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Analysis of municipal waste bin sensing and control based on improved capacitive pressure sensor and microcontroller processing system

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Abstract

Aiming at the current problems of garbage overflow or garbage decay and deterioration due to untimely cleaning of garbage bins in city streets, this paper constructs a new intelligent city garbage bin control and monitoring system. This system includes the hardware part of intelligent garbage bin weight sensing and the software part of intelligent city garbage bin control and monitoring system. The hardware part mainly involves the improvement of the capacitive pressure sensor and the analysis of the cooperation of the temperature sensor and humidity sensor, while the software part mainly refers to the control by monitoring various indicators of the intelligent bins and using them as the basis for rational planning of the number of bins and the arrangement of garbage cleaning tasks. The simulation results show that the improved capacitive pressure sensor can accurately sense the weight of the front-end garbage, and the control and monitoring system can easily control the start/stop and quantity arrangement of the garbage bins in the urban area and can be reasonably scheduled, which shows that the proposed method in this paper has an important role in improving the urban environment, reasonably cleaning the garbage, and improving people's comfort.

Keywords

Intelligent control and monitoring system, intelligent waste bin, capacitive pressure sensor.

1. Introduction

Nowadays, society is evolving rapidly and the livelihood of people has been greatly improved. However, along with the rapid economic expansion, the issue of waste disposal has become more and more serious. In this case, the problem of garbage bins in the living environment has become the focus of people's attention. Problems such as overflowing garbage in the dumpster, failure to clean up in time and decay and deterioration seriously affect people's living standards and the city's environmental health, and the traditional urban dumpster management system becomes a major drawback to urban environmental protection problems. Therefore, the development of intelligent city dumpster control and monitoring systems is imminent.

For a long time now, countries have been working on the design of smart urban bins, building good urban trash disposal systems, developing hardware and software for bins, and improving the ecological conditions of cities. Today's bins can be opened and shut without the need to touch them [1], they can be automatically treated with chemical substances [2], and they can identify different types of waste and achieve intelligent operations [3]. Currently, city bin control and monitoring systems can be used to locate bins and determine their exact location [4], and the Internet of Things technology can be used to unite the city's various regions [5],

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enabling intelligent networking. However, the rate of waste decay and spoilage in the bins depends largely on the weight of the waste and the temperature and humidity of the environment, and the above studies do not consider this issue. In summary, this paper constructs a new intelligent urban waste bin control and monitoring system. Firstly, the built-in sensors of the intelligent bins are improved to detect the ambient temperature and humidity and to sense the weight of the waste more accurately. Secondly, the system design is also designed to help the management staff to manage the city bins by the weight, temperature and humidity of each bin in the city, to realize the city waste recycling route planning based on the priority of the integrated factors. The new intelligent city bin control and monitoring system proposed in this paper can meet the control and monitoring of bins in large-scale cities and greatly improve the living standard of people.

2. Model principle analysis

2.1. Principle of Capacitive Pressure Sensor

The primary operating Principle of the Capacitive Pressure Sensor Pass is the conversion of pressure into a change in capacitance. The transducer structure is relatively simple and highly accurate and is presently widely used in industrial production. The principal structure of a capacitive pressure sensor is shown in Figure 1.

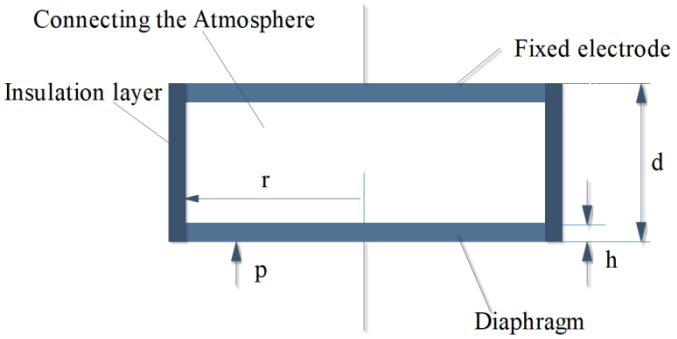

Figure 1 Capacitive pressure sensor structure schematic

The thickness of a diaphragm of some material is *h*, the radius of the electrodes is r_0, the distance between the two electrodes is *d*, and the difference between the external and internal pressures is *p.* The deflection at position *r* is

