Design and Research on Control System of Pure Electric Sugarcane Leaf Returning Machine

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Abstract: The design of the control system for pure electric sugarcane leaf returning machines that includes the design of hardware and program parts. The STC89C52RC is taken in the system as the control core to expand its I/O ports and design the peripheral circuits. That adopts radio remote control as the control method of the whole machine, and designs and selects the working mode of its receiving board to achieve the independence of traveling and working of the whole machine, solved the complicated problems of the remote control buttons, and after the completion of the overall design of the control system, its relevant performance was tested and verified. Through the verification, it was found that the control system has fast response, high reliability, good climbing ability, that can adapt to the complex terrain of the sugarcane field, and meet the work requirements; its remote control distance can avoid the impact of dust, that has improved its working environment and meets modern agronomic requirements.

1. Introduction

At present, although the domestic sugarcane leaf returning machines have achieved certain results, they can meet the requirements of sugarcane leaf returning to a certain extent, but due to the need for supporting the use of large machinery in the work process, the sugarcane field is seriously affected by pressure, and has a greater impact on the growth of sugar cane. Furthermore the sugarcane leaf is picked up with a knife on the work process of returning. Due to the complex terrain of the sugarcane field, it is inevitable that the knife will cut into the soil or impact the stone in the work process. The power consumption and machine operation cost is high, that seriously affect the service life of the knife and easily hurt the cane roots which had a serious impact on the growth of rattan cane[1]. The small sugarcane leaf returning machine can not only effectively avoid the above problems, but also can adapt to the hills and slopes in the south. However, during the operation of the sugarcane leaf returning field machine, due to the high speed rotation of the working motor, a large amount of dust will be aroused, and the operating environment of the operator is poor. The battery is used as the power source of the whole machine and the operating cost is reduced. With the remote control method, the operator can maintain a certain distance from the operating point and keep away from the influence of dust. Therefore, the control system of the
small sugarcane leaf returning machine is designed and researched in this paper.

2. Design of overall system

The core of the control system of the design is the STC89C52RC chip, through the remote control button to control the traveling and working of sugarcane leaf returning machine, the overall block diagram of the system shown in Figure 1. When the remote control button is pressed, the MCU will detect the signal and process the signal, then issue an instruction to drive the motor drive circuit, thereby controlling the start-stop of the motor and the steering.

![Figure 1 Overall System Block Diagram.](image)

3. Design of hardware system

The design of the hardware part of the system mainly includes the design of the minimum system of the single chip microcomputer, the design of the remote control circuit, the design of the voltage stabilizing circuit and the design of the motor drive circuit. Now the design of each part of the circuit is explained one by one.

3.1 Design of the minimum system of one-chip computer

The minimum system of the one-chip computer is made up of CPU, power, crystal oscillator circuit, reset circuit[2]. The core of the MCU is the STC89C52RC chip produced by STC company, the circuit is shown in Figure 2.

![Figure 2 The minimum system circuit diagram.](image)

Power-on reset and external key reset are used for the reset circuit. When the microcontroller is powered on, the capacitor charging current is the largest and the capacitor is short-circuited, making the RST pin in the high level state and the microcontroller reset. In order to ensure that all parts of the system can reach the initial state, the high level of the RST pin must be maintained for a certain period of time. The capacitor charging formula is Equation (1).
\[ V_t = V_0 + (V - V_0) \times \left[ 1 - e^{(-t/RC)} \right] \]  

(1)

Where \( t \) is the time of capacitor charging, \( R \) is the value of resistance, \( C \) is the value of capacitor, \( V_0 \) is the initial voltage value of the capacitor, \( V \) is charging power supply voltage, \( V_t \) is the voltage capacitor on the \( t \).

From the publicity, we can see that only when \( t \) tends to infinity, the voltage on the capacitor will reach a stable level and charging will be over. However, in the actual process, \( e^{(-t/RC)} \) will soon tend to 0, and the voltage across the capacitor will change very little. At this time, the charging is terminated by default. And in the charging process will be accompanied by the loss of energy, the voltage across the capacitor will not reach the voltage of the power supply, so take \( V_t = 0.9V \) into Equation (2).

\[ t = 2.3RC = 2.3 \times 10^4 \times 22 \times 10^{-6} = 506ms \]  

(2)

The microcontroller is reset in 20ms or more[3], so the designed reset circuit meets the requirements. When the capacitor is charged, the RST pin is set low level and the microcontroller enters a working state. During the work process, when the program has an error, you can press the key, 5V power will be directly added to the RST pin, so that the RST pin is set high level and the microcontroller reset. Human operation takes several tens of milliseconds to fully meet the microcontroller reset time. After the key is disconnected, the microcontroller will re-enter the working state.

