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Design of a Discharge Output Assembly for Blasting Controllers with Automatic High-Voltage Detection

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Abstract

Aiming at the industrial pain points that traditional blasting control equipment lacks an independent discharge output assembly and multi-channel delay initiators are short of core supporting modules, a discharge output assembly for blasting controllers with automatic high-voltage detection adapted to multi-channel delay initiators was designed. The assembly adopts a modular architecture, consisting of an output voltage circuit, a comparison and detection circuit, a dual-channel assembly interface and a discharge control unit, and is powered by a lithium battery. It can realize accurate automatic detection and real-time feedback of the discharge voltage of high-voltage capacitors as well as precise control of discharge on-off. This assembly fills the market gap, solves the problems of no voltage detection, no state feedback and poor stability of traditional circuits, and is convenient for production, installation and maintenance. It can significantly improve the discharge stability of blasting controllers, provide core technical support for the marketization of multi-channel delay initiators, and has prominent engineering application value.

Keywords

Blasting Controller; Discharge Output Assembly; Automatic High-Voltage Detection; Modular Design; Multi-Channel Delay Initiator; High-Voltage Capacitor.

1. Introduction

Blasting technology is widely used in mining, civil engineering and other fields. As the core control equipment, the initiator's accuracy and stability directly determine the safety and efficiency of blasting operations[2]. At present, traditional initiators adopt an integrated structure without an independent discharge output assembly module, and the discharge control circuit is highly integrated with other circuits. There is no real-time automatic detection and feedback mechanism for the voltage of high-voltage capacitors, which is prone to mis-discharge and discharge failure[3]. In addition, the control stability is poor due to high-voltage impact.

With the increasing demand for multi-channel delay initiation in engineering blasting, multi-channel delay initiators have become the core direction of market development. Their research, development and promotion are in urgent need of an independent, stable and highly adaptable discharge control supporting module. Therefore, an independently modular discharge output assembly for blasting controllers with automatic high-voltage detection was designed in this paper[1]. Integrating automatic high-voltage detection, state feedback and precise discharge control, and taking into account engineering practicability, the assembly fills the market gap and provides key technical support for the marketization of multi-channel delay initiators.

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2. Overall Structure Design

The discharge output assembly with automatic high-voltage detection designed in this paper is a core supporting module for multi-channel delay initiators. With the design objectives of accurate automatic detection, real-time feedback of high-voltage capacitor voltage and precise discharge control, it adopts an independent modular architecture, composed of an output voltage circuit, a comparison and detection circuit, an assembly interface and a discharge control unit, and works in coordination with lithium batteries, high-voltage capacitors and the control assembly.

