

Design of Setting-type Programmable Controller

Yun Gong¹, Yujie Shi², Baoqiang Zhao³, and Zongxiao Yang¹

¹ Sanda University, Shanghai 200120, China

² Gunma University, Kiryu City, Japan

³ Huanghe S&T University, Jiyuan 510000, China

Abstract

The way of modern industrial production and processing is developing towards automation. In order to meet the needs of mechanical designers for low-cost automatic control equipment without programming, we have designed a setting-type programmable controller which can assist debugging on site and automatic control process on site. It is mainly composed of HMI, HMI interface module, control module and programs running on it. The system takes HMI as the operation and control core and the control module as the driving and executing part, which can realize the functions of on-site debugging of equipment operation, setting of executive programs (editing or self-learning), automatic program operation and so on. As the platform of human-machine interaction and the host computer of the system, HMI completes the functions of human-machine interaction, command sending, control parameter generation, execution program editing and saving. The setting-type programmable controller has the advantages of simple operation and stable operation. It is a new automatic control system. Compared with general industrial controllers, it is more economical, timely, without professional programmers, easy to operate and can save a lot of production and processing costs.

Keywords

HMI; System; On-site Debugging; Self-learning; Control.

1. Introduction

A product is composed of many parts. The assembly of these parts needs to be completed manually, so a certain number of operators are required. With the gradual increase of labor cost, equipment that can replace manpower to complete these tasks has become a necessary demand. However, only front-line technicians know the functional characteristics and performance requirements of these equipment. Therefore, the development of these equipment can only be completed by front-line technicians driven by interests and needs. Usually, the mode from the proposal of the project to the establishment of the development team, and then developed by professional developers. In reality, due to the characteristics of complex requirements and unique functions, the development cost is greater than the development profit. So, this development model can not continue, which is also the reason why many labor-intensive industries have not realized automation. To replace intensive labor with automatic production, it mainly depends on front-line technicians, and mainly depends on front-line machinery manufacturing or machinery maintenance personnel. However, these technicians often do not master the development technology of PLC, so the development of some complex equipment that needs programmed automatic execution cannot be realized. If there is a control system that can complete programmed automatic operation according to target setting, it can help solve this problem [1].

An automatic equipment that can complete certain actions is often driven by some pneumatic, hydraulic or motor. If the cost of control system is too high, the cost of equipment is bound to be too high. Therefore, it is necessary to reduce the cost of the control system and remove unnecessary functions or performance. Because front-line technicians usually do not have the quality of system design, they often use empirical exploratory methods in development and improvement, which requires on-site debugging and on-site operation adjustment. Therefore, the automatic control system used here can assist debugging and set automatic control process on site.

2. Structure of Controller

This design consists of three parts. It includes control module, interface module and serial port HMI.

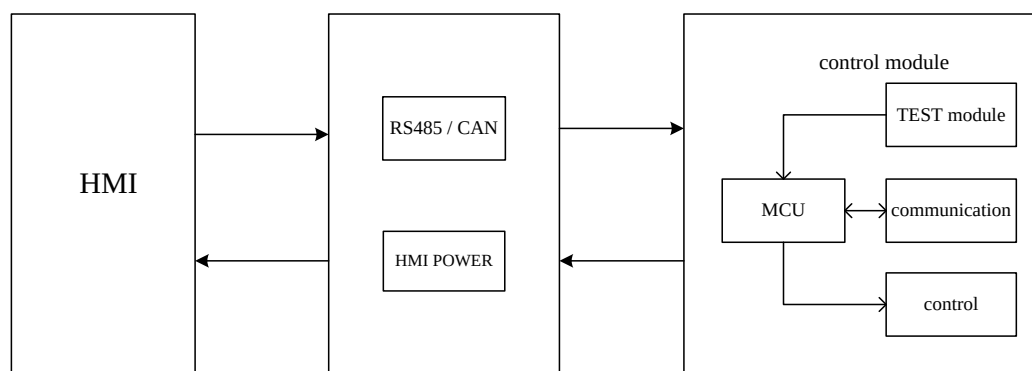


Figure 1. Structure of setting-type programmable controller

2.1. Control Module

It can realize two working modes: automatic control and manual control. Under the automatic control mode, the driving signal is output according to the received instructions of the main control HMI, and the state of the control equipment is collected and fed back to the main control HMI [2]. In the manual control mode, the driving signal is directly output according to the combination of two keys on the control module.