### 3.2 Design of regulator circuit

The total voltage of the system is 24V, and the working voltage of the selected remote control circuit is 12V. The operating voltage of the single-chip microcomputer is 3.3V~5.5V, so the voltage regulator circuit must be used during the system operation. Because it needs 12V and 5V voltage, so choose LM7812 and LM7805 steady voltage chip.

With an output voltage of 3 to 18 V, the input voltage of the LM78 series can be as high as 35 V. Therefore, the total system voltage can be used as the input voltage of the LM7812. By LM7812 will be 24V down to 12V, as a remote control circuit operating voltage; Then reduce 12V to 5V through LM7805, as the operating voltage of the microcontroller circuit, so as to achieve the system voltage requirements. The voltage regulator circuit is shown in Figure 3. In the figure, D1 and D2 are the power indicator lamps; 0.33μF electrolytic capacitors are connected to the input and output terminals of the power supply to filter out high-frequency harmonics and sharp pulses[4].

![Regulator circuit](image)

**Figure 3** Regulator circuit.

### 3.3 Design of remote control circuit

In the field operation, a large amount of dust will be generated and there will be some interference with the signal transmission, and in order to improve the operator's working
environment, a certain remote control distance is required, and radio transmission is non-directional and has certain penetrability. Distances of up to tens of meters, or even kilometers, so use radio remote control as a remote control of the machine [5,6].

The remote control circuit uses SC2260 as the encoding chip and SYN470R as the decoding chip. When the remote control button is pressed, the SC2260 processes and encodes the signal, and transmits the signal through the radio; after receiving the signal, the SYN470R decoding chip decodes the signal through the OOK demodulator on the receiving module, and the digital signal is guaranteed by the comparator. The output, in turn, drives the relay on the receiver board.

The returning machine has a total of four motors, two as drive motors and two as working motors. When returning machine to work, the control of the drive motor and the work motor is required to be independent, so the receiving board adopts a combination of the jog and self-locking work modes. The drive motor realizes forward, backward, turns left and right. The related functions are realized by the four-way jog relays. Therefore, when controlling the traveling of the entire machine, it is necessary to keep pressing the corresponding button, and after releasing, it stops the movement. Four-channel self-locking relay is used to control the start-stop and steering of the working motor. After the corresponding button is pressed, the working motor is in the traveling state, and pressing again stops. Therefore, it is determined that the remote controller uses the eight-key control mode.

3.4 Design of motor drive circuit

The motor drive circuit consists of a relay, an optocoupler TLP521-2, a transistor and a motor driver. The circuit is shown in Figure 4. The motor is controlled by the driver. The control of the motor is converted into the control of the motor driver. By controlling the on-off of the driver signal, the start-stop and control of the motor are controlled.

![Figure 4 Traveling motor drive circuit.](image)

Circuit working principle: when P1^1 output is high, through TLP521-2, which makes NPN triode conduction and relay Relay1 works, RUN and COM shorted, the motor rotates according to its setting direction; Similarly, when P1^0 output is high level, which makes relay Relay2 work, DIR and COM are shorted, and the motor rotates in the opposite direction. Since the driver cannot receive two signals at the same time, that is, P1^0 and P1^1 cannot be set high level at the same time, one pin is pulled high while the other pin is pulled low level, ensuring that the driver always
receives only one signal. The driving circuit of the working motor is shown in Figure 5. Relay 5 is used as the control switch. When P3\(^4\) outputs high level, it passes TLP521-2, turns on the triode, and then drives Relay5 to make the normally open contact closed. Turn on the power and turn it.

![Figure 5 Working motor drive circuit.](image)

4. Design of control system program

In the control system, the program code occupies an important position in the entire system, and the receiving and processing of system instructions are all completed by the program code in the system. Therefore, the control system must have complete and correct code as a support to achieve an ideal working condition.

4.1 Programming Overview

There are eight keys on the remote controller of the sugarcane leaf returning machine control system. Each key corresponds to a different command and each command does not interfere with each other. After the button is pressed, the sample machine must perform the corresponding action. The receiving end of the remote control circuit is connected to the I/O port of the single-chip microcomputer. When the button is pressed, the corresponding pin is set low level, and the CPU sets the corresponding pin high level according to the program, and drives the corresponding components to realize the corresponding functions.

The traveling and steering of the prototype is driven by the two traveling motors at the same time, that is, when the corresponding pins are set high level, after the two relays work, the corresponding pin of the previous instruction is also set low level to disconnect the driven relay. To ensure the correctness of the motor driver to receive the control signal.
Figure 6 Program flow chart.

The control of the two working motors is independent of each other and does not interfere with the traveling motors. When the instruction is issued, the corresponding pin is set low level, and the pin of the drive relay is set high level, which makes the relay work, and the motor starts; pressing the corresponding direction key, the motor will rotate in the opposite direction. Program flow chart shown in Figure 6.

