Study and Realization of Auto Testing Device for Protection Against Electric Shock

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Abstract: In this paper, the microcontroller STM32F407 is used as the control core. The automatic detection device for protection against electric shock is designed and produced. The mechanism and characteristics of residual energy which is generated by the power cut-off at peak voltage are analyzed. This study has accomplished the design of peak voltage power cut-off and residual energy measurement system, software programming and hardware circuit construction, and displaying residual voltage and residual energy value through the touch screen. The device has stable performance and simple operation, and can accurately detect the residual voltage and energy value of electronic, electrical equipment and medical equipment. It has great significance for testing institutions and enterprises.

1. Introduction

The electrical and electronic equipment maintains a certain voltage for a certain period of time after the power cut-off at peak voltage. The remaining energy is generated by the residual voltage discharging. Due to the existence of energy storage devices in the power supply system of the equipment, such as capacitors and inductor materials, when the electrical equipment is powered off, the stored electrical energy in the power supply system would be released through its own circuit [1]. If the capacity of the energy storage device is large enough and the resistance of the release circuit is much larger than the resistance of the human body, it may cause an electric shock and pose a potential hazard. Therefore, it is particularly important to develop a detection device that can measuring the residual energy of the power outage at peak value.

2. Overview of domestic and foreign research and existing problems

Foreign engineers have been using the oscilloscope test method to measure the residual voltage. In the early tests, it was found that the manually plugging and unplugging would cause great deviation. And the sudden unplugging of the power plug would generate strong spark interference when the equipment under testing was turned on. Many safety laboratories made the unplugging tool to work with the oscilloscope to detect the remaining voltage.

In the domestic market, there are some power cut-off devices which can be used in combination with the oscilloscope, but they are limited to a fixed frequency of 50 Hz and 60 Hz. These devices require the operator judging the power supply frequency of the electrical equipment and manually selecting the frequency point firstly, and then the device can cut the power off at peak voltage [2]. This method has great limitations. It can only perform the power cut-off action, but the remaining energy after the power cut-off cannot be measured. The ability to balance the residual energy test is only in the theoretical research, and no mature detection device has been developed in the market.

At present, some laboratories use the plug of the power plug to disconnect the power supply. The digital multimeter and even the pointer meter are used to measure the residual voltage between the plugs. In addition, the laboratory uses a storage oscilloscope to record the residual voltage. To ensuring the safety of the inspector, a floating oscilloscope or an isolation transformer is required to power up the oscilloscope or sample.This test method is too random, and the test results would be deviated. The test usually needs to be repeated several times to obtain the test data close to the power cut-off at peak voltage. In addition, reading the residual voltage value from the oscilloscope screen is not affected by many factors such as burrs.

3. Introduction

The automatic detection device for protection against electric shock mainly includes four parts: voltage measurement module, peak voltage power off module, energy measurement module and the display module. The voltage measurement module measures the voltage of the power supply, and then passes it to the peak voltage power-off module to notify the electric relay to be powered off after the AC voltage reaches a peak value. The test circuit is used to test the residual voltage and finally display it via the liquid crystal display module.

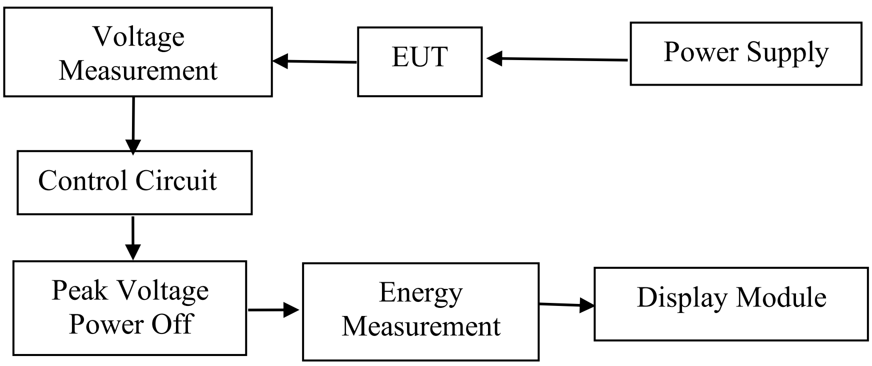

Figure 1. Automatic detection device design block diagram

4. Device composition

The detection device is mainly composed of STM32F407 microcontroller, AD converter AD7606, isolation and signal conditioning circuit, detection control circuit, liquid crystal display and control button, and RS485 and USB communication interface, as shown in Figure 2 [3].