$$W_{max} = \frac{3}{16} p \frac{1-\mu^2}{Eh^3} r_0^4 \tag{1}$$

In the equation, E is the Yang's modulus and m is the Poisson's ratio. When r = 0, the maximum value of the flexural value is

$$W(r) = \frac{3}{16} p \frac{1-\mu^2}{Eh^3} (r_0^2 - r^2)^2 \tag{2}$$

When a certain external pressure is applied, the pressure will change and the diaphragm of a specific material will deform, which will lead to a change in the capacitance value of the sensor. Where the capacitance value of *dC* indicates that at this time is to be in the vicinity of *r*, taking the electric capacity of the tiny circle of *dr*, $dC=2\pi rdr$[6]

$$C = \int_0^{r_0} dC = \int_0^{r_0} \frac{\varepsilon 2\pi r}{d - w(r)} dr = C_o \left(\frac{d}{w_{max}}\right)^{\frac{1}{2}} arctan\left(\frac{w_{max}}{d}\right) \tag{3}$$

The distribution of the entire capacitance is not uniform, so the integration operation is performed to find *C*. In the above equation， $C_o=\varepsilon\pi r^2/d_o$ coupling formula(1-3), it can be derived that[7]

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$$\frac{C}{C_o} = \left(\frac{16Eh^3d}{3\left(1-\mu^2\right)r_o^4 p}\right)^{\frac{1}{2}} arctan\left(\frac{3\left(1-\mu^2\right)r_o^4 p}{16Eh^3d}\right)^{\frac{1}{2}} \quad (4)$$

2.2. Principle of microcontroller control system

The microcontroller consists of a microprocessor CPU, memory, including ROM and RAM, I/O interface, timer, interrupt system and other circuits and is called a single microtype computer. The microprocessor CPU is eight-bit, and the internal RAM implements data storage, which stores temporary data of the running process, including temporary operation results, temporary variables, etc. The data memory ROM can realize the program power-down storage, no need to burn repeated programs after power-down. four eight-bit parallel I/O ports are the input or output channels of the microcontroller, which can realize the data exchange with the outside world, signal control, etc. Timer/Counter: Realize the function of timing or counting. It can count external pulses, can generate a period at regular intervals, realize the overall control of the system, etc. A UART serial port: can communicate with external devices, etc.

The microcontroller contains many internal parts, independent of the microcontroller can not work properly, the external part of the microcontroller needs to be an external circuit to work properly, the external circuit is called the microcontroller minimum system as shown in Figure 2. The minimum system circuit is composed of a clock circuit, reset circuit, etc. The clock circuit provides the clock frequency for the microcontroller, and the reset circuit enables the microcontroller to execute the program from zero.

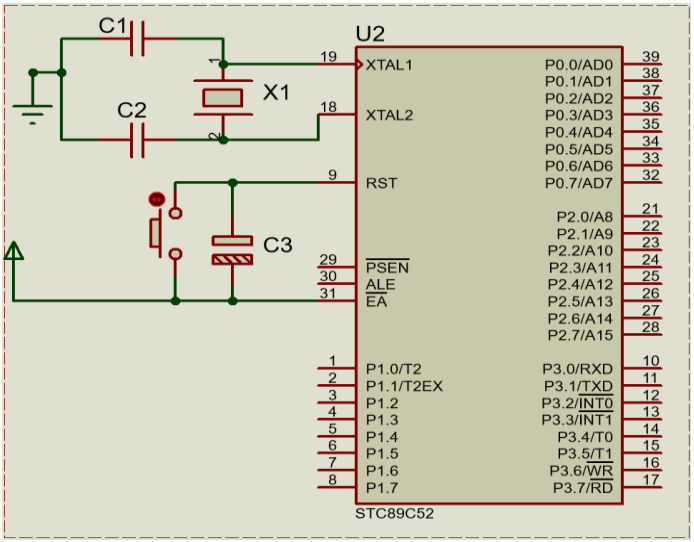

Figure 2 Minimum control system diagram

3. Simulation model analysis

3.1. Simulation analysis of improved capacitive pressure sensor

The capacitive pressure sensor is highly accurate, taking into account several aspects such as pressure, temperature and other effects. The geometric model of this capacitive pressure sensor is shown in Figure 3, with a voltage of 1 V applied to the film, separated from the grounded sealed cavity, with the cavities on both sides insulated. Considering the symmetry of the space of the model, 1/4 of the geometric model is modelled and analyzed in COMSOL. The chip film will produce a small displacement after feeling the external pressure, and the change of displacement will cause a change in capacitance value.