4.2 Design of main program

The receiving end of the designed remote control circuit is connected to the P2 port. The signal input terminal of the motor drive circuit is connected to the P1 port and the P3^4 pin. Let P2 port be high level, with P1 and P3 port be low level, set up the delay function and the sub-function of the corresponding function. When executing the program, the program is first initialized to detect whether there is a key pressed. If a key pressed is detected, the delay function is called to delay 5ms to eliminate the effect of the key jitter; once again, if the key is pressed, then the corresponding pin of P2 port is set low level. The MCU calls the corresponding sub-function, which drives the relay to work, and then drives the motor to rotate or change direction.

5. Test verification

In this paper, the correctness and reliability of the control system were tested and verified, which includes testing of the running speed, the climbing angle and the remote control distance of the whole machine under different working conditions. To verify whether the actual conditions can meet the working requirements and the test data recorded and analyzed.

5.1 Test site and method

According to the road surface and working environment of the prototype, two types of working condition which are cement pavement and simulated sugarcane field, were selected to test the running speed. The test site is shown in Figure 7.
The test method of the traveling speed: 1) according to the theoretical value of the traveling speed of the whole machine, the traveling motor is speed-adjusted and calibrated with a hand-held digital tachometer to ensure the same speed of the two traveling motors and calculate the theoretical traveling speed; 2) the initial position of the field returning machine is selected at the test site; 3) align the axis of the rear wheel turning machine with the initial position; 4) press the remote control button while timing the time, and measure the time taken for the random traveling distance of the field returning machine. There are 5 groups.

The operation site of the field returning machine is the sugarcane field. The terrain is complex and there is little ridge height and furrow. This needs the returning field machine to have a certain ability to climb the slope. Therefore, the climbing test is performed and the test site is shown in Fig. 8.

5.2 Test results

After the test is completed, the test data of the traveling speed is recorded and analyzed. The test data is shown in Table 1 and Table 2.

<table>
<thead>
<tr>
<th>Number</th>
<th>Motor output speed(r/min)</th>
<th>Theoretical traveling speed(m/s)</th>
<th>Distance(m)</th>
<th>Time(s)</th>
<th>Actual travel speed(m/s)</th>
<th>average value</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Figure 7 Cement pavement (left), simulated sugarcane field (right).

Figure 8 Climbing test site.
Table 2 Simulated traveling speed of sugarcane field returning machine.

<table>
<thead>
<tr>
<th>Number</th>
<th>Motor output speed(r/min)</th>
<th>Theoretical traveling speed(m/s)</th>
<th>Distance(m)</th>
<th>Time(s)</th>
<th>Actual travel speed(m/s)</th>
<th>average value</th>
</tr>
</thead>
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<td>15.983</td>
<td>32.45</td>
<td>0.492</td>
<td>0.492</td>
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<td>2</td>
<td></td>
<td></td>
<td>16.116</td>
<td>32.65</td>
<td>0.493</td>
<td>0.493</td>
</tr>
<tr>
<td>3</td>
<td>37</td>
<td>0.51</td>
<td>18.094</td>
<td>36.75</td>
<td>0.492</td>
<td>0.492</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>28.082</td>
<td>56.98</td>
<td>0.493</td>
<td>0.493</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>21.776</td>
<td>44.31</td>
<td>0.491</td>
<td>0.491</td>
</tr>
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</table>

It can be seen from Table 1 and Table 2 that the traveling speed of the reverting machine on the cement road surface is 0.492 m/s, which is close to the theoretical value; in the case of the simulated sugarcane field, due to the complex terrain and high friction, the traveling speed is 0.467 m/s, but its theoretical value is within an acceptable range.

After testing the ability of returning the field to climb, it can be passed over a slope of 30° and has good climbing ability, which can adapt to the working environment of the sugarcane field. The remote distance was tested and found that the longest distance that the remote controller can remotely control is 75.4m. During the working process, the operator can perform remote control within this distance range, which can completely avoid the bad working environment caused by returning machine during work.

In the test process, the working motor can be started, stopped and turned by remote control. The rotation speed of the motor can be adjusted according to actual needs.

6. Conclusion

In this paper, the STC89C52RC is taken as the control core and completes the design of the control system for the sugarcane leaf returning machine. Through experiments, it was verified that the designed control system can realize the traveling of the whole machine as well as the start-stop of the working motor. It has good climbing ability, and the difference between the traveling speed and the theoretical speed is within an acceptable range, and it can meet the requirement in the sugarcane field. The use of radio remote control separates the control of the traveling motor from the working motor, enabling traveling and working independently, solving the problem of complex control system keys, and simplifying remote control operations. The operator can remotely control the operation of the sugarcane leaf returning machine at a certain distance to improve the working environment and have a wide range of application prospects.

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