Design of High-voltage Electrostatic Generator Based on STM32

Fan-xue KONG(孔凡雪), Shi-guang LI(李世光), Zheng-zhong GAO(高正中),
Xiang-bin LIN(蔺相斌), Hong-wei ZHANG(张洪薇)
(*College of Information and Electrical Engineering*, *Shandong University of Science and Technology*, *Qingdao* 266510, *China*)

Abstract – **This paper introduced a high-precision high-voltage electrostatic generator which utilized STM32F103 as the main controller. The hardware and software design of the system were detailed. The full use of ample on-chip resources of STM32F103, such as ADC and the PWM output of timer, contributed to the small size and low cost of the system. The 16-bit PWM signals, generated by the timer on chip, served to adjust the output voltage accurately. The touch screen was responsible for the setting and display of output voltage, and the friendly human-computer interaction was built. Experimental results indicated that this high-voltage static generator was of high precision and great practicability for application.**

Key words – ***STM32F103; high-voltage static generator; voltage multiplying rectifier***

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1 Introduction

With the development of research, the high-voltage electrostatic technology[1] has been already widely applied in many fields such as electric precipitation, electrostatic spraying, electrostatic flocking, electrostatic separation and so on. Meanwhile, the implementation of the national compulsory certification system attaches extraordinary status to electromagnetic compatibility tests. The electrostatic discharge immunity as one of the most important electromagnetic compatibility tests has caught more people's attentions. As requirements for antistatic property of electronic products are being increased step by step, to develop a high-performance electrostatic generator is of great importance. The high-voltage electrostatic generator proposed in this paper has practical application value.

The high-voltage electrostatic generator utilizes the 32-bit processor STM32F103 made by STMicroelectronics as the main controller. This system makes full use of the ample on-chip resources of STM32F103 including timer's 16-bit PWM output[2], A/D converter, serial communication interface, etc, for the real-time monitoring of the high-voltage electrostatic output. The whole design scheme is shown in Fig.1.

The closed-loop control is employed. Firstly, the high-voltage output is sampled by the resistive voltage divider and then serves as the input of A/D converter, after which the data acquisition is realized. Afterwards, STM32F103 compares the converted results with the set value, and adjusts the duty cycle of PWM signals continually until the high-voltage output accesses the set voltage and keeps stable.

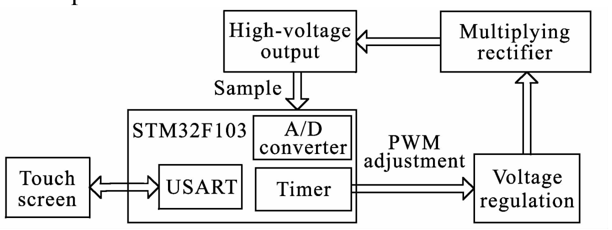

Fig.1 Block diagram of whole design scheme

The range of output voltage is from 0 to 30 kV and the output value can be set by the touch screen, which communicates with the main controller using the MODBUS protocol via the RS-485 interface.

2 STM32 resources on chip

STM32F103 incorporates the high-performance ARM Cortex-M3 32-bit RISC core and is rather suitable for a wide range of applications.

The ADC of STM32 F103 is a successive approximation analog-digital converter with 12-bit resolution, and provides several modes including single mode, continuous mode, scan mode and discontinuous mode for each channel. This system uses the continuous regular mode. Considering that conversion results of channels are stored in a unique data register in regular mode, it is necessary to use DMA[3] for data transmission, which effectively prevents data loss. Data can be quickly transmitted from the ADC data register to RAM by DMA without intervention of CPU.

The PWM mode of timer can generate a signal with the frequency determined by the register TIM_ARR and the duty cycle determined by the register TIM_CCRx. Firstly, set the clock frequency for timer, the count modes and the output polarity, enable the PWM output, and then start the timer so that the PWM signal can be generated. This system uses of the timer T1 to generate four 20 kHz signals and the duty cycles can be adjust by changing the value of TIMx_CCRx.