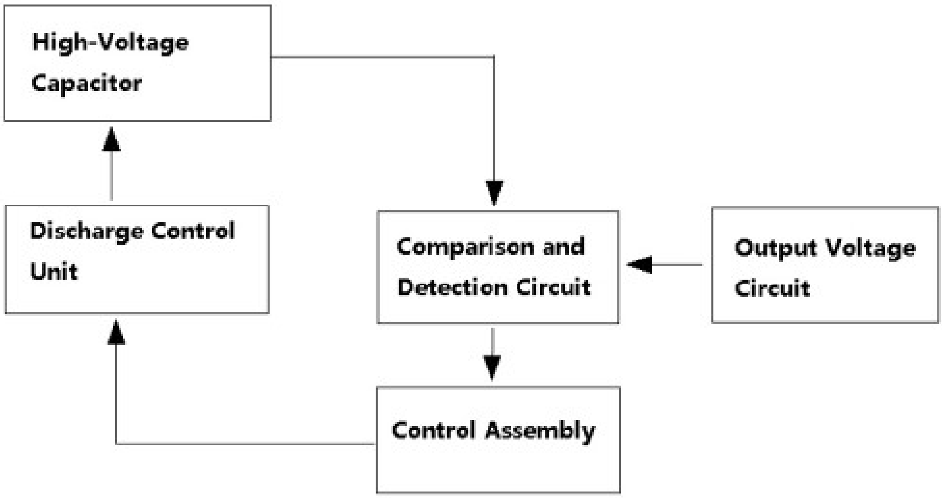

Figure 1. Overall structural block diagram of the discharge output assembly

The core functions and connection relationships of each module are as follows: ① The output voltage circuit is connected to the lithium battery to provide a precise and stable reference comparison voltage for the operational amplifier (op-amp) IC of the comparison and detection circuit; ②The comparison and detection circuit adopts a multi-branch parallel structure, with a single branch independently monitoring the voltage of one high-voltage capacitor to realize real-time and synchronous automatic detection of multiple channels[4]; ③The assembly interface is divided into the first and the second interface, the first interface feeds back the automatic detection results to the control assembly, and the second interface receives the discharge control signal from the control assembly; ④The discharge control unit is a multi-branch structure, corresponding to the detection circuit one by one, with a single branch connected to one high-voltage capacitor to realize precise on-off control of the discharge loop.

The assembly follows a closed-loop control process of reference generation - automatic voltage detection - signal feedback - precise discharge: the output voltage circuit generates a reference voltage, and the detection circuit compares the actual voltage of the high-voltage capacitor with the reference voltage. When the threshold is reached, the result is fed back to the control assembly through the first interface; the control assembly sends a discharge signal to the discharge control unit through the second interface to connect the corresponding high-voltage capacitor for discharge; if the threshold is not reached, the circuit remains disconnected to avoid invalid discharge. The multi-branch structure can be directly adapted to multi-channel delay initiators to realize independent automatic detection and delay discharge of each branch.

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3. Modular Design of Hardware Circuit

The assembly adopts a fully modular hardware circuit design, with each functional circuit independently modularized and the interface standardized. It not only ensures working stability, but also reduces the difficulty of production, installation and maintenance, meeting the industrialization demand.

3.1 Output Voltage Circuit

The output voltage circuit is an independent reference voltage module, and its circuit structure is shown in Figure 2, which is composed of a voltage reference IC U3 (AMS1117-5.0), voltage stabilizing and filtering capacitors (C4, C5, C6) and precision step-down resistors (R13=5KΩ, R9=1KΩ).

