment for experiment is easy to carry and the operation is simple. Arduino software and hardware are convenient to use and friendly for a green hand to operate. Additionally, the principles of equipment are easy to understand and the weight and the volume are small for equipping and using. In the end, the output results will display on the screen of computer. CAN bus can make the transmission of information fast and accurate, which greatly raises the efficiency of transmission.
2. Disadvantages:
   Since the limitation of technology of SHARP dust sensor, the single dust is difficult to be detected and the measurement error cannot be avoided.

DESCRIPTION OF DRAWING

Figure 1: The structure of Arduino Mega 2560.
Figure 2: Programming schematic diagram.
Figure 3: Output voltage vs. Dust density characteristics of GP2Y1010AU
Figure 4: Recommended input condition for led input terminal
Figure 5: Output Signal Diagram of GP2Y1010AU
Figure 6: Principle diagram of CAN bus node
Figure 7: Schematic diagram of sensor and Arduino connection
Figure 8: Overall structure of detection system

DESCRIPTION OF PREFERRED EMBODIMENT

I Technique principle

2019101181 05 Dec 2019

1. Principle of Arduino Mega 2560
   Figure 1 shows the structure of Arduino Mega 2560. Arduino Mega2560 is the core circuit board with USB interface. It has 54 digital input and output channels. It is suitable for the design of IO interface which needs a large number of IO interfaces. The core of the processor is AT mega2560, which has 54 digital input/output ports (15 of them can be used as PWM output), 15 analog inputs, 4 UART interfaces, a 16MHz crystal oscillator, a USB port, a power socket, an ICSP header and a reset button. In digital interface 2, the total period of output voltage is 320 ms, the time of low point is 280ms, and the time of high point is 40 ms. The data of analog interface A0 is read at low point, and the "analogRead" function is used to convert the electrical signal information. According to figure 3, we can get the formulas of output voltage V and dust concentration "dustDensity": dustDensity=0.17*V-0.1, and then the dust concentration in the air is calculated. We have carried out 20 cycles in succession. In the programming, we set the measured data into a group of 20, excluding the value of zero concentration caused by excessive resistance, and take the average value of this group of data as the value of dust concentration in the air. Figure 2 is the Programming schematic diagram.
2. Principle of GP2Y1010AU
   GP2Y1014AU dust sensor is an optical dust monitoring sensor module developed by Sharp. There is a hole in the middle of it for flowing air freely. There are infrared light-emitting diodes and phototransistors in the adjacent corner. Infrared light-emitting diodes can send infrared directionally. When there are particulates in the air that hinder infrared from infrared light-emitting diodes, the receiver can receive corresponding information. Line transmits diffuse reflection, phototransistor receives infrared, so the output pin voltage of signal transmits change. According to Fig. 4, the detection period is 10ms. It takes few moments for infrared to transmit and be received. According to Fig. 5, a stable value can be obtained by setting the sampling time to 0.28ms.
3. Connection Principle between CAN Bus and Arduino Board
   CAN bus node is the key equipment for distributed detection of communication network. It consists of microprocessor, controller, transceiver and optocoupler isolator. The processor uses STC89C52 chip, which has low power consumption, strong anti-interference ability, fast operation speed, built-in

2019101181 05 Dec 2019

8K-byte Flash, 512-byte RAM and 2 KB EEPROM, 32 universal I/O ports, 3 16-bit timing/ counter, and 4 external interrupts. MCP2510 is selected as the CAN controller. The device fully supports CAN2.0 A/B technical specifications. It contains three sending buffers and two receiving buffers. Its transmission rate is up to 5 Mbps. It can generate and receive standard and extended messages. It also has the functions of acceptance filtering and message management. TJA1050 is chosen as transceiver. The highest communication rate of the chip can reach 1 Mbit/s. It can resist strong electromagnetic interference and has a wide common mode range of differential reception and transmission capability. The pins TXCAN and RXCAN of MCP2510 are not directly connected with pins RXD and TXD of TJA1050. The 6N137 is used for electrical isolation to prevent interference and influence between nodes and communication network. The CAN bus node circuit is shown in Fig. 6 and the overall structure of detection system is shown in Fig. 8.

