

# Design and Implementation of Ion Implantation and Deposition Signal Generator Based on PLC and Touch Screen

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**Abstract**—In order to improve ion implantation and deposition signal generator to make it more stable and convenient, take advantage of the great anti-jamming characteristic of PLC and the convenient usage of touch screen, use the pulse output and high-speed counter ability of PLC and communication ability of the touch screen, to realize the pulse output and parameter control. This device can generator two high-speed pulse (main arc pulse and the bias pulse) at the same time, enabling 4 parameters measured in microsecond, which are named the main arc pulse width, the bias arc pulse width, frequency and the delay time respectively. The final designed PLC and touch screen can work normally and have been applied to the original generator now as the source of pulse signal.

**Keywords**—signal generator; PLC; touch screen; communication

## I. BACKGROUND AND RESEARCH SIGNIFICANCE

Ion implantation technology has wide application and broad future in semiconductor manufacture and metal surface modification. As a material surface engineering technology, ion implantation has some unique advantages which some other normal technologies do not have.

- It is a pure and harmless surface treatment technology.
- It does not need heat activation, and can work without high temperature environment, so it will not change the shape size and surface smoothness of the work piece.
- The ion implantation layer is a new surface layer formed by a series of physical and chemical interactions between the ion beam and the substrate surface. There is no spalling issue between the ion implantation layer and the substrate.
- No further machine work and heat treatment needs to be done after ion implantation.

Ion implantation technology has high requirements of ion energy, pulse frequency stability, pulse width and so on, so it has strict requirements in signal control, the signal source must have high anti-jamming and reliability. And the PLC uses modern large-scale integrated circuit technology, extremely strict procedure, and advanced anti-jamming technology in its internal circuit to reach high reliability. Compared with the same scale relay contactor system, the number of wiring and switch of the control system made by PLC is reduced to one of

hundreds or even one of thousands which means the possibility of breakdown is also greatly reduced. In addition, PLC has the ability of hardware self-detection and the warning function while failure occurs. Developer can also make program to help peripheral devices realize self-diagnostic function. Therefore, PLC has very high anti-jamming and reliability. At present, PLC is widely used in industrial automation, consider its stable, safe, efficient performance in experiment and production, we hope to apply it to signal generator and realize real time monitoring.

## II. PRINCIPLE AND RESEARCH CONTENT

Ion implantation and deposition technology is an important technology in the welding surface modification research area. It can realize the vertical and uniform ion implantation and deposition on the surface of complex shaped parts, and has wide application prospects in the field of surface modification. Ion implantation and deposition signal generator is aimed at ion implantation technology, by adjusting four input factors (main arc pulse width, the bias arc pulse width, frequency and the delay time), to control the whole injection and deposition process, and ensure the integrity and efficiency of ion implantation and deposition process.

The working principle of PLC is shown as FIGURE I, the control signal is first sent through input circuit into PLC, then the internal control circuit (the user program coded according to controlled motor's requirements) does some calculations and returns the signal according to some certain algorithms, at last the signal will be specialized by output circuit and transformed into output signal by signal generator.

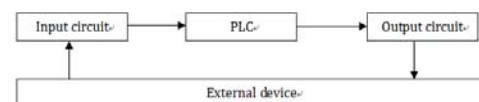


FIGURE I. WORKING PRINCIPLE OF PLC

The main research content of this article is:

- Output of pulse signal based on PLC design, and enhancement of anti-jamming and reliability of the signal generator.
- Regulate and control the signal generator (main arc pulse width, the bias arc pulse width, frequency and the

delay time) through touch screen, replace the old button control with touch screen.

### III. PLC PROGRAM AND COMMUNICATION OF TOUCH SCREEN

Considering the practical application requirements and the PLC's hardware limits, two sets of programs are formulated according to two different design ideas:

- Using PWM instructions and output two pulses, the delay time between them is realized by PLSY and high-speed counter, that is, the delay time can be controlled by counting the rising edges of wave form.
- Using PLSY instruction and high-speed counter instruction to generate pulse output, set the counting value and reset value of the counter to specify the pulse width and period of the pulse (FIGURE II), and the delay time is still following the above method.

