

# Circuit Protection

## *What is Circuit Protection?*

In an electrical circuit, we refer to an excess (FLA) flow of current as an overcurrent. Overcurrents, since they exceed design or rated values, are considered abnormal. Our customers look for ways to limit or interrupt these overcurrents, which (if allowed through equipment) may cause damage. Circuit Protection Equipment provides our customers with the means to prevent the damage overcurrents can cause.

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## *Why Do Our Customers Require Circuit Protection?*

“Overcurrent protection is necessary in order to prevent a small, controllable problem from becoming a much larger issue. Potentially damaging overcurrents can result form excessive voltages, component failure or an accidental shorting of a circuit. Currents above the level the circuit was designed to handle produce excessive heat. The higher heat level may destroy other components or result in a fire. The purpose of circuit protection devices is to prevent the excessive current from producing damaging heat.”<sup>1</sup> Most electric and electronic devices cannot distinguish between normal loads or overloads. Without circuit protection, these devices would draw more current as the load increased, until finally the equipment burned itself out. Danger of fire is always a possibility. For these reasons, safety agencies such as the UL, CSA, VDE require circuit protection on most equipment. The faulty circuit must be interrupted for protection.

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## *What are the choices available in equipment protection?*

Fuses

Polymer Products

Thermal Circuit Breakers

Magnetic Circuit Breakers

*All serve useful functions and have their purpose, which will be discussed in the following pages.*

### **Important Factors in CBE Selection**

Agency approval requirements	Ambient temperature
Number of poles	Inrush
Voltage	Duration before trip (Trip Curve)
Current (continuous duty, in amps)	Options required
Fault current	Mounting configuration
Catastrophic fault current	Location and amount of space
Type of load	What specifically is being protected?

## I. Fuses

A fuse is a device which breaks the circuit under conditions such as heating by a short circuit, sustained inrush current, or overcurrent conditions. A traditional fuse will “provide protection from an overload by opening only once and then it needs to be replaced. The heart of a typical fuse is a length of wire that is heated to its melting point by the excessive current. The circuit current flow decreases to zero as the wire melts open.”<sup>2</sup>

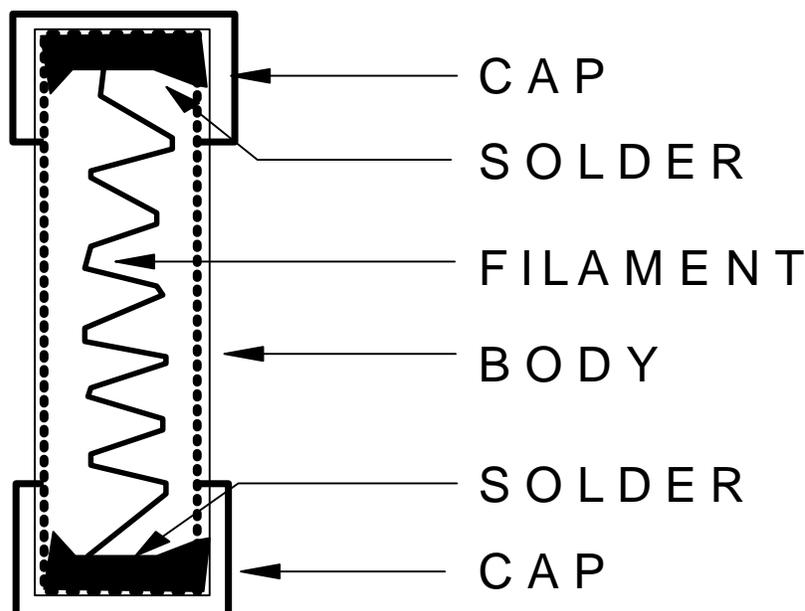
Fuses can be an inexpensive, dependable means of protecting equipment and wiring, since they offer relatively high current interrupting capacity for their cost. Disadvantages to using a fuse are that they destroy themselves in the protection process, and they are somewhat imprecise due to the effects of ambient temperature changes and repeated exposure to surges and minor overloads.<sup>3</sup>