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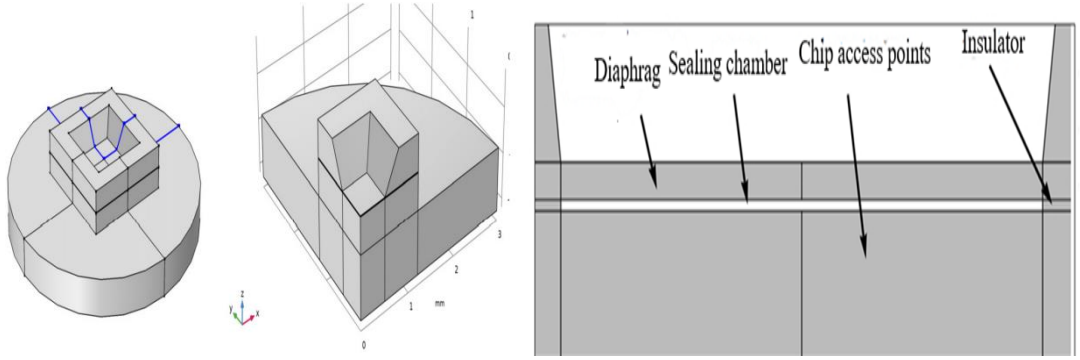

Figure 3 Schematic diagram of the model of the capacitive pressure sensor

The pressure sensor belongs to a silicon chip that has been embedded in a metal plate at 70oC. Considering the different temperatures during the bonding process, the thermal conductivity effect between the silicon chip and the metal plate will generate thermal stresses inside the model, and these stresses are also temperature dependent, with temperature dependence, both of which will change the capacitance value and easily measure the results.

Considering the above effects together, the variation of the diaphragm capacitance under external pressure considering thermal stress and temperature is compared with the linear zero-pressure capacitance of reference [8]. As shown in Fig. 4, the change of capacitance is nonlinear and the slope of the curve reflects the sensitivity. The sensitivity of the model is 7.3*10-6pF/Pa, so the sensitivity of the whole device is 29*10-6pF/Pa, while the sensitivity of reference [8] is 26*10-6pF/Pa, which improves the accuracy of the model. The displacement of the centre of the film when an external fixed pressure of 25 Kpa is applied, is shown in Figure 5. The improved model yields high precision capacitance values, and the weight is obtained by certain capacitance conversion, which is sent to the city in the control and monitoring system.

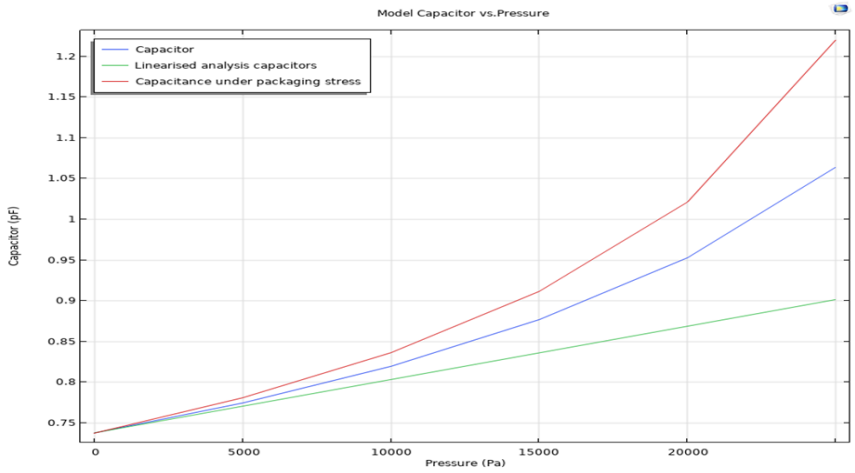

Figure 4 Variation of diaphragm capacitance with external pressure under different conditions