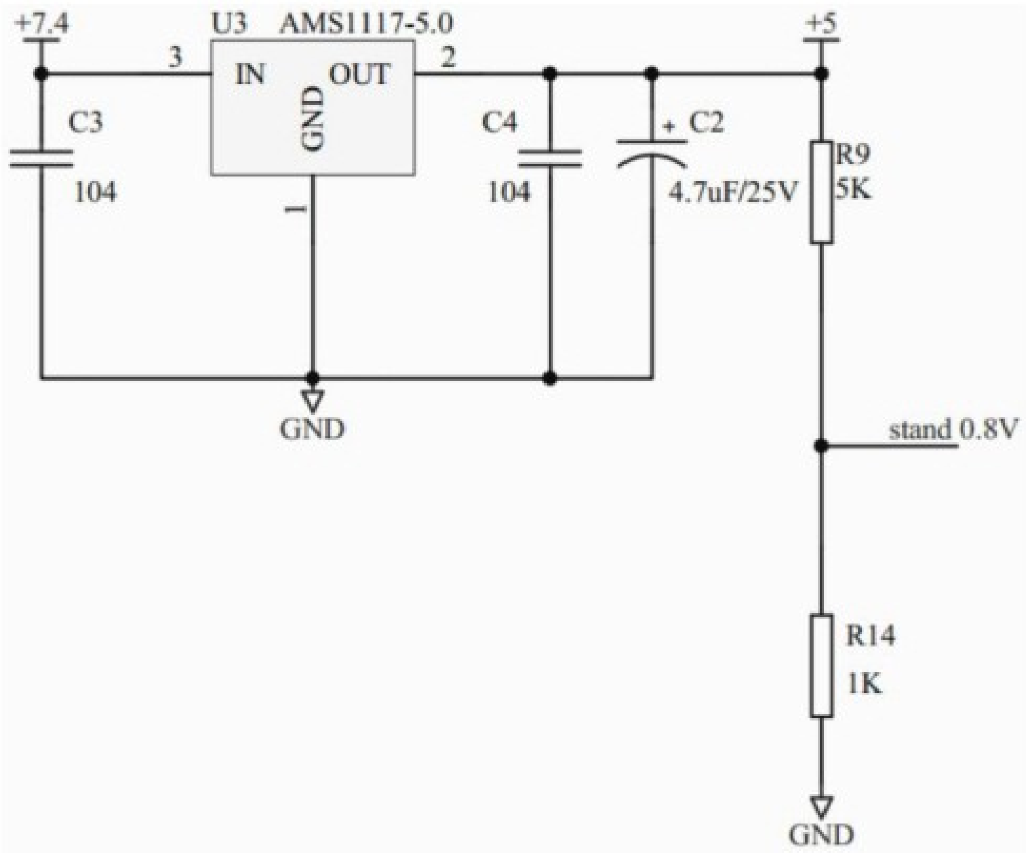

Figure 2. Circuit structure of the output voltage circuit

The 7.4V lithium battery supplies power to U3, the IN pin is grounded through C4 to suppress voltage fluctuation, and the OUT pin outputs a stable 5V voltage. After parallel filtering by C5 and C6, a precise 0.8V reference comparison voltage is generated through two-stage voltage division of R13 and R9, which is transmitted to the input end of the op-amp IC of the comparison and detection circuit. The module is independently modularized and can be produced and debugged separately, ensuring the stability of the reference voltage and the accuracy of automatic detection.

3.2 Comparison and Detection Circuit

As the core automatic detection module, the comparison and detection circuit adopts a multi-branch parallel structure, and the circuit structure of a single branch is shown in Figure 3.

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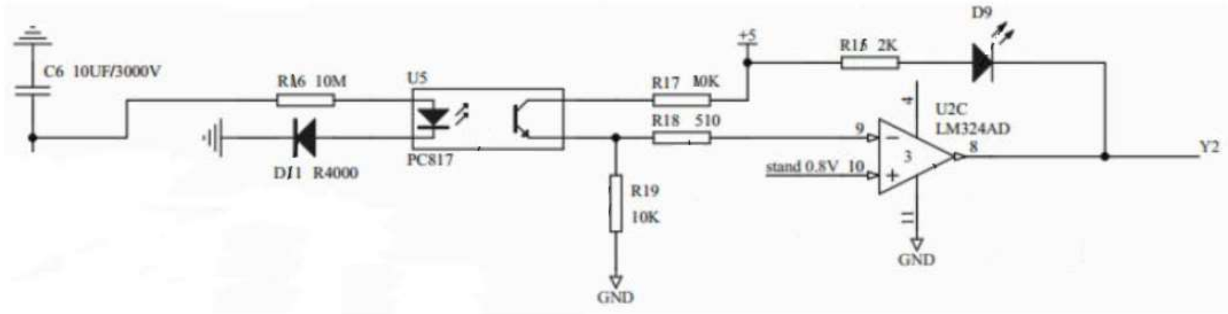

Figure 3. Circuit structure of a single branch of the comparison and detection circuit

It is composed of an operational amplifier, modulation resistors, protection resistors, a light-emitting diode (LED), an optocoupler isolator (PC817), a first high-voltage diode and a voltage divider resistor, and the number of branches can be flexibly increased or decreased as needed.

The positive input end of the op-amp is connected to the 0.8V reference voltage, and the negative input end is connected to the positive pole of the high-voltage capacitor through the second modulation resistor, optocoupler isolator and second protection resistor to complete automatic voltage detection through real-time comparison. The optocoupler isolator realizes electrical isolation between high and low voltage to eliminate high-voltage interference[5]; the first high-voltage diode prevents current backflow to protect core devices. Each branch is equipped with a state indicator: 5V DC is connected to the op-amp output end through the first modulation resistor, first protection resistor and LED. The diode lights up when the voltage reaches the standard, and goes out when the voltage does not reach the standard, facilitating on-site debugging. In this design, the first protection resistor is 2KΩ, the first modulation resistor is 10KΩ, the second modulation resistor is 51Ω, and the voltage divider resistor realizes voltage adaptation of the op-amp IC. The branches can be replaced independently, reducing maintenance costs.