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Corresponding author: Fan-xue KONG(kongxue-0104@163.com)

3 Hardware design

The hardware proportion of this high-voltage electrostatic generator consists of voltage acquisition circuit, voltage multiplying rectifier, RS-485 communication interface, etc. To strengthen the electromagnetic compatibility, a great many of measures are taken such as the corresponding TVS diodes and decoupling capacitors attached to the power terminals, and isolation between the analog ground and the digital ground. The control information can be input from touch screen which contributes to the friendly human-computer interface, and the convenient and prompt operation.

3.1 Voltage acquisition circuit

The voltage acquisition circuit consists of the voltage follower built by the LM358 and the first order filter circuit.

Firstly, the high-voltage output is sampled by the resistance voltage divider. To improve the property of the resistor divider circuit, the circuit inductance and stray capacitance effects are fully taken into account so that resistors of smaller parasitic inductances are chosen and the current is calibrated. The voltage follower[4] plays the role of impedance matching to improve the input impedance. The first order low-pass filter serves to filter out the high-frequency noise of the signal. Then the filtered voltage signal comes into the A/D converter of STM32. The circuit of voltage acquisition is shown in Fig. 2.

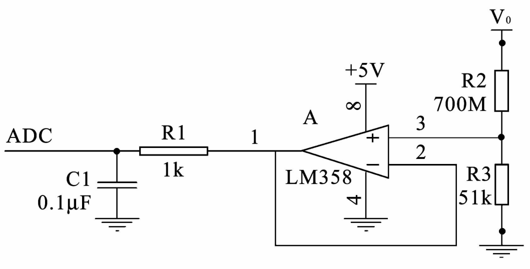

Fig. 2 Voltage acquisition circuit

3.2 Voltage multiplying rectifier

Considering that the output voltage is high but the output current is small, this paper adopts the multiplying rectifier as shown in Fig. 3. This circuit only uses several diodes and capacitors to obtain the high-voltage output that is several times as much as the secondary voltage of the transformer. The circuit is of simple structure and low cost.

The timer *T*1 of STM32 is configured as the PWM mode to generate the 16-bit PWM signal, of which the frequency is fixed and the duty cycle is adjustable. PWM signals control the conductions of two *N*-channel MOSFETs at two different half-cycles in order to realize the high-frequency invertion after which an adjustable high-

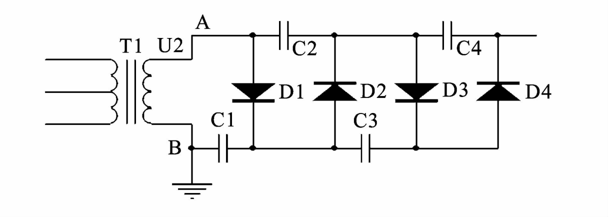

Fig. 3 Voltage multiplying rectifier

frequency voltage can be got. The dead-time control guarantees that two power switches shall not turn on at the same time. This system uses the timer T1 to generate the 20 kHz PWM signals, and the dead-time is set to 5 milliseconds according to experimental results.

The high-frequency output of the transformer secondary winding is $U_2 = 0 \sim 7$ kV(peak value). The output of multiplying rectifier can be up to 30 kV. The reverse voltages of rectifier diodes D1～D4 and capacitors C2～C4 are 2U2 while the reverse voltage of capacitor C1 is U2. The multiplying rectifier uses the fast recovery rectifier diode 2CL2FM, which maximum reverse voltage is 20 kV higher than 2U2. And the high-voltage porcelain capacitors are utilized. The withstand voltages of C2～C4 are 25 kV, and the withstand voltage of C1 is 15 kV, all of which are more than 1.5 times of their actual voltages. In addition, the voltage multiplying rectifier is packaged with epoxy resin for good insulation.