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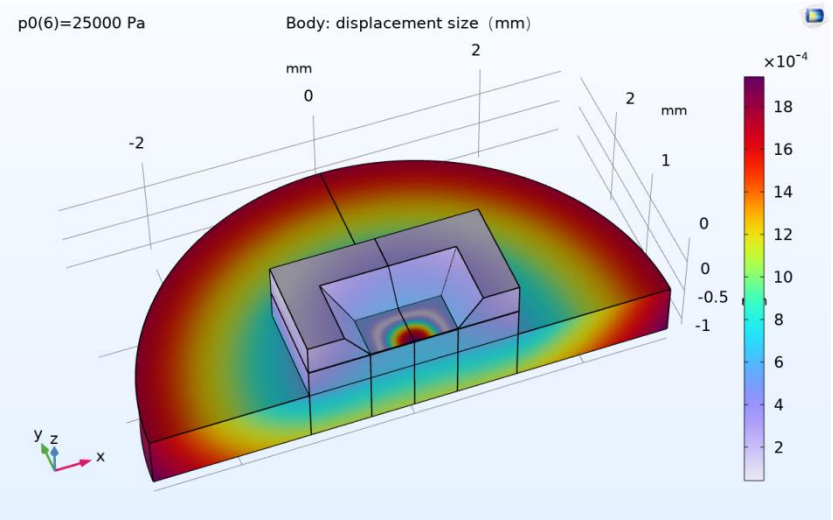

Figure 5 Deformation degree of 1/4 geometry model when 25kpa is applied

3.2. Simulation analysis of urban waste bin control and monitoring system

MCU technology is now widely used in industrial production and has great advantages in the field of control. The core control system is the STC89C52, which can be used for the management and control of municipal waste bins. The detailed control functions are the activation and deactivation of the bins and the monitoring of the temperature and humidity in the bins. The weight of the waste in the bins can also be accurately checked and when the weight of the waste exceeds a certain threshold, A buzzer sets off an alarm which tells the individual concerned that the bin should be disposed of. With this control system, the daily weight data of the bins in the city can be stored and analysed, enabling the inputs and modifications of the bins to be optimised, thus increasing the efficiency of industrial production and improving the urban ecological environment. Figure 6 shows the control system for the distribution of bins and the detection of the weight of waste in the cultural, industrial, commercial and residential areas of the city.

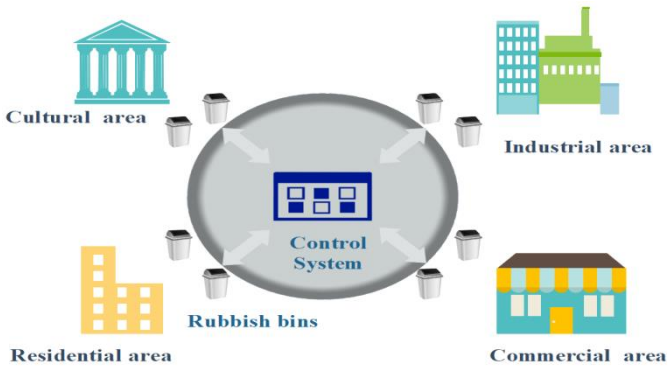

Figure 6 Schematic diagram of urban area distribution

The city dumpster control and monitoring system consist of three parts, which are waste weight sensing system, temperature and humidity monitoring and control system, and dumpster quantity allocation monitoring system. Through this paper, the three control parts are integrated to realize the optimal control of city bin weight monitoring and bin quantity distribution.

3.2.1. Garbage weight sensing system

The garbage weight sensing system consists of a weight sensing module, weight alarm module, weight display module, storage module, and weight processing module, which realizes the accurate measurement of garbage weight of the garbage bin, over-the-limit alarm and other related functions, and its control circuit is shown in Figure 7.

