

Simple Energy-Tripped Circuit Breaker with Automatic Delayed Retry

Design Note 495

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Introduction

A circuit breaker protects sensitive load circuits from excessive current flow by opening the power supply when the current reaches a predetermined level. The simplest circuit breaker is a fuse, but blown fuses require physical replacement. An electronic circuit breaker provides the same measure of circuit protection as a fuse without the single-use problem. Nevertheless, an electronic circuit breaker with a fixed trip current threshold, while effective for protection, can become a nuisance if tripped by short duration current transients—even if the circuit breaker self-resets.

One way to minimize nuisance breaks is to employ a slow-blow technique, which allows relatively high levels of current for short intervals of time without tripping the breaker. Ideally, the breaker's trip threshold would be a function of total transient energy, instead of just current. This article describes an electronic circuit breaker, combining current sensing with timing to create an energy-tripped breaker, which protects sensitive circuits while minimizing nuisance trips.

Higher Currents Permitted for Shorter Time Intervals

The circuit of Figure 1 has three distinct parts – circuit breaking, current sensing and timing.

The circuit breaking function can be any type of electronically controlled relay or solid state switch, properly sized for voltage and current ratings of the load being protected.

Load current sensing is achieved via an LT[®]6108-2 current sense amplifier with built-in comparator. The LT6108-2 converts the voltage drop across a small valued sense resistor to a ground-referenced output voltage that is directly proportional to the load current. The trip threshold is created by scaling the output voltage via resistor divider and feeding the result to the integrated comparator with a precision 400mV voltage reference. The comparator changes state when the load current exceeds the threshold.

To prevent short duration transients from causing nuisance trips, an LTC[®]6994-2 Timerblox[®] delay timer is

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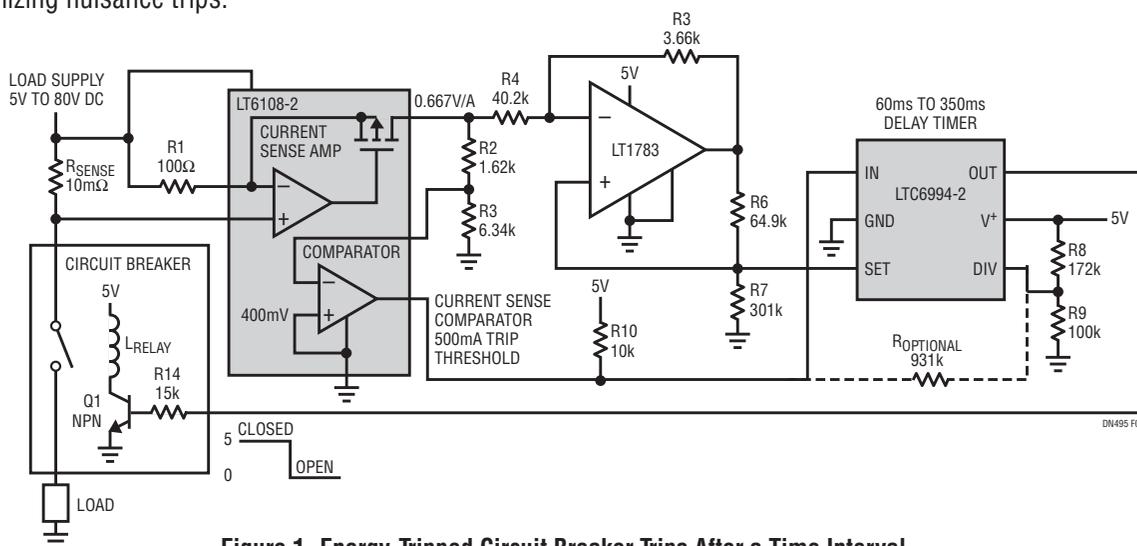


Figure 1. Energy-Tripped Circuit Breaker Trips After a Time Interval That Varies as a Function of Sensored Load Current

added between the comparator output and the circuit breaker. Once tripped, the comparator falling edge starts a variable time delay interval, which, if allowed to complete, signals the circuit breaker to open. Nothing happens if the transient duration is shorter than the delay.