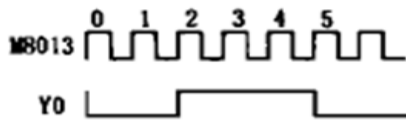


FIGURE II. ILLUSTRATION OF IMPULSE DESIGN

#### A. PLC Program and Analyze

The program can be divided into five parts, the specific flow diagram is shown in FIGURE III: the pulse output part, the delay control part, the clocker, the timer and the reset part. It can not only realize the output function of main arc pulse and bias pulse at a certain delay time, but also the time display and time setting, so that the device is more optimized

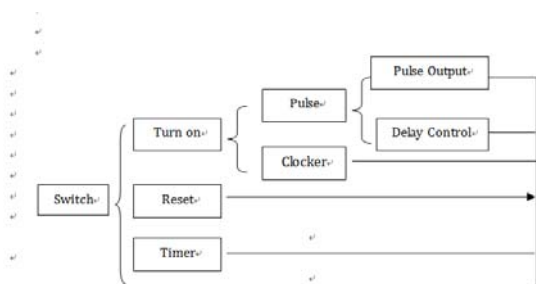


FIGURE III. PLC PROGRAM FLOW DIAGRAM

Taking program flow (FIGURE III) as an example, here we will analyze five parts respectively.

#### 1) Principle of pulse output

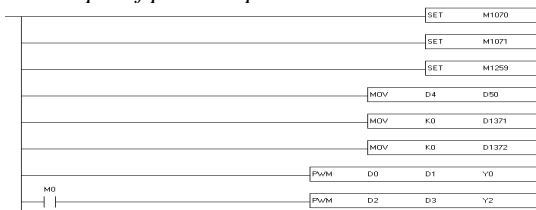


FIGURE IV. PULSE OUTPUT

FIGURE IV is part of the program design for pulse output, the pulse output part uses two PWM instructions as the main arc and bias pulse respectively, because the bias voltage outputs negative high voltage and the low level is effective, so it needs to cooperate with the special relay M1259 to do the inverting output. It needs special relays M1070, M1071 and special registers D1371, D1372 to work together to make the minimum adjustment pulse width to 10 us. The registers D0, D1, D2 and D3 get the specific parameters by reading the external communication data, and pass them to PWM as instructions, representing the main arc width, the main arc period, the bias voltage pulse width and the bias voltage cycle respectively. A relay M0 exists between the two PWM instructions, which is used for delay triggering bias pulses

#### 2) Principle of delay control

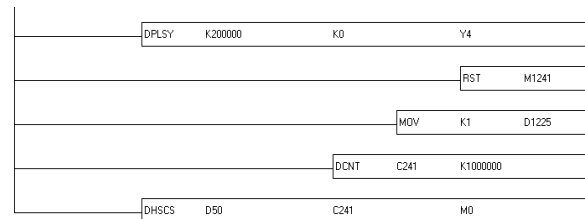


FIGURE V. PULSE DELAY

The delay part needs to work with the PLSY instructions and the high speed counter instructions, as shown in FIGURE V. PLSY is the 200 KHz high frequency pulse signal instruction with 50% duty cycle, C241 is a high speed counter with counting frequency of 200 KHz. The special register D1225 is assigned to 1, which is to set the counter as a single - phase single - input mode. The output Y4 of the PLSY is connected to the input of the C241, and each time the pulse signal reaches the rising edge, the time interval is 5 us. The pre-counting value is passed to register D50 through the external. When the number reaches the pre-counting value, M0 is closed and the bias pulse instruction is activated, the bias pulse will launch after the main arc pulse 5×D0 us.

#### 3) Principle of clocker

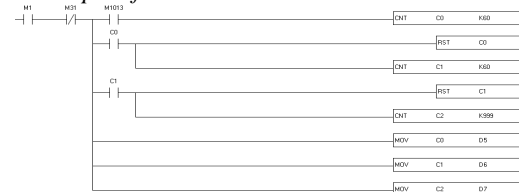


FIGURE VI. CLOCKER

As shown in FIGURE VI, the clocker uses 3 ordinary counters, C0, C1 and C2 as second, minute and hour. When the number of seconds and minutes reaches 60, both unit reset to zero and start counting again, the carry is produced and propagated to the next high-order place. In order to enable display time on the touch screen, the data of C0, C1, and C2 are moved to register D5, D6, D7 with MOV instruction.