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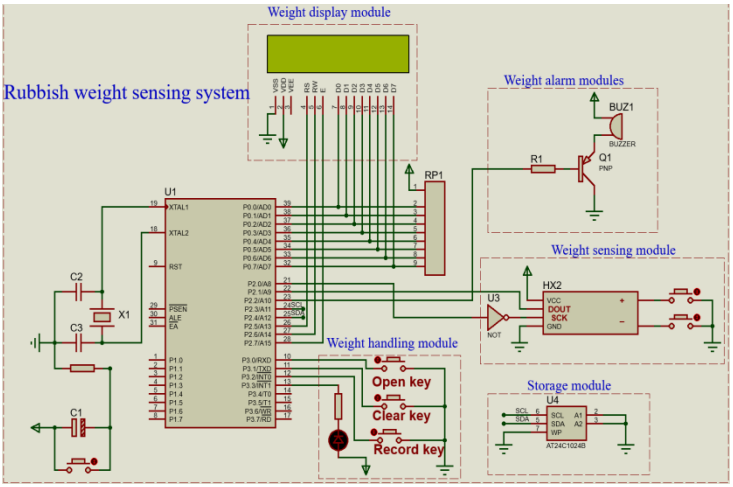

Figure 7 Circuit diagram of the waste weight sensing system

The weight signal input from the weight sensor is connected to the weight sensing module, which includes a 24-bit A/D converter chip that converts the weight signal into a digital signal and sends it to the garbage weight sensing system for processing, and after the processing is completed, the weight of the garbage is displayed on the weight display module with a minimum resolution of 1g, and the buzzer will send an alarm signal when the maximum threshold is exceeded. There are three controls in the weight processing module and storage module, which are switch control, zero control and storage control. The switch control controls whether the weight sensor in the bin is working or not. The zeroing control allows the weight to be zeroed. The storage control allows the weight data to be stored for subsequent analysis.

In the actual operation process, the data information is input by the external bin weight sensor, and the signal is accessed and processed through the control system receiver. This paper equates this actual situation by building a virtual weight increase in the simulation system to simulate the weight data input, and then realizes the real-time weight display. The results are shown in Figure 8.

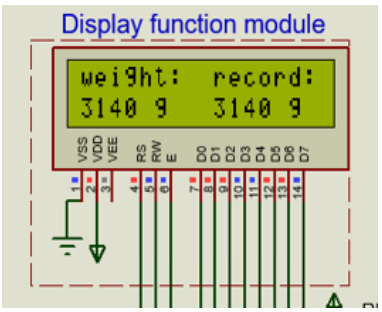

Figure 8 Simulation results of the waste weight sensing system

The set virtual weight is 3140g, and the weight is displayed on the LCD, and the data is stored in the EEPROM after storage control is performed to achieve preservation.

3.2.2. Temperature and humidity monitoring and control system

The Temperature and Humidity Measurement Module forms the temperature and humidity surveillance and control system that monitors the temperature and humidity of the bin, as shown in the control circuit diagram in Figure 9.

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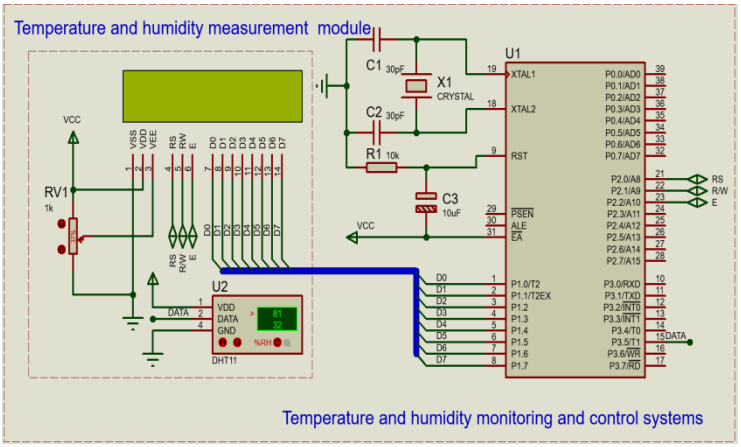

Figure 9 Temperature and humidity monitoring and control system circuit diagram

The temperature and humidity module is mainly used to feel the temperature and humidity of the bin, display the current temperature and humidity, and realize the corresponding control.

The temperature and the humidity sensors externally acquire the signals and the receiver of the control system receives them and carries out the next stages of their processing. This paper simulates this actual situation by constructing a specific temperature and humidity in the simulation system to realize the data input, and then realizing the real-time temperature and humidity display. The results are shown in Figure 10.