II Laboratory process

1. Step A: The Arduino Mega 2560 single chip microcomputer, SHARP GP2Y1010AU dust sensor and computer have to be prepared firstly. Besides, for completing the network between Arduino system and CAN bus, MCP2510 chip and TJA1050 transceiver need to be connected to Arduino single chip microcomputer on 9 to 12 ports as SPI ports. Then, the six pins in SHARP dust sensor should be inserted to the corresponding ports on Arduino single chip microcomputer. To be specific, the first pin and the sixth pin should be inserted into the 5-voltage port with a 150Ω resistance in series which can avoid burning the electric circuit. In addition, the second pin and the fourth pin should be connected to the GND ports, which means the two pins are linked with ground. The last two pins are for providing the power to the Infrared light-emitting diodes and photo transistors and outputting the information. The third pin has to be inserted into PWM 2 port while the fifth pin has to be inserted into A0 port. When the electric circuit is checked, the next step is coming.
2. Step B: The program is significant for the whole system to run properly. In our design, we use Arduino software in computer to program our system. To begin with, we have to understand the characteristics of SHARP GP2Y1010AU dust sensor. In one power cycle period, the total delay time is 0.32ms and we receive the data at 0.28ms. Thus, in our program, we set two

2019101181 05 Dec 2019

delay time, 280ms and 40ms. 280ms is the time for collecting data and after 40ms the period is end. We also use loops to calculate the dust concentration for 20 times and use the valid statistics to achieve the mean value, which increases the accuracy of the data. Additionally, for linking the Arduino system with CAN bus, we also need to have the program to control the downloading and uploading of the data. When the program is prepared, the system can be linked to computer with USB cable and the program can be uploaded to the Arduino single chip microcomputer. Finally, the ventilation equipment and audible and visual alarm system should be linked to the computer. When the dust concentration that is detected by dust monitor reaches to the set value, the computer will drive the ventilation equipment and alarm system to run and the dust concentration will drop. The whole system can be tested after the program uploading is completed.

3. Step C: A box which is well-ventilated is used in our experiment to fix our system. In the factory, the box should be set where most people work to monitor the real time concentration of dust and upload to computer. Since the system has CAN bus, we can increase the number of sensors in the factory to have more accurate information. Then, the dust in the factory is controlled and our aim, reducing the influence of dust, is reached.

2019101181 05 Dec 2019

What we claim is:

1. A dust Concentration Detection System, wherein said system has 54 digital input and output channels; it is suitable for the design of IO interface which needs a large number of IO interfaces; the core of the processor is AT mega2560, which has 54 digital input/output ports, 15 analog inputs, 4 UART interfaces, a 16MHz crystal oscillator, a USB port, a power socket, an ICSP header and a reset button; in digital interface 2, the total period of output voltage is 320 ms, the time of low point is 280ms, and the time of high point is 40 ms; the data of analog interface A0 is read at low point, and the "analogRead" function is used to convert the electrical signal information.
2. A dust Concentration Detection system said as claim 1, wherein said dust sensor is an optical dust monitoring sensor module developed by Sharp; there is a hole in the middle of it for flowing air freely; there are infrared light-emitting diodes and phototransistors in the adjacent corner; infrared light-emitting diodes can send infrared directionally; when there are particulates in the air that hinder infrared from infrared light-emitting diodes, the receiver can receive corresponding information; line transmits diffuse reflection, phototransistor receives infrared, so the output pin voltage of signal transmits change.