#### 4) Principle of timer

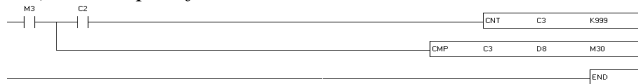


FIGURE VII. TIMER

The timer part is composed of a counter C3 and a comparison instruction CMP (FIGURE VII). C3 is used to record working hours, compared to the value of D8, M30 is closed when  $C3 < D8$ , M31 is closed when  $C3 = D8$ , and M32 is closed when  $C3 > D8$ . Therefore, a usually closed relay M31 is defined in the pulse output and timer parts, when the working time reaches the set time, pulse output and the timer stop working.

#### 5) Principle of reset



FIGURE VIII. RESET

As shown in FIGURE VIII, the reset function is used to reset all the counter of the signal generator before a new round of experiment is carried out so as to initialize the pulse and working time.

Compared with the first plan, the biggest difference in Plan 2 is the partial bias pulse output part.

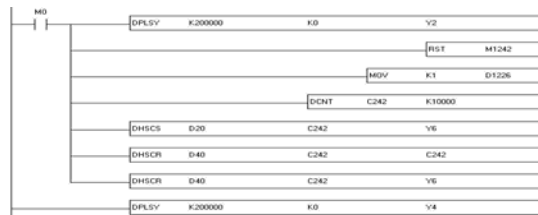


FIGURE IX. BIAS PULSE OUTPUT

As shown in FIGURE IX, connect port Y2 with counting end of high-speed counter C242 (same type of high-speed counter with C241), count one when meet a rising edge. Set comparison value (D2) of DHSCS means set pulse width of bias pulse, when the value of C242 reaches D2, the value of Y6 will change to high level from low level. Set comparison value(D2) of DHSCR means set circle of bias pulse, when the value of C242 reaches D2,the value of Y6 will change to low level from high level and continue counting loop, so as to achieve a high speed pulse output with pulse width adjustable.

#### B. Communication of Touch Screen

The communication between touch screen and PLC mainly involves three parts, serial port connection, communication protocol setting and man-machine interface design.

Serial interface is also known as serial communication interface (SCI), it is the extension interface of serial communication. The SCI has two basic ways of communication which are synchronous serial communication

and asynchronous serial communication. Asynchronous serial communication refers to the UART (Universal Asynchronous Receiver/Transmitter). The sender and receiver do not work synchronously, and both clocks do not interfere with each other and can receive and send data at any time, only to identify the start bit and stop bit. Therefore, this kind of communication devices is simple and cheap, but the transmission efficiency is low. There are mainly RS232, RS422, RS485 and other standards. The synchronous serial communication works different ways, the sender and receiver should first establish synchronization which means both clocks should work under the same frequency. The sender and receiver need to keep sending and receiving continuous synchronous bit streams. The accuracy and efficiency of data transmission is higher than that of asynchronism, but communication devices are often more complex and expensive. In the communication between PLC and touch screen, the touch screen and the PLC both support RS485's communication standard, so it just to need to connect the RS485 line from the COM of the touch screen with the PLC terminal.

Communication protocol is a system of rules that allow two or more entities of a communications system to transmit information, it make unified provision about data format, synchronization, transmission speed, transmission step, error correction method, and other problems. PLC supports many ways of communication, it only needs to choose communication standard and baud rate when communicating with touch-screen. In this paper, we choose RS485 communication standard and baud rate of 9600.

The man-machine interface design is based on the touch screen software design, it is a software bridge between the touch screen and PLC. Through the design of man-machine interface, each touching switch and data transmission point correspond to a single PLC register, so as to provide the signal transmission and build the main part of ka touching signal generator.

#### C. PLC Wiring Diagram and General Wiring Diagram

##### 1) PLC wiring diagram

FIGURE X shows 2 PLC wiring diagrams corresponding to 2 programs. In the left figure, S/S is the public port, zp0 is the low voltage, and both need to be parallel connected and ground connected. As outputs, Y0 and Y2 also need to be parallel connected and ground connected. Y4 works as counting feedback, is connected directly with counting input X0, does not need to ground connected. X3 works as the relay of C241, high voltage effective, and up0 is a high voltage point, both of them should be connected with +24V. In the right figure, Y0 and Y6 are pulse output, should be ground connected, as well as the public side. Y2 and Y4 work as the output of high speed counter, should be connected directly with the X0 and X4(counting input of C241 and C242), does not need to be ground connected. X3 and X7 are the delay of two high speed counters, high voltage effective, should be parallel connected with +24.