2.2. Interface Module

As the communication bridge between the control module and the main control HMI, the TTL serial port signal of HMI is converted into RS485 or CAN communication signal, and the working power supply is provided for the main control HMI.

2.3. Serial Port HMI

Complete the functions of man-machine interface, information storage and master control, and realize the functions of on-site driving equipment, executive program (editing or self-learning) setting, work production status display, automatic program execution and on-site monitoring.

3. Functions of Controller

3.1. On-site Debugging

It can debug the operation of the equipment on the production site in real time ("debugging" function), assist in the detection of mechanical equipment and the adjustment of mechanical equipment function and accuracy, and also serve as a helper for the maintenance and operation verification of mechanical equipment [3].

3.2. Program Setting

There are two modes: edit setting mode and manual control record (autonomous learning) mode. According to the settings of editing output channel code, trigger conditions and execution delay time, or generating element files by recording the simulated operation process of manual control equipment, the program setting of automatic operation can be completed, which is intuitive, simple and convenient.

3.3. Automatic Execution

The steps can be executed according to the set program to make the control mechanical equipment run automatically again and again until the operation fault occurs or the operation clicks “pause” or “return”.

3.4. Human Machine Interaction

According to the “debugging” in HMI interface, the mechanical equipment is directly controlled on site. According to the “three elements” rule, set the program to automatically execute the control of mechanical equipment and display the production and equipment operation status in real time.

4. Circuit of Controller

The MCU of the control circuit adopts ATmega16, which has applicable performance and lower price. It belongs to 8-bit microprocessor. It also has the function of prefetching instructions, which can execute instructions in one clock cycle. Therefore, the execution time and efficiency of ATmega16 are sufficient for 8-channel output control and 20 channel input information acquisition. ATmega16 has 32 programmable I/O ports, so that the control module has sufficient drive output capability and sufficient control capability. The wide working voltage is 2.7V to 6V, which makes the control module have strong power anti-interference. The independent serial asynchronous communication UART interface can ensure the stability and efficiency of the system.

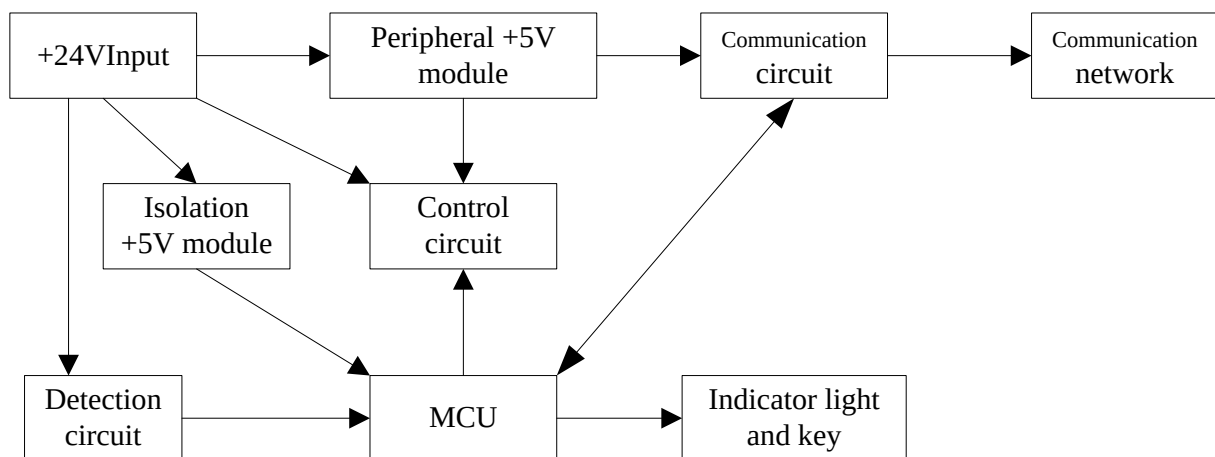


Figure 2. Structure of control module

In the detection circuit, the optocoupler is used to receive the external input signal and convert it into the corresponding signal on the MCU side to complete the conversion of the input switching value or potential signal to form an optocoupler isolated input circuit [4]. The MCU obtains the detection information through the matrix scanning circuit and feeds back the information to HMI.

