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A Circuit Design to Protect Current Surge for Unmanned Factories

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Abstract

With the increasing dependence on precision electronic equipment, self-protection becomes essential. The protection circuits usually used in the past include fuses and circuit breakers. However, these circuits are not enough for the current need of high-speed protection and automatic engineering logic. In this paper, we develop a new high-speed protection circuit, which is over 20 times faster than the traditional circuit and has the ability to self-recovery when any failure occurs. Thus, there is no need to do manual restart and it also meets the future needs of precision electronic equipment protection. This design provides more convenience and reliability for the unmanned manufacturing factory in the future.

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1. Introduction

A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current, typically resulting from an overload or short circuit [1]. Its basic function is to interrupt current flow after a fault is detected. Unlike a fuse, which operates once and then must be replaced afterwards, a circuit breaker can be reset (either manually or automatically) to resume its normal operation. Circuit breakers are made in a various sizes of small devices that protect low-current circuits or individual household appliance up to large switchgear designed to protect high voltage circuits.

With an increasing development of electric-driven facility applications, traditional mechanism or No Fuse Breaker (NFB) is no longer to meet the safety protection in industry. This may cause some disaster occasionally. The main problem is that the fastest breaker currently can react only in 0.1 sec. For the 3A rapid fuse, its reaction time takes about 1 sec. There were no commercial breakers can efficiently protect fragile devices in this condition. Therefore, the development of rapid and current-adjustable electric breaker turns to be a crucial research topic. In this paper, we design a rapid and current-adjustable electric breaker to protect the modern sensitive electronic facilities.

The current limiting technology in the high precision machinery is used a DC to DC converter, which is a built-in over-current protection mechanism [2]. This method focuses too much on the protection of the converter itself that limited the flow of the protection mechanism, thus it avoids the continuous supply of overload current and destruction of the protection mechanism. So we did not make a special improvement of current limit to the current stream [3].

Our rapid and current-adjustable electric circuit is a high precision mechanism to avoid electromagnetic attacks on the pure hardware architecture design. This paper focuses on pure hardware architecture design difficulties which include the use of special electronic components, rapid and current-adjustable electric breaker design principles. We also introduce a self-designed verification system to confirm the performance of current-adjustable electric breaker. The followings are the functional requirements of our designed circuits:

(1) Input Voltage: 12V~28V
(2) Output Voltage: 12V~28V
(3) Max. Current/ Peak power: 50A/1400W
(4) Adjustable current limiting mode: 10A/30A/50A
(5) Short-circuit protection speed: <1ms

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(6) Overcurrent protection speed: <5ms.

2. The principles of high-speed and current-adjustable electric breaker

In this paper, the development of rapid electronic short circuit protection mechanism is high-speed and it does not produce arc current limiter. In order to achieve high-speed function, the circuit must be designed from the most basic electronic components, there is no any capacitor and MCU (single chip) [4] on the main line to avoid influencing switching speed. Because the device is in more harshly environment, we must also consider about the noise problem in order to reduce the chance of misjudgment of the action. In the selection of parts with the device environment is similar to the high specifications of electronic components, with high-pitched noise capacity and stability. We employ the same mechanism as the human body reaction, which is divided into two ways. One is after-thinking and then responding (by the brain to determine). The other is nerve direct response (no brain judgment). The second way is the fastest, we also use this method to meet the high-speed characteristics.

Figure 1 is the systematic framework of the development for high-speed and current-adjustable electric breaker.

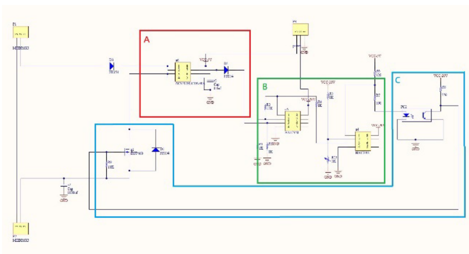

Fig. 1. systematic framework of proposed electric breaker.

The specifications of high-speed and current-adjustable electric breaker are the followings:

Area A is current sensing circuit: Hall effect sensor is used to detect the current amount and converted into a voltage signal.

Area B is voltage amplifier and comparator circuit: The voltage signal received from Hall effect sensor is amplified and connected with the comparator to check if the load current is over the limit.

Area C is timer circuit: Based on IC 555 timer, the trigger signal can be generated once the current is beyond the predefined value. Then, the output of timer circuit can provide a trigger signal for a certain period of time.

3. Design instructions of high switching protection circuit

The specifications of the system controlled chip selection are as follows:

(1) Area A is current detection circuit (Figure 2 and Figure 3): In order to achieve the rapid detection, this circuit use Hall-effect sensor ICs to achieve this purpose. For detecting overload, achieving rapid protection and avoiding excessive delay time, the G point signal output is coupled with fast-recovery diode and the pull-down resistance to prevent the signal floating which can be disturbed.

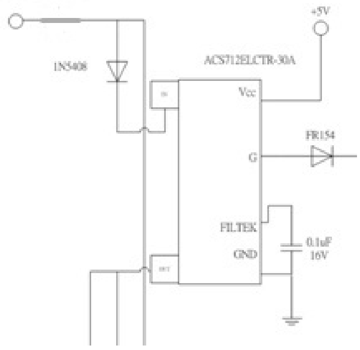

Fig. 2. Hall-Effect Sensor ICs.

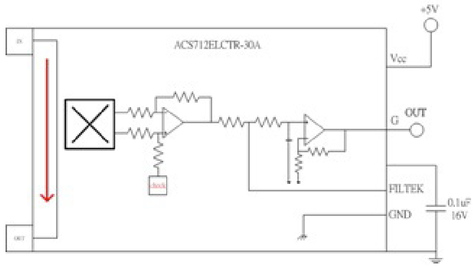

Fig. 3. Internal structure of Hall-Effect Sensor ICs

(2) Area B is voltage amplifier circuit (Figure 4): After receiving the signal, we must filter the unnecessary voltage to obtain a valid reference voltage (This Hall-effect IC signal output is 2.5V, the tolerance for the voltage is around 0.01V). To achieve the rapid detection, this circuit cannot use MCU (single chip). We have to use the barrier voltage of diode to capture 1.7V (the voltage cannot be less than the minimum voltage of amplifier).

In the meanwhile, we also notice the internal IC (which is designed by the semiconductor) shall have the barrier voltage problem. In this case, we have to enlarge 0.01V to the range which can be resolved by its hardware structure. Therefore, the amplification factors would be very high. To avoid the noise jamming which can cause mistake, we must use the ICs which can be used in the high noise environment. These ICs are different from the commercial market which have the characteristics of amplifier and comparator. We use DC30V as VCC for noise resistance and stability [5].

(3) Signal comparison circuit (Figure 5): After comparing signals, the circuit was under the noise and EMI jamming environment, so the rate of misjudgment was relatively high. In this case, this comparison circuit use DC30V to suppress noise. Signal was fed to external port which separated with the internal circuit and minimize jamming.