The characteristics of a fuse design refer to how rapidly the fuse responds to various current overloads. Fuse characteristics can be classified into three general categories, Fast Acting, which has virtually no delay, Medium-blo, which protects devices subjected to moderate to high inrush currents, and Slo-blo, which can withstand some inrush current. Current rating and characteristic are both needed to define a fuse since fuses with the same current rating can be represented by considerably different time-current curves. Slo-blo fuses have additional thermal inertia designed in so that they can withstand inrush or transient currents. Some of the factors that are involved in the selection of a fuse include operating current, voltage (AC or DC), physical size limitations, agency approvals (UL, CSA, VDE, or Military), as well as overload current (in breaking capacity) and length of time in which the fuse must be open.<sup>4</sup>

### Cartridge Type Fuses



### Basic Fuse Components



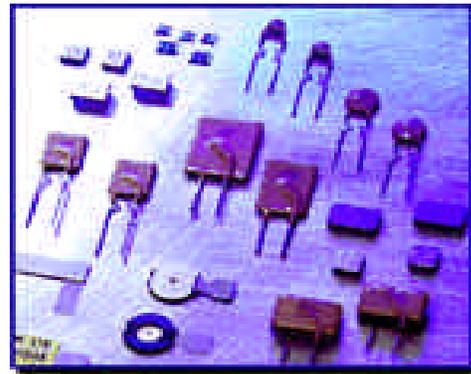
## II. *Polymer Products*

Unlike traditional fuses, polymeric fuses provide resettable circuit protection by limiting fault current. Polymeric fuses are made from a conductive plastic (made from a non-conductive crystalline polymer and a highly conductive carbon black) formed into thin sheets, with electrodes attached to either side. The electrodes ensure even distribution of power through the device, and provide a surface for leads to be attached or for custom mounting. The phenomenon that allows conductive plastic materials to be used for resettable overcurrent protection devices is that they exhibit a very large non-linear Positive Temperature Coefficient (PTC) effect when heated. PTC is a characteristic that many materials exhibit whereby resistance increases with temperature.<sup>5</sup>

The benefits of polymer products as circuit protectors have been widely recognized and applied to the following products and industries:

- ◆ Communications equipment
- ◆ Personal and laptop computers
- ◆ Small and medium electric motors
- ◆ Audio equipment and speakers
- ◆ Test and measurement equipment
- ◆ Security and fire alarm systems
- ◆ Medical electronics
- ◆ Marine electronics
- ◆ Battery-operated toys
- ◆ Industrial controls

### Polymeric Positive Temperature Coefficient Devices



## III. *Circuit Breakers*

### Circuit Breakers

A circuit breaker, designed for higher current applications, will interrupt the circuit during a short circuit or inrush of current. An advantage this product offers is its repeatability. Circuit breakers may be used many times. There are two types of circuit breakers: Thermal and Magnetic.

### A. *Thermal Circuit Breakers*

With simple operation through the heating effect of current, thermal circuit breakers offer one of the most reliable and cost effective forms of protection device available. As a result they are well-suited for the protection of a broad range of components and systems - from motors and transformer windings, through printed circuit boards, to the low voltage power distribution circuits of road vehicles, boats, and battery powered machines. "Thermal circuit breakers utilize a bimetallic strip electrically in a series with the circuit. The heat

### Thermal Circuit Breakers



generated by the current during an overload deforms the bimetallic strip and trips the breaker. Thermal breakers have significant advantage over traditional fuses in that they can be reset after tripping. They can also be used as the main ON/OFF switch for the equipment being protected.”<sup>6</sup>

Such applications all require the ability to discriminate between safe switch-on surges or transients on one hand, and harmful sustained overloads on the other. Thermal circuit breakers can withstand high level surges, which arise from lamp loads or motor-starting, for example. At the same time they afford protection against the effects of genuine failure such as motor locked rotors. The characteristics of thermal CBE’s (Circuit Breakers for Equipment) can be matched closely to the ratings of the component or system they are protecting. This eliminates the need for over-sizing of wiring and connectors, while offering dependable protection, even under low level overcurrent conditions which cannot be adequately provided for other methods of circuit protection.<sup>7</sup>

Thermal circuit breakers utilize one of three different mechanisms optimized for their range of operation:

- ◆ A snap action disc type bi-metal and contact assembly
- ◆ A bi-metal with a mechanical latch and separate spring loaded contact
- ◆ A hot wire design with extremely fast switching time

All are individually calibrated in the factory to ensure safe, predictable performance under a wide range of conditions.