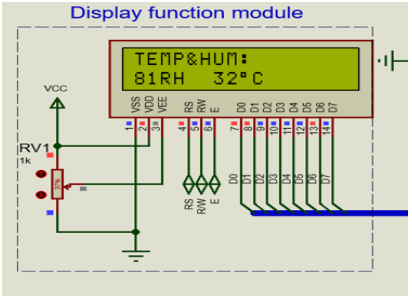

Figure 10 Simulation results of temperature and humidity monitoring and control system

The set temperature and humidity are 81RH and 32oC, which are displayed on the LCD.

3.2.3. Waste bin quantity distribution monitoring system

The waste bin quantity distribution monitoring system consists of a counting control module, waste counting module and counting display module, which realizes the function of controlling the quantity distribution of city waste bins, and its control circuit is shown in Figure 11.

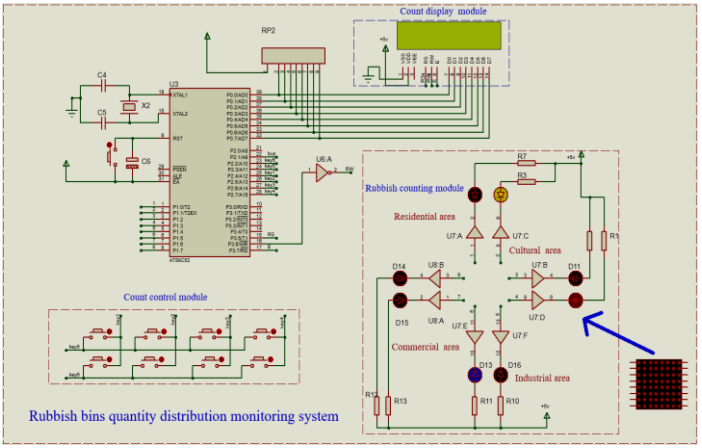

Figure 11 Circuit diagram of the waste bin quantity distribution monitoring system

In the simulation system, each indicator represents a dot matrix, and the dot matrix is used to simulate the number of bins placed in an area, clockwise for residential, industrial, commercial

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and cultural areas respectively. The counting control module enables the activation and deactivation of garbage bins by checking whether various sensors are working or not. The counting display module shows the number of bins in each area that are working properly.

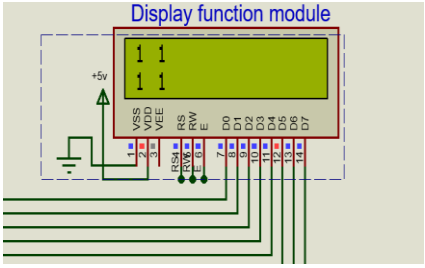

Figure 12 Simulation results of temperature and humidity monitoring and control system

In the actual process, a certain number of garbage cans are placed in each area, and each garbage can has two states of whether it is working properly or not. This design simulates the actual situation and virtualizes the deactivation and activation status of each bin by the lighting situation in the simulation system, and the results are displayed. The results are shown in Figure 12.

Press the button in the control system to light up the indicator lights in each area separately. Only one indicator is lit in each area of the diagram, and the result displayed is 1, 1, 1, 1.

4. Conclusion

This paper proposes a method for controlling and monitoring urban garbage bins based on an improved capacitive pressure sensor and a microcontroller processing system for the rational planning and garbage disposal of urban garbage bins, which can reasonably participate in the construction process of urban eco-environmental improvement and guide environmental protection personnel to dispose of domestic garbage and arrange the number of garbage bins in a timely and proper manner. The main innovations of this paper are as follows.

This paper constructs an improved capacitive pressure sensor with high accuracy and accurate measurement results to improve the front-end sensing capability to accurately sense the weight of the bin and send the weight to the control system.

This paper builds a city garbage bin control and monitoring system based on the STC89C52 microcontroller and other functional modules. The control system can monitor the use of garbage bins in each area, including the weight of the bins, temperature and humidity, etc., so that the staff can clean the bins in time and realize the intelligent management of city garbage and improve the ecological environment of the city.

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