3.3 Discharge Control Unit

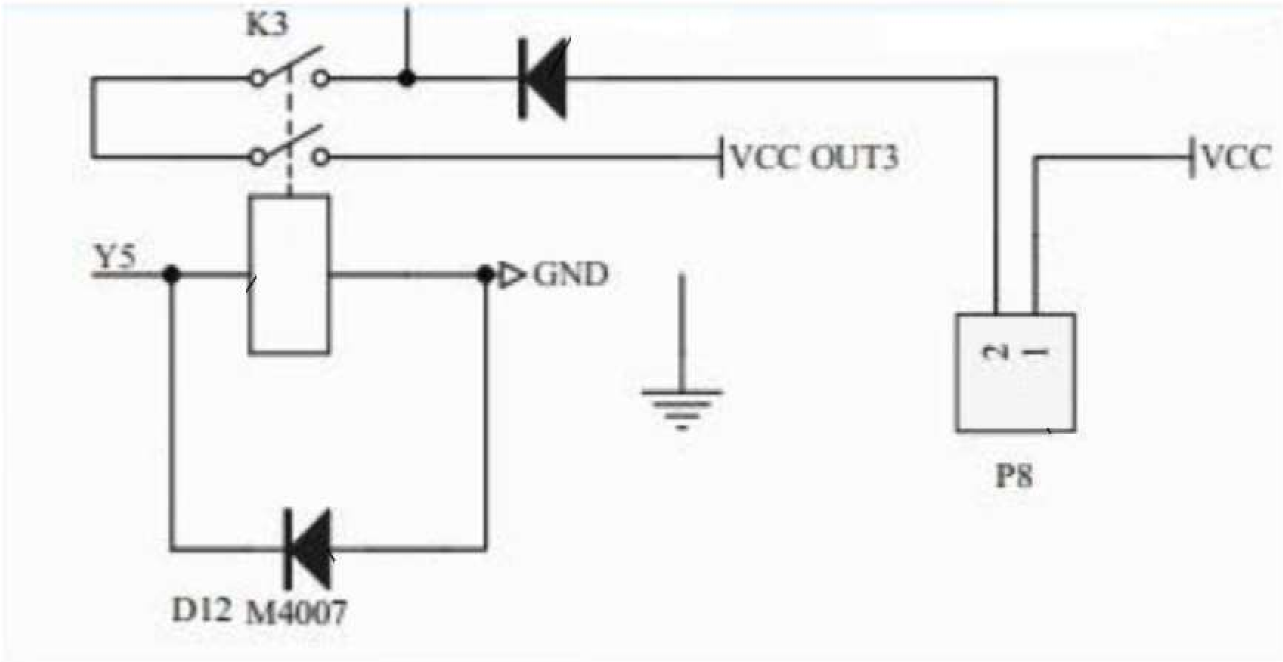

Figure 4. Circuit structure of a single branch of the discharge control unit

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As the core execution module, the discharge control unit is matched with the detection circuit one by one and adopts a multi-branch parallel structure. The circuit structure of a single branch is shown in Figure 4, which is composed of a relay, a protection diode, an output port, a second high-voltage diode and a voltmeter port.

The control end of the relay is connected to the second assembly interface, and the main circuit end is connected to the high-voltage capacitor and the discharge port to realize on-off control of the discharge loop; a protection diode is connected in parallel at both ends to prevent surge current and short circuit. The output port is connected to the high-voltage capacitor through the second high-voltage diode, and an external charging assembly boost circuit charges the capacitor. The second high-voltage diode prevents current backflow to protect the charging assembly. Each branch is equipped with a voltmeter port, which can be connected to an instrument to monitor the real-time voltage of the capacitor. After charging, the closed-loop control of charging - automatic detection - discharge for a single branch is realized through detection and control, ensuring the accuracy of multi-channel initiation.

3.4 Assembly Interface

The assembly interface is an independent signal interaction module, adopting a dual-channel independent standardized design to achieve precise docking with the control assembly. The first interface is a detection signal feedback interface, connecting the op-amp output end of each detection branch with the control assembly to feed back the automatic detection result of each branch in real time; the second interface is a control signal receiving interface, connecting the control assembly with the relay of each discharge branch to receive targeted discharge control signals. The independent design of the dual-channel interface avoids signal interference and ensures accurate and timely transmission. The standardized interface improves the adaptability of the assembly to different control assemblies and facilitates installation and disassembly.