2019101181 05 Dec 2019

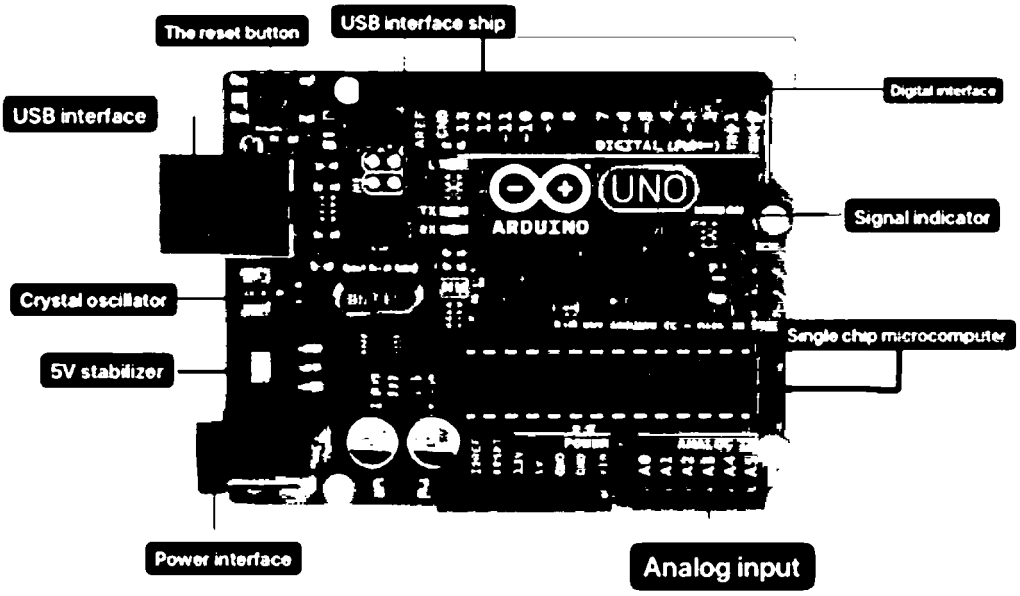


Figure 1

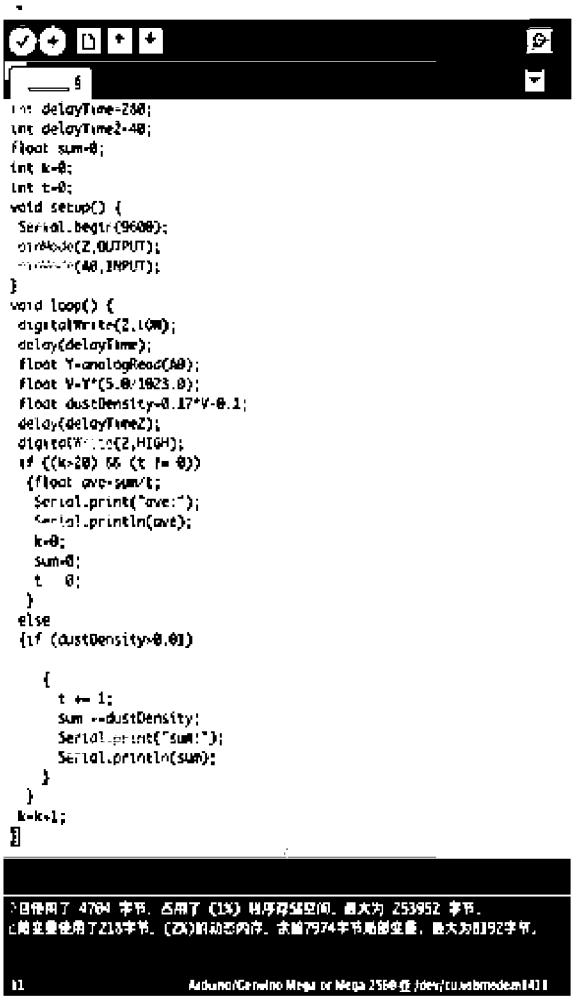


Figure 2

2019101181 05 Dec 2019

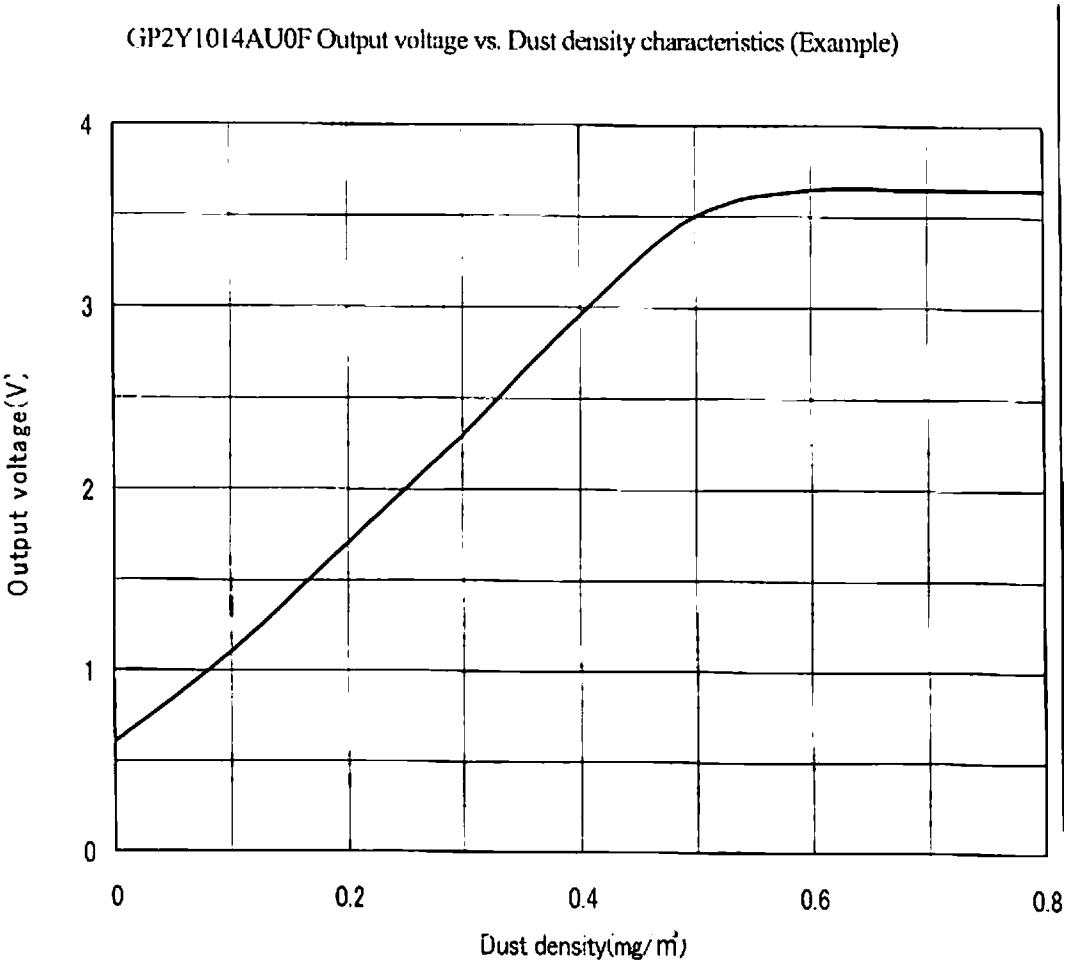


Figure 3