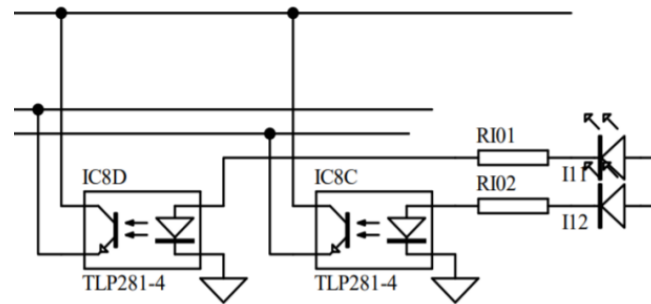


Figure 3. Detection circuit

I11 and I12 are light emitting diodes, RI01 and RI02 are current limiting resistors, and IC8D and IC8C are isolated optocouplers. Whether I11 and I12 emit light or not can know whether there is signal input, and can also be used as the judgment basis for detecting whether the input side of the circuit works normally. When a signal is input, the output side of the optocoupler is in the low resistance state, on the contrary, when there is no signal input, it is in the high resistance state. Figure.4 is a scanning detection matrix composed of 20 such circuits, which constitutes 20 channels working state detection circuit of the control module.

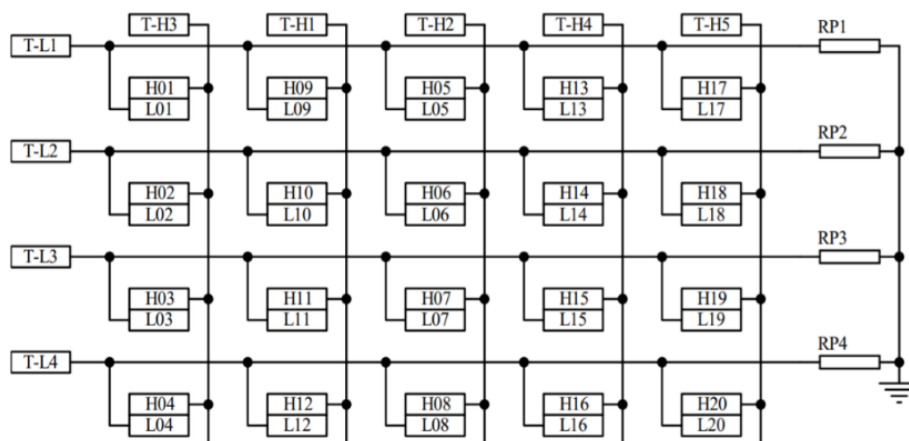


Figure 4. Detection matrix

T-H1~T-H5 are the signal input of the scanning detection matrix, and T-L1~T-L4 are the signal detection of the scanning detection matrix. During detection, the signal voltage is applied to the signal input pin in turn. Each time the signal voltage is applied, the signal detection pin is read, and then the data is saved. The voltage signal is applied 5 times in a detection cycle, and the complete 20-channel input state can be read out. The scanning frequency in the system is greater than 20kHz.

The output driving element of the control module is L298N, which is an integrated monolithic circuit with a built-in high-voltage and high current double full bridge drive and provides two input signals (enabling or disabling the device). The maximum driving voltage of L298N is 50V and the maximum output current is 3A, which can fully meet the expected driving requirements for common pneumatic solenoid valves, hydraulic solenoid valves, relays and ordinary DC motors.

Figure.5 shows the control circuit, in which IC2 is the optocoupler isolation drive chip control circuit, and four groups of such circuits constitute a complete 8-channel output control circuit. The isolation optocoupler converts the control signal of MCU into the control signal of the driving chip L298N, which can protect MCU from external current impact or interference. At

the same time, the control signal is transmitted to the output driving chip to complete the isolated output driving circuit controlled by MCU.