A Current-Controlled Delay Interval

The LTC6994-2 delays from an edge appearing at its IN pin by a time ranging from 1 μ s to 33 sec. The delay time is controlled by the current sourced by the SET pin, which programs an internal oscillator frequency, while the bias voltage on the DIV pin selects a frequency divide ratio.

The LT1783 op amp circuit takes the output voltage from the current sense amplifier and adjusts the SET pin current, thereby making the delay time a function of the load current (see Figure 2). As shown, the current sense comparator trip threshold is 500mA. A current of 500mA creates a falling edge and starts a time delay of 350ms. Should the load current drop below 500mA before the delay time expires, the timer output remains high and the circuit breaker does not trip.

Higher load currents correspond to higher current sense amplifier output voltages, which in turn reduce the delay time interval (Figure 2). For instance, a 5A load current trips the circuit breaker in only 60ms. Depending on the average load current in excess of the 500mA threshold, the delay interval or trip time will fall somewhere between 30ms and 400ms.

Once tripped, the load current drops to zero. This resets the current sense comparator high. This rising edge is also delayed by the LTC6994-2. The minimum current sense

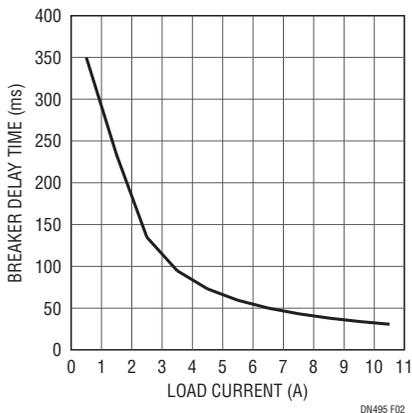


Figure 2. Low Current Transients Must Last Relatively Longer to Trip the Breaker. Higher Currents Trip the Circuit Breaker in Less Time

output voltage stretches this delay to a maximum time of ~1.3 sec. After this delay the circuit breaker closes and reapplies power to the load. This automatic retry function requires no additional components.

The response of the circuit to a 5A load current spike and automatic retry is shown in Figure 3. If the load current remains too high, the trip/retry cycle repeats continually. A current surge is fairly common when the circuit breaker is first closed and can trip the comparator. If the duration is less than the timer delay, the breaker remains closed, thus avoiding an endless loop of self-induced nuisance trips.

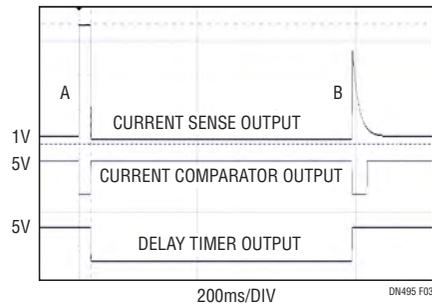


Figure 3. An Example Trip and Retry Sequence. At Time Point A, the 5A Load Current Spike Trips the Comparator and 60ms Later the Breaker is Opened. At Time B, After a Delay Time of 1.3 sec, the Timer Closes the Breaker. The Resulting Short Duration Spike of Start-Up Current Is Not Large Enough or Long Enough in Duration to Trip the Breaker Again

Extending the Retry Time Interval

The LTC6994-2 delay timer has eight divider settings for a wide range of timing intervals. Adding the single optional resistor shown in Figure 1 shifts the delay block to a new setting, increasing the retry time interval if desired. This can give any fault condition more time to subside. The circuit breaker response time interval is not affected.

For the values shown, when the circuit breaker trips and the current drops to zero, the comparator high level biases the DIV pin to a higher voltage level, resulting in a longer retry delay time of 10 seconds.

Conclusion

The circuit shown here can be easily modified to different timing requirements with a few resistor value changes. Other current sense devices such as the LT1999 can also be used to monitor bidirectional load currents with variable breaker timing functionality.

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