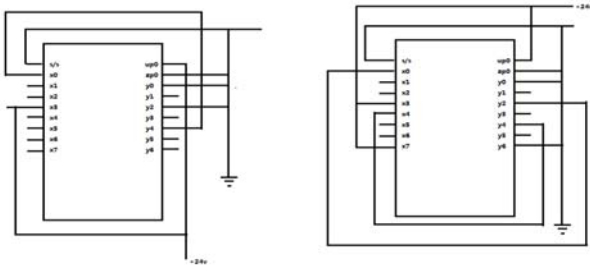


FIGURE X. PLC WIRING DIAGRAM

## 2) General wiring diagram

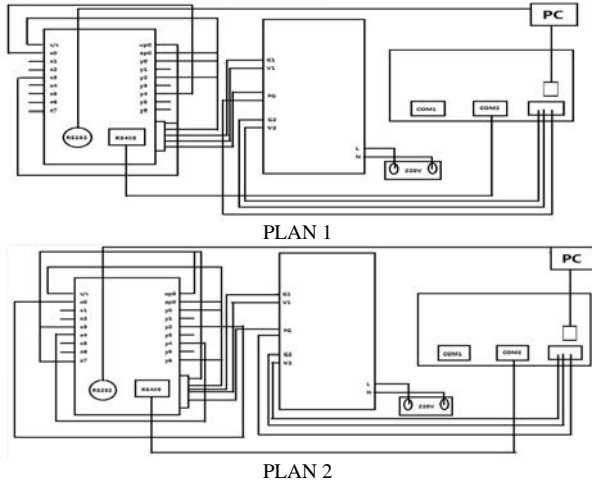


FIGURE XI. GENERAL WIRING DIAGRAM

FIGURE XI shows 2 general wiring diagrams corresponding to 2 programs, includes PLC, power supply voltage converter, touch screen, computer (from left to right), and several wires and communication lines. The interaction between PLC and computer is realized by USB-RS232 conversion line on hardware. The touch screen and computer are connected by special USB interface line. The communication between touch screen and PLC is realized by the COM2 and RS485 interface. The L and N terminals of the power supply voltage converter are connected to the 220 V zero line and the live wire respectively. G1 and V1 represent the ground wire and the +24 V, and connected with the corresponding end of PLC. G2 and V2 are also connected with the corresponding end of the touch screen. FG is also a ground line. Unlike the G, the FG requires connected to the earth, and the G is DC output grounding.

To detect waveform after the communication between PLC and touch screen works. The parameters are set as follows: frequency 200 Hz, main pulse width 1000us, high voltage pulse width 20us, and delay time 600 us. Connect output terminal of PLC with the oscillograph, transform the waveform into data file by WaveAnalysis, and use Origin to draw the waveform as FIGURE XII, which proves that the signal generator can work normally.

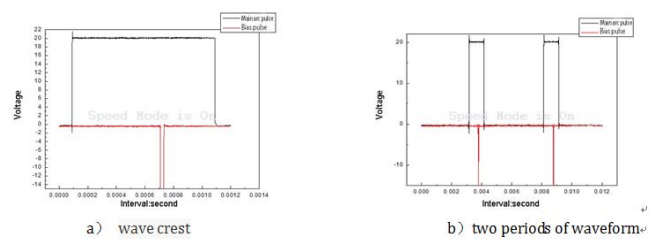


FIGURE XII. WAVEFORM OF SIGNAL GENERATOR

## IV. CONCLUSION

Use PWM (adjustable pulse width output) instruction, output two pulses, the delay time between them is realized by PLSY (continuous execution pulse output) and high-speed counter, that is to control the delay time by counting the number of rising edges. It has the advantages of simple programming, directly applying pulse to output instruction, without other complex instructions, and reduces the error caused by the software operation. However, the precision of pulse width adjustment is only 10 us, and more fine adjustment width is often needed in some ion implantation and deposition experiments.

We use PLSY instruction and high-speed counter instruction to generate pulse output. We set pulse value and reset value of the counter to set pulse width and period, and delay time is still following the above method. The advantage is that the precision of pulse width reaches 5 us, which can satisfy most of the ion implantation deposition experiments. However, the drawback is that the transmitting pulse is complicated, needs more instructions and calculations, which may cause greater computation error.

The two plans finally realize the function of independent output of two pulse signals separated by a certain delay time, and the range of parameter adjustment reaches the predetermined target.

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