4. Working Principle and Technical Advantages

4.1 Core Working Principle

The assembly is an independent modular working unit, and its working process is divided into four stages with efficient coordination:

Reference voltage generation: The lithium battery supplies power to the output voltage circuit, and a 0.8V reference comparison voltage is generated through U3 voltage stabilization, capacitor filtering and resistor voltage division, which is transmitted to the positive input end of the op-amp of all detection branches;

Real-time automatic voltage detection: The charging assembly charges the high-voltage capacitor, and the actual voltage of the capacitor is transmitted to the negative input end of the op-amp of the corresponding detection branch after protection, isolation and step-down, and the op-amp completes independent automatic detection by comparing the voltages of the positive and negative input ends;

Detection signal feedback: When the voltage reaches the 0.8V threshold, the op-amp outputs a high level, the diode lights up, and the automatic detection result is fed back to the control assembly through the first interface; if the voltage does not reach the threshold, the op-amp outputs a low level, the diode goes out, and an invalid signal is fed back;

Precise discharge control: According to the initiation sequence, the control assembly sends a high-level discharge signal to the branch with valid signals through the second interface, and the relay is turned on to realize delay discharge; a continuous low level is sent to the branch with invalid signals to keep it disconnected.

4.2 Core Technical Advantages

Designed specially for multi-channel delay initiators, this assembly with automatic high-voltage detection fills the market gap and has five core advantages compared with traditional circuits:

Strong market adaptability: The independent discharge output assembly with automatic high-voltage detection is designed for the first time, and the multi-branch structure is perfectly adapted to the demand of multi-channel delay initiation, providing core technical support for the marketization of initiators;

Precise automatic detection and feedback: A reference voltage + multi-branch automatic detection + closed-loop feedback system is constructed, which solves the problems of no detection, no feedback and easy mis-discharge of traditional circuits and improves the initiation reliability;

Modularization and easy industrialization: Each functional circuit and branch is independently modularized with standardized interfaces, which can be produced and debugged independently, and faulty branches can be replaced separately, greatly reducing production and maintenance costs;

Perfect protection and high stability: The design of optocoupler isolation + high-voltage diode anti-backflow fundamentally reduces the risk of high-voltage interference and device damage, and improves the service life and working stability of the assembly;

Strong expandability: The number of branches can be increased or decreased as needed, and the standardized interface is adapted to different types of control assemblies and initiators without large-scale transformation, having a broad market application prospect.

5. Conclusion

Aiming at the pain points that there is no independent discharge output assembly for blasting controllers in the market and multi-channel delay initiators lack core supporting modules, an independent fully modular discharge output assembly with automatic high-voltage detection was designed in this paper. Integrating automatic high-voltage capacitor voltage detection, state feedback and precise discharge control, the assembly fills the market gap and provides key technical support for the marketization and promotion of multi-channel delay initiators.

Powered by a lithium battery, the assembly is composed of four core modules. It can accurately generate a 0.8V reference voltage, realize real-time automatic detection, state indication and precise delay discharge of the voltage of multi-channel high-voltage capacitors, and construct a perfect circuit protection system to ensure working stability. The fully modular design makes the assembly convenient for production, installation and maintenance, meeting the needs of engineering industrialization and marketization. Practical tests show that the assembly can accurately detect the discharge threshold of capacitors, feed back detection information in a timely manner, realize independent and precise discharge of multiple channels, significantly improve the discharge stability and reliability of blasting controllers, and can be directly used as a core supporting module for multi-channel delay initiators.

The design of this assembly solves the technical defects of traditional blasting control circuits and provides a new scheme for the modularization and integration of blasting control equipment, having extremely high engineering application value in the field of engineering blasting. In the follow-up, the circuit parameters can be further optimized and low-power devices can be selected. Combined with wireless communication and intelligent algorithms, remote monitoring and intelligent control can be realized to improve the intelligence level of initiators.

Acknowledgments

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References

[1] Qiu Q A, Liu G L, Luo X Y, et al. A Discharge Output Assembly for Blasting Controllers: China, 217904083U[P]. 2022-11-25.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202603_12(3).0034

[2] Wang J H, Li J M, Zhang W. Blasting Engineering Technology and Application[M]. Beijing: Metallurgical Industry Press, 2018: 125-130.

[3] Liu J, Zhao Q, Wang L. Circuit Design and Optimization of Mining Blasting Controller[J]. Coal Mine Machinery, 2020, 41(7): 123-125.

[4] Zhang M Y, Li L, Chen G. Design and Implementation of High-Voltage Capacitor Voltage Detection Circuit[J]. Application of Electronic Technique, 2019, 45(5): 89-92.

[5] Chen T, Huang Y, Zhou M. Application of Optocoupler Isolation Technology in Industrial Control Circuits[J]. Electronic Design Engineering, 2021, 29(10): 178-182.