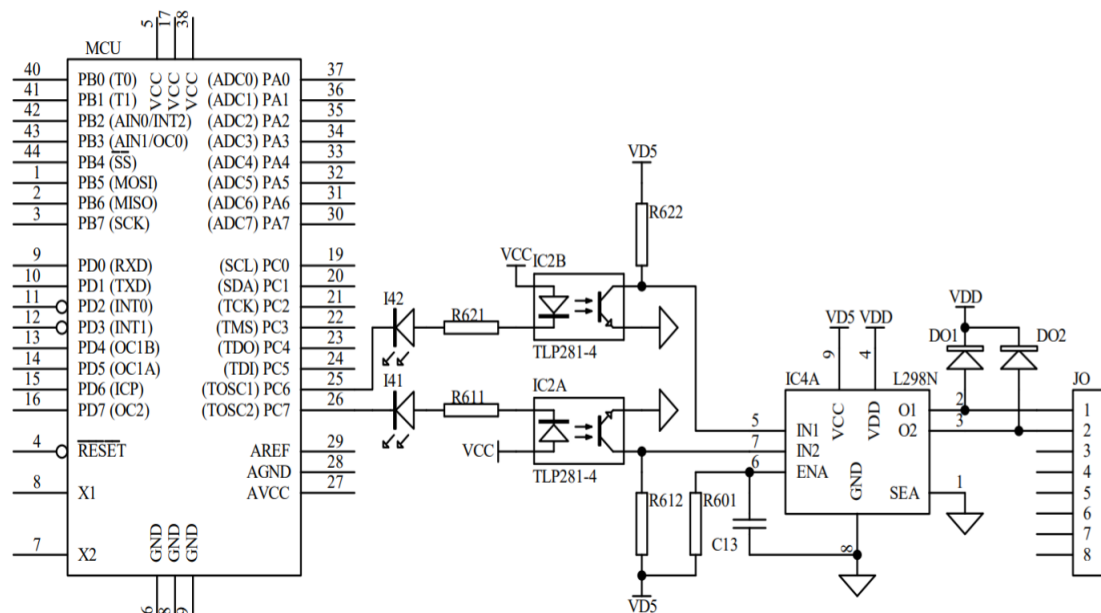


Figure 5. Control circuit

The I41 and I42 LED indicate the state of the output. When emitting light, it indicates that the channel outputs, otherwise, there is no output. R611 and R621 are current limiting resistors, IC2A and IC2B are isolated optocouplers, R612 and R622 are pull-up resistors. When the output control pin PC6 or PC7 of MCU is at a low level, the isolation optocoupler is presented in a low resistance state to make the circuit output at a low level. Conversely, high level output.

R601 and C13 are connected to the enable control pin of L298N. They slowly rise to the high level when powered on to avoid the unexpected output of control signal by L298N when just powered on. SEA is not used in this circuit, but can be used as precise control output and protection L298N in the future. D01 and D02 are output protection diodes, these are freewheeling diodes, which are used as reverse discharge channels for inductive loads.

5. Running Program of Controller

The work interface is used to control the equipment operation and realize the automatic operation of the equipment. This interface displays the date and time, and prompts the equipment operation status, the cumulative count of successful operation and the cumulative count of unsuccessful operation. It is used to tell the user the quantity of finished products and defective products.

After entering the working interface, if you click start, it will mark the working state, take the operation parameters set in the database, send the control command according to the operation parameters, and mark that it has been sent. After receiving the monitoring information fed back by the equipment, judge whether the control target task is completed according to the operation parameters. If the control expectation is reached, take down an operation parameter and continue the same processing until you click pause or return. If you click pause, mark the working status as stop working, stop executing the command sending and wait. If you click return, a reset command will be sent to control the operation and homing of the equipment, and exit the operation interface at the same time.

In this system, the control module interrupts the data of the host computer through the serial port, then calls CRC16 to verify the validity of the data and parse the valid data to get instructions. The output control is carried out according to the received control instructions of the main control module, and the matrix scanning mode is called to collect 20 channel equipment input states. The status information of these equipment is fed back to the main control board to realize the purpose of on-site commissioning and automatic control.