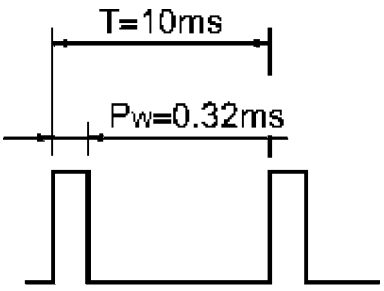


Figure 4

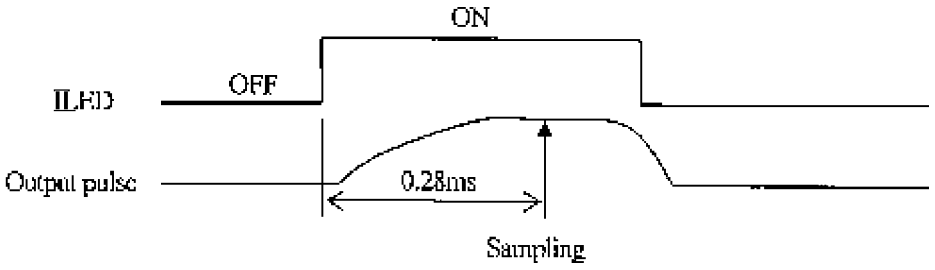


Figure 5

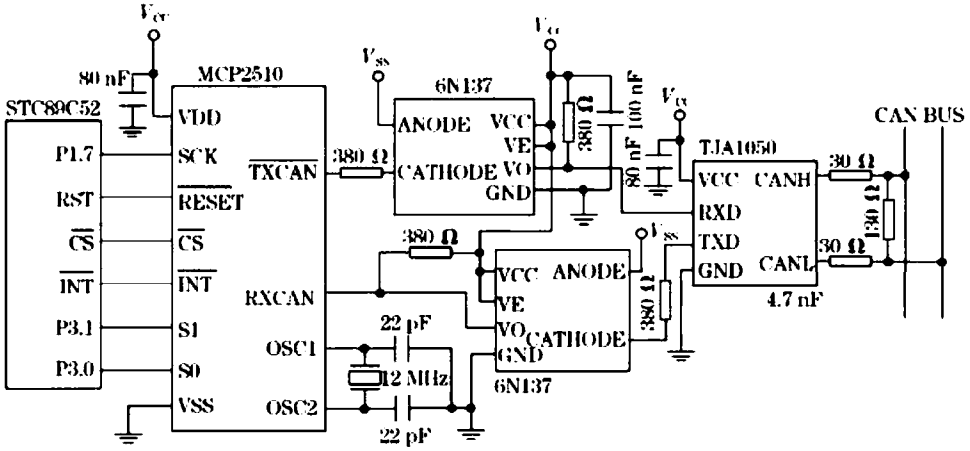
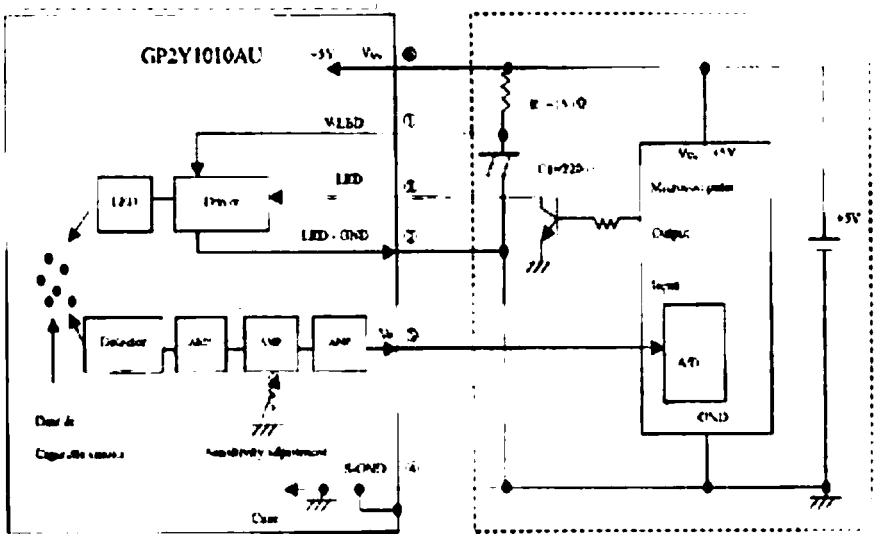


Figure 6