As the control core of the detection device, STM32F407 microcontroller is used to realize the initialization of AD7606, liquid crystal display and USB interface. It is also used to control the detection, acquisition, storage and operational processing of related data [2]. In this design, it is used to realize the collection of the power supply voltage of the device under test and the discharge voltage and current data after the peak voltage power cut-off. The STM32F407 collects the power supply voltage of the device under test by controlling the AD7606, detects the positive zero-crossing point, and sets the peak voltage power-off time according to the time difference between the positive zero-crossing point and the peak value, and the electric relay action delay time of the detection control circuit. At the peak voltage power-off time, the power supply of the device under test is disconnected by the control detection control circuit, and the AD7606 is controlled to collect the discharge voltage and current data of the device under test. The residual energy of the tested equipment after power cut-off at peak voltage is obtained by integral calculation of discharge voltage and current data [4].

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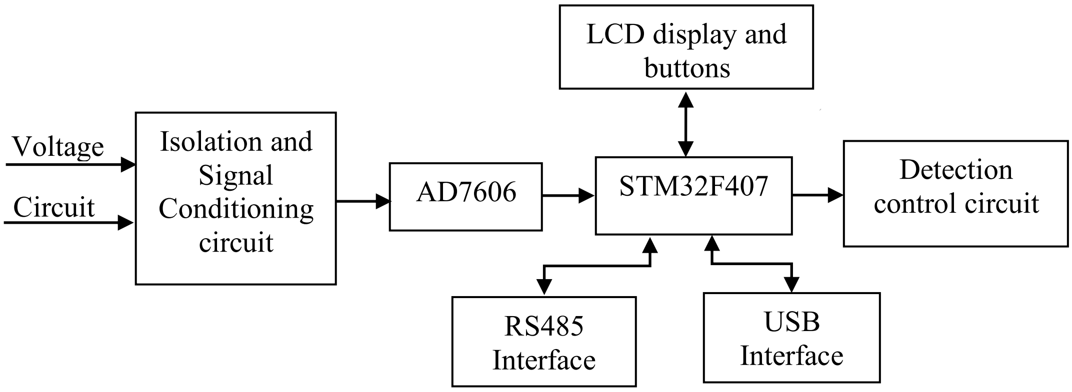

Figure 2. Structure of Detection device

4.1. *Hardware circuit design*

The main functions of the signal isolation and conditioning circuit are isolating the singnal and signal conditioning. On the one hand, it can fulfil the isolation of the measured voltage and current intensity signals between the internal signal acquisition and processing circuit implemented within the device; and on the other hand, it can adjust the signals of power supply voltage , the discharge voltage and current from EUT to match the signal input range requirement of the AD7606 and achieve anti-aliasing filtering. Signal isolation is achieved by the AMC1301, a high-precision isolated amplifier that isolates the output and input circuitry through an isolation barrier with high magnetic field immunity. The barrier provides enhanced galvanic isolation up to 7kV PEAK.See Figure 3 below.