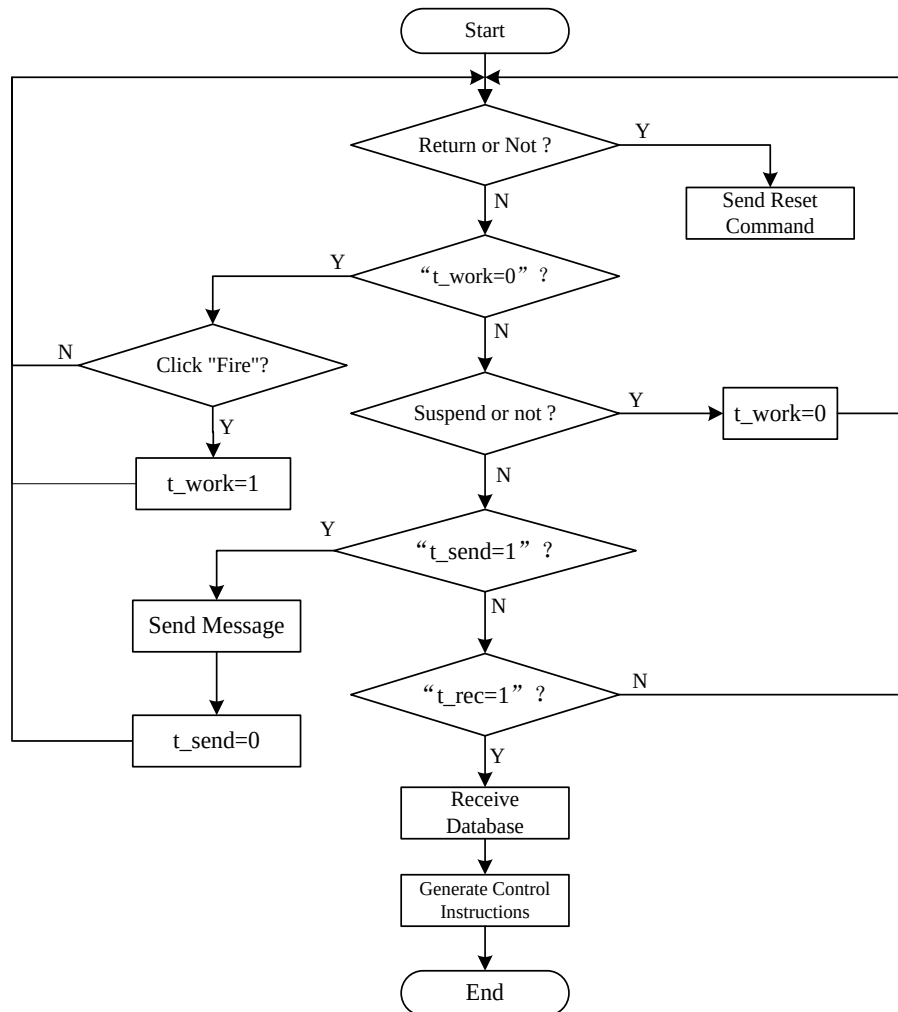


Figure 6. Working procedure flow chart

Figure.7 shows the program flow of the control module according to the main control instruction. If two keys are pressed at the same time, the manual control mode program is called. If data is received, the validity of the data is detected. If the data is valid, mark that the data is valid, and call the instruction execution program at the same time. After detecting the completion of the equipment execution instruction, mark the working state, reply the working state to the master control state information, and clear the working state after the data is sent. The manual control of the control module is to ensure the function used by the control board when it is out of HMI main control or does not need to start HMI. Under this function, HMI is not required, and the manual control of the equipment can be realized only when the main control board is powered on. This can facilitate the function test of control board, equipment installation and commissioning or equipment maintenance, and better realize the on-site commissioning function.