3.3 RS-485 communication interface

The four-wire resistive touch screen AMT9532 responsible for the setting and display of output voltage is used for friendly human-computer interaction. AMT9532 exchanges data with STM32 via the RS-485 interface, which fits to long-distance, low-cost and high-speed data transmission. This system uses the isolated RS-485 transceiver ADM2483 which maximum transmission rate is up to 500Kbps. ADM2483 uses the slew-rate-limited driver, and the low slew rate helps to reduce the inappropriate terminal matching. The receiver input has a real failure protection. ADM2483′s driver can limit the short-circuit current and the thermal shutdown circuitry can set the output as high resistance state to avoid excessive power loss.

4 Software design

The system software design is based on the high-performance ARM development environment Realview MDK[5] recently launched by Embest and ARM. The software includes the main program, the data acquisition and processing program, and the serial communication program.

The main program works to finish the configuration of clocks, GPIO ports and nested interrupts, and the initialization of timers, ADC and serial communication. The abnormal operating protection in software serves to prevent the destruction of circuit components due to high-voltage discharge. Moreover, only the clocks of peripherals used in this design are enabled in order to reduce power consumption. Meanwhile, the clock security system can enhance the reliability of the system. When the external clock is lost, system clock is automatically switched to the internal clock. In addition, the independent watchdog prevents program fleet effectively.

As shown in Fig.4, the data acquisition and processing program consists of A/D conversion, digital filtering and PWM adjustment. The A/D conversion uses the continuous conversion mode. The moving average filter realizes the digital filtering. Then, the filtered voltage is compared with the set value and STM32 adjusts the duty cycle of PWM signals continually until the high-voltage output accesses the set voltage.

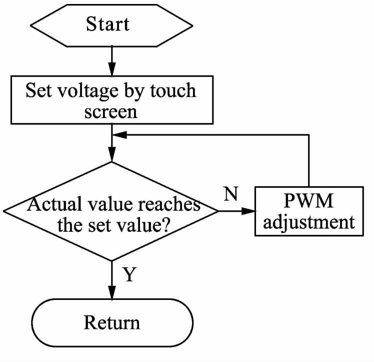

Fig.4 Data acquisition and processing

The serial communication program is responsible for the communication between the controller STM32 and the human-machine interface. Receiving the data from touch screen, STM32 enters the interrupt service program, and then judges the received data, such as effective data length, CRC check. If the data is correct, the output voltage is set correspondingly, and then STM32 sends answer-back signal to touch screen. CRC check of MODBUS[6] heightens the security of communication, decreases the error rate significantly and improves the efficiency of code execution greatly.

5 Experimental tests

This high-voltage electrostatic generator has been implemented successfully and then made performance test after aging test for a long time. Some experimental results are shown in Tab.1.

The results showed that the maximum output of the high-voltage electrostatic generator was 29.84 kV, and the output voltage could be conveniently set as 0～30kV by the touch screen. This electrostatic generator exhibited high performance with precision superior to 1% and ripple factor less than 4%.

Tab.1 Experimental results

Voltage		Error(%)
Set value(kV)	Actual value(kV)	
5.00	4.98	0.40
10.00	9.95	0.50
15.00	14.92	0.53
20.00	19.93	0.35
25.00	24.86	0.56
30.00	29.80	0.67

6 Conclusion

This paper introduced the design of high-voltage electrostatic generator using low-power, high-performance ARM chips STM32F103 as the main controller. This system made full use of the ample on-chip resources of STM32F103 such as the timer's 16-bit PWM output, A/D converter, the serial communication interface, etc, to reduce the volume and hardware cost and performed low power consumption and high reliability. The 16-bit PWM signal of timer on chip as the control signal improved the accuracy of output voltage. As the application of electrostatic technology further expands, this high-voltage electrostatic generator based on STM32 will have greater practical value and market prospect.

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