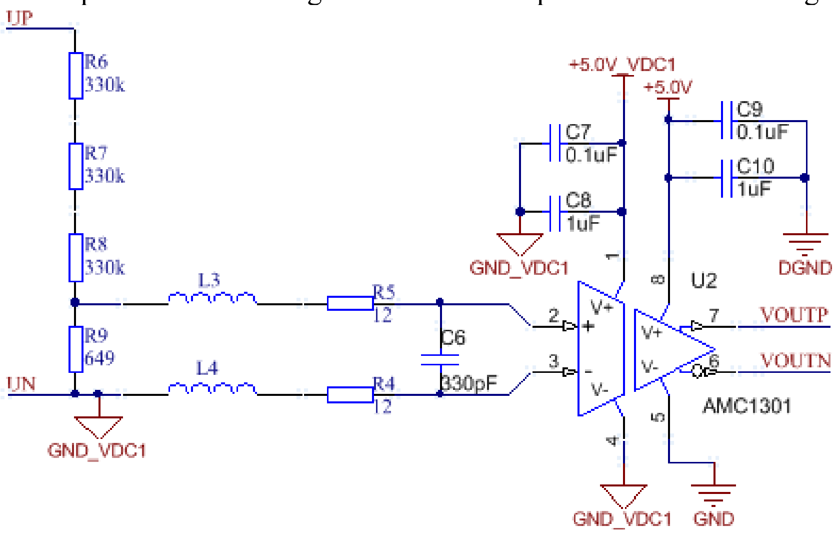

Figure 3. Voltage channel based on AMC1301

4.2. *Software process design*

The voltage value of the power supply is calculated by the voltage measuring circuit. When the voltage reaches the peak value, the control circuit notifies the relay to disconnect the power supply, and then the sampling circuit module performs voltage sampling. STM32 collects the voltage value and the timer is 1s [3]. Sampling is controlled by determining whether the timer is high-level or not. When the timer is 1s, the sampling is stopped, and the residual energy value is tested by the energy measurement module [4]. The shorter the sampling time is set, the more accurate it is. The peak power down and energy test software flow chart are shown in Figures 4 and 5.

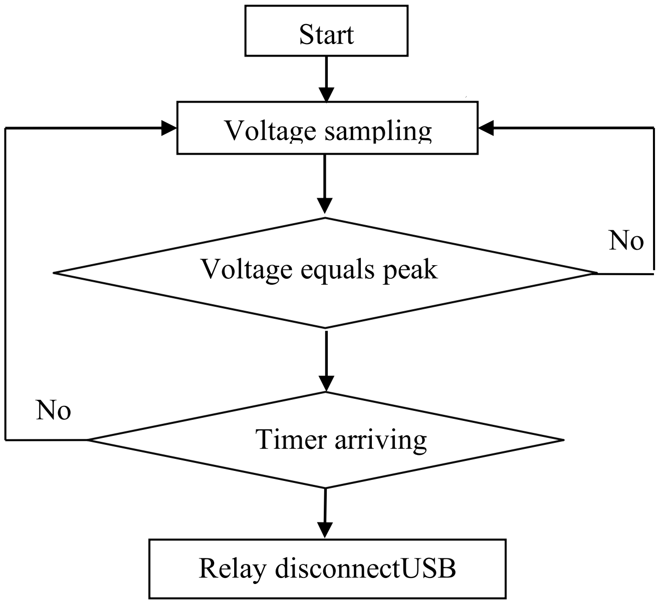

Figure4. Flow chart of Peak power down software

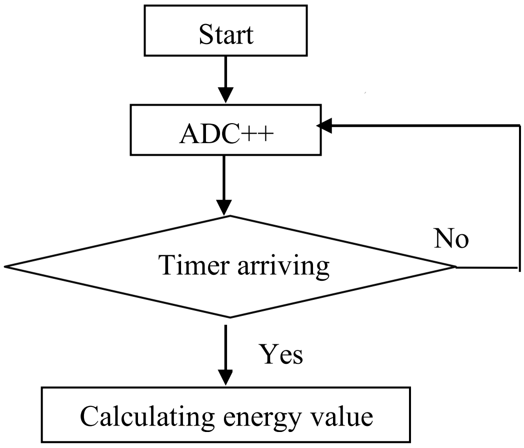

Figure 5. Flow chart for Energy test software

5. Test results

5.1. Test connection diagram

Before the test, the EUT is powered on and warmed up for half an hour. Then, connect the automatic detection device for protection against electric shock with the EUT according to the following figure, and connect the power supply end of the EUT to the power output socket of the automatic detection device, as shown in Figure 6.

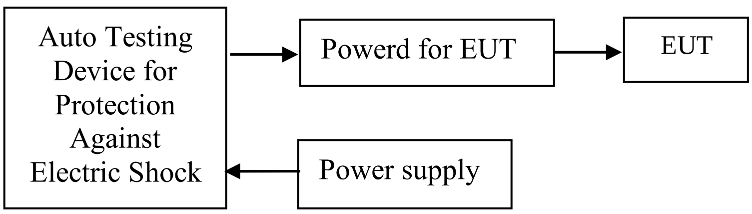

Figure 6. System test block diagram

5.2. *Test result chart*

Connect the automatic detection device for protection against electric shock to the power supply. The EUT's power input terminal is connected to the single-phase variable frequency power supply. The power supply of the EUT is connected to the output socket of the device, then pressing the device's button to turn on the power and the device is powered on. That is, the peak voltage value of discharge, the voltage value after 1s of discharge, and the residual energy after 1s of discharge are displayed. Moreover, the peak voltage value of discharge, the voltage value after 2s of discharge, and the residual energy after 2s of discharge would be displayed [5]. See Figure 7 and Figure 8 below.