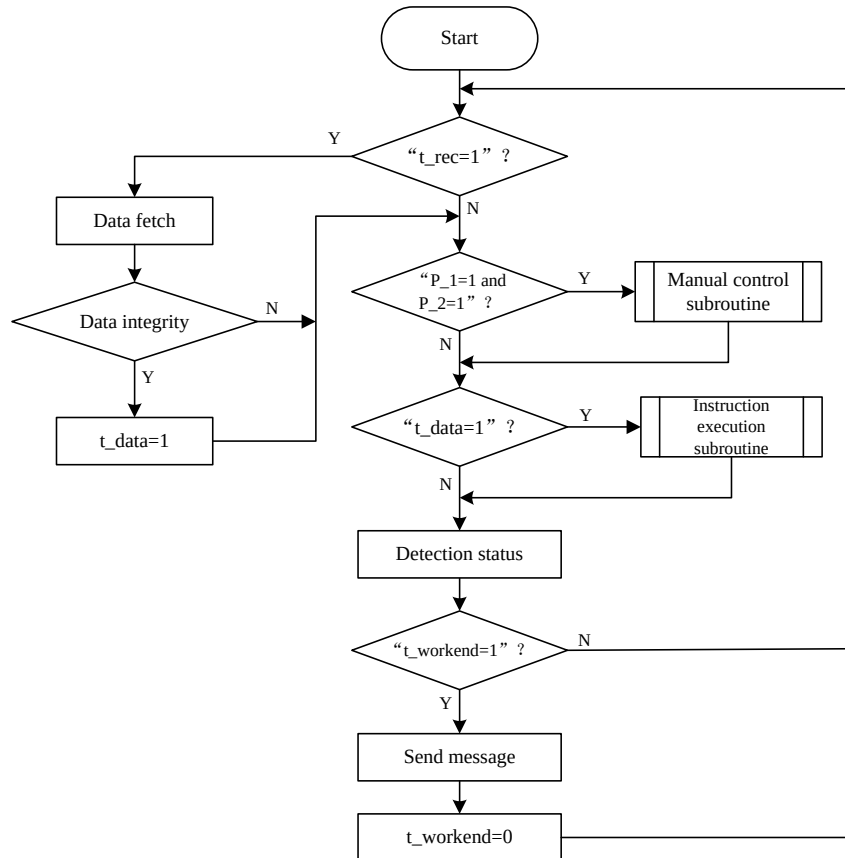


Figure 7. Automatic working flow chart of control module

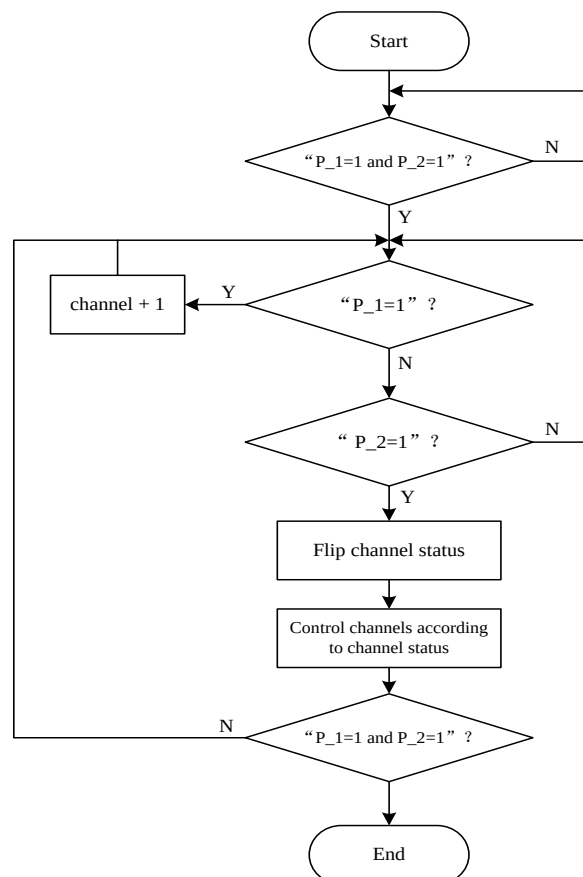


Figure 8. Manual control flow chart of control module

Figure.8 shows the manual control program flow of the control board. After the control board (control module) is powered on, if two keys are detected to be pressed at the same time, it will enter the manual control mode. In the manual control mode, if the left key is detected to be pressed, the number of operating channels will be increased by one. If the right key is detected to be pressed, the channel state will be reversed, and the channel will be controlled to open or close according to the channel state. If two keys are detected to be pressed at the same time, the manual control mode will be exited. In the above operation, three indicator lights on the control panel will display the channels controlled in the operation.

6. Internal communication-protocol

Frame header+ Address+ Instruction+ Data1+ Data2+ Data3+ Data4+ CRC16-1+CRC16-2;

Data1: Control data;

Data2--data4: Parameter;

CRC16-1, CRC16-2: Check data of CRC16;

For example: AA 01 32 01 00 00 00 F2 39. That is to say, the command requiring 1# control board to open the first channel and close other channels is issued.