Sensor Pin		Arduino Pin
1 Vled	-->	5V (150ohm resistor)
2 LED-GND	-->	GND
3 LED	-->	Digital pin 2
4 S-GND	-->	GND
5 Vo	-->	Analog pin 0
6 Vcc	-->	5V

Figure 7

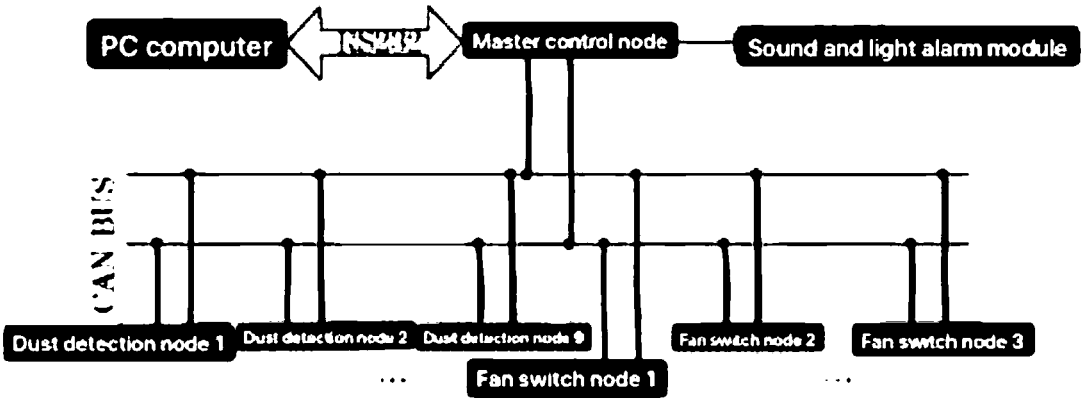


Figure 8