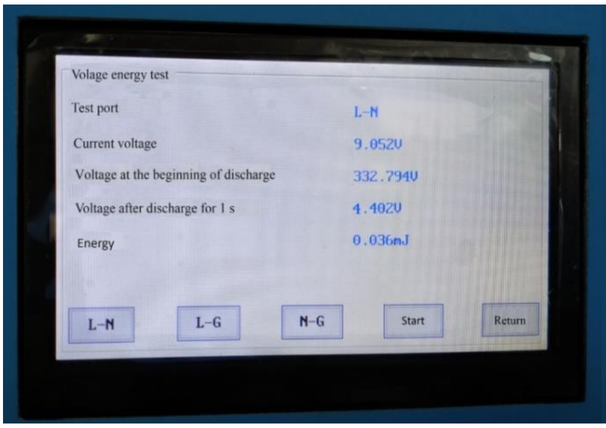

Figure 7. Test result after 1s

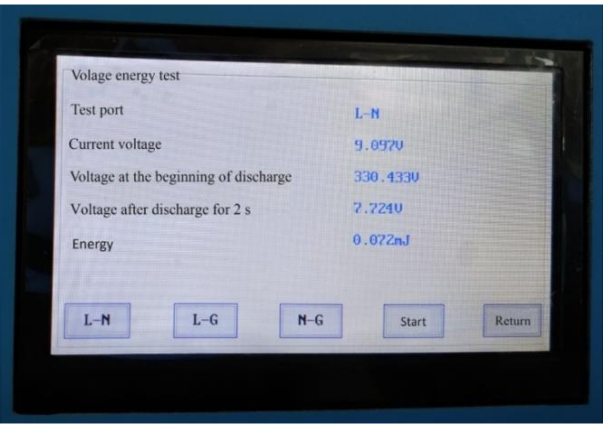

Figure 8. Test result after 2s

5.3. *Test Data*

According to the standard GB4943.1-2011 Information technology equipment—Safety Part 1: General Requirements, a printer, a microcomputers and a liquid crystal display is selected as representative samples for testing. The results are as follows:

Table 1. Information technology equipment test data

Serial number	Product name	Voltage after 1s（V）	Residual energy after 1s（mJ）
One	Printer	4.402	0.036
Two	Microcomputer	4.917	0.039
Three	LCD Monitor	6.941	0.098

According to the standard GB8898-2011 Audio, video and similar electronic apparatus—Safety requirements, an active speaker, a LCD TV and a digital video recorder is selected as representative samples for testing. The results are as follows:

Table 2. Audio and video equipment test data

Serial number	Product name	Voltage after 2s（V）	Residual energy after 2s（mJ）
One	Active speaker	4.175	0.064
Two	LCD TV	7.724	0.072
Three	DVR	5.117	0.085

According to the standard GB4706.1-2005 Household and similar electrical appliances—Safty Part 1: Gerneral requirements, a washing machine, an electric fan and an electric kettle is selected as representative samples for testing. The results are as follows:

Table 3. Household appliance equipment test data

Serial number	Product name	Voltage after 1s（V）	Residual energy after 1s（mJ）
One	Washing machine	4.002	0.201
Two	Electric fan	2.636	0.298
Three	Electric kettle	2.228	0.087

According to the standard GB9706.1-2007 Medical electrical equipment—Part 1：General requirements for safety, a ultrasonic therapy device, a non-contact tonometer and an osteoporosis treatment system is selected as representative samples for testing. The results are as follows:

Table 4. Medical device equipment test data

Serialnumber	Product name	Voltage after 1s（V）	Residual energy after 1s（mJ）
One	Ultrasound therapy device	1.102	0.055
Two	Non-contact tonometer	2.053	0.098
Three	Osteoporosis treatment system	4.089	0.143

6. Conclusion

This paper presents the domestic and foreign research status, working principle diagram, hardware and software design and test results of the electric shock protection device [5]. The device can be developed to fulfil the peak voltage power cut-off energy analysis of various types of electrical appliances such as household electrical equipment, medical equipment, information technology equipment, audio and video apparatus, etc. and address the safety standards for the control of the residual voltage after peak voltage power off [6]. It not only can be used as a quality inspection department for testing, as well as for the factory inspection of production enterprises, providing technical support for the laboratory to carry out relevant tests, but also can provide design guidance for enterprise research and development.

References

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