7. Program-editing Code Conventions

The manual editing program setting of the setting-type programmable controller follows the following rules: edit the program according to the "three elements" of channel setting, trigger condition and waiting delay time. The agreement is as follows two conventions.

One is about working agreement. We agree on the three elements of control, namely trigger condition, delay and driving target. Any step of driving of the equipment has a trigger condition. After the condition is triggered, a delay can be set, and then the predetermined action can be driven. After this action is completed, the next condition can be triggered, and then the predetermined action can be driven after waiting for the set delay. In this way, it will start again and again until a work cycle is completed, so as to achieve the purpose of automatic work.

The other is about work description. According to the contract of work, we agree on the way of expression, that is, defining trigger conditions, then defining delay time, and then defining the target of driving, by which a driving process can be completed, thus enabling the programmatic controller to complete automatic control.

8. Program Setting Self-Learning of Controller

The setting-type programmable controller can also manually operate the controller to control the operation of the equipment, and then the controller will automatically reproduce the control process according to the process of manual operation, that is, the manually executed control process will be executed automatically.

To realize this function, the controller automatically records the manual operation process, generates the program code of the controller according to the record, and then the controller can automatically execute according to the generated code. The workflow of this process is as Figure 9.

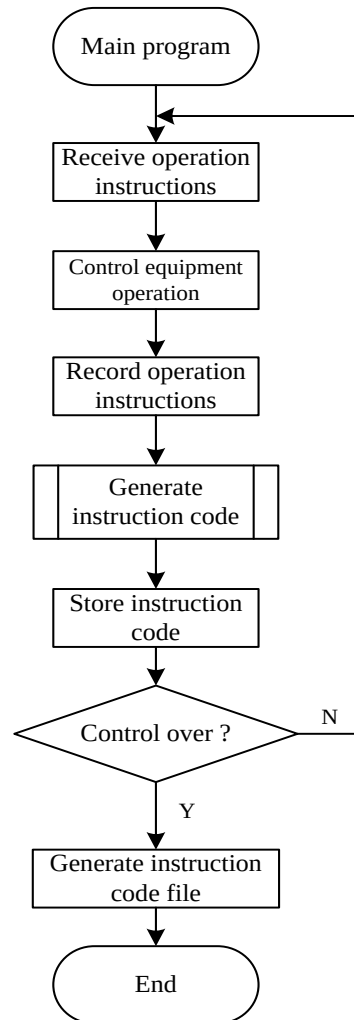


Figure 9. Setting process of self-learning

9. Conclusion

The setting-type programmable controller can meet the needs of replacing the low-cost and special auxiliary or special control equipment manufactured in labor-intensive industries. It can replace the use of PLC in automatic control equipment and reduce the industrial manufacturing cost of enterprises. It also enables the front-line mechanical operators to operate the programmable controller more conveniently and simply, so as to reduce the capital and time spent on enterprise training and reduce the cost of automatic control equipment development. The programmable serial port HMI is used as the main controller to realize human-computer interaction. RS485 or can chip is used to realize the bus communication between the internal control module and the main controller, so as to realize the functions of on-site debugging, program setting and automatic control.

The setting-type programmable controller can also increase the functions of environmental detection, personalized setting of control interface and network data exchange. If these functions are realized, the system will be more intelligent, humanized and information-based, and will be more popular.

References

- [1] Yan Gao and Chen Ye and Xin Zhuang: Design and Research of Automatic Control Production System Based on PLC Technology. *Advances in Higher Education*, vol. 4 (2020), 4-8.

- [2] Singh Harpreet Pal and Kumar Parlad: Developments in the human machine interface technologies and their applications: a review. *Journal of medical engineering & technology*, vol. 45 (2021), 21-22.
- [3] Kutsmeda, Kenneth: Commissioning on-site electrical systems. *Consulting - Specifying Engineer*, vol. 44 (2008), 30-34.
- [4] Zhejiang Holip Electronic Technology Co. Ltd: China. Patent 10,630,210 (2020).
- [5] La Xiang: Research on Key Technologies and Innovative Development of Electronic Communication System Based on Serial Communication. *Journal of Physics*, vol. 5 (2020), 52-68.