### ***B. Magnetic Circuit Breakers***

Magnetic circuit breakers provide highly precise, reliable and cost-effective solutions to most design problems. They have the advantages of thermal breakers without their disadvantages. Since the magnetic circuit breaker is considered to be temperature stable, it is not appreciably affected by changes in ambient temperature. These circuit breakers are designed to give our customers reliable automatic circuit protection, power switching and circuit control in a versatile, compact, cost-effective package.<sup>8</sup>

## Magnetic Circuit Breaker



Magnetic circuit breakers offer a more precise trip time for delicate circuits than thermal circuit breakers. Generally, wherever precise and reliable circuit protection is required, a magnetic circuit breaker is specified.

Magnetic circuit breakers protect the following:

- |   |                                       |
|---|---------------------------------------|
| ◆ wiring                                      | ◆ machine tools                       |
| ◆ motors                                      | ◆ medical and dental equipment        |
| ◆ generators and transformers                 | ◆ instrumentation                     |
| ◆ solid state systems                         | ◆ vending machines                    |
| ◆ telecommunications systems                  | ◆ process control systems             |
| ◆ microprocessors                             | ◆ linear and switching power supplies |
| ◆ peripheral and printing devices             | ◆ marine control panels               |
| ◆ industrial automation and packaging systems | ◆ office machines                     |

C.

<b>Characteristics of Thermal and Magnetic Circuit Breakers</b>	
<b><u>Thermal</u></b>	<b><u>Magnetic</u></b>
Temperature Sensitive	Not Temp Sensitive
Not Voltage Sensitive	Voltage Sensitive
Single Pole	Single or Multi-pole
Fixed Time Delay	Various Time Delays
Push-to-Reset or Switch Function	Switch Function
Limited Circuit Functions	Variety of Circuit Functions
Small Package Size	Larger Package Size
Lower Cost	Higher Cost

#### ***IV. Applications***

- Circuit Protection is an area where operating characteristics must meet precise performance parameters. The aircraft you fly in, the house you live in, the computer you operate and the photocopier you run all probably have circuit protection devices.
  - ***Power Supplies:*** Switches, Linear, UPS, Rectifiers
  - ***Power Distribution:*** Telecommunications, Computers, Boat Panels, Theatrical Lighting, Rail Cars
  - ***Appliance Protector:*** Photocopiers, Workstations, Test & Measurement Equipment, Medical Equipment, Printers
  - ***Motor Protector:*** HVAC Equipment, Submersible Pumps, Vacuum Cleaners, Generator Sets
  - ***Battery Chargers***
  - ***Domestic Appliances:*** Food Processors, Washing Machine, Dryers
  - ***Military Equipment:*** Radios & Broadcast, Ground Support, Aerospace & Airborne
  - ***Surge Protectors***

#### ***V. Safety and Regulatory Agencies***

The need for ensuring consistently safe products and equipment prompted the creation of safety agencies, whose prime responsibilities include writing standards, evaluation of product to those standards, and issuing marks indicating compliance to the applicable standards. These agencies are concerned with safety in forms such as electrical shock, mechanical hazard, fire and other hazardous/emergency conditions. This concern is extended to the component power supply as well as end use equipment or product.

The incompatibility of standards between nations makes it impossible to use the same fuse across the world in a given application. Attention needs to be given to the fact that governing standards are different. Observation of this fact in the early design stage will save trouble and confusion during the agency approval process. Look to each nation's markings to ensure compliance. Some popular national agencies include: UL (United States), CSA (Canada), VDE (Germany), SEMKO

(Sweden), BSI (United Kingdom), IEC (Europe)

#### *Underwriters Laboratories, Inc. (UL)*

This agency, founded in 1894, is a National Recognized Testing Laboratory in the United States. UL maintains and operates laboratories for the standards development, examination and testing of devices, systems, and materials to determine their relation to life, fire, casualty hazards and crime prevention. Once compliance has been determined, UL will authorize the use of one of two marks. The "Listed" mark is for end use products and the "Recognized" mark is used for components such as power supplies. Using UL Recognized components in an end user product simplifies listing of that product for the manufacturer.

#### *Canadian Standards Associates (CSA)*

Founded over 75 years ago, CSA develops standards and maintains certification programs for both consumer and industrial products based on those standards. Eligibility for Certification is determined by testing and evaluation of representative samples of product. Products found in compliance are then authorized to display the CSA mark. Unlike UL, the CSA mark does not distinguish between the component or end use equipment Certification.

#### *European Committee for Standardization (CEN)*

#### *European Committee for Electrotechnical Standardization (CENELEC)*

#### *European Telecommunications Standards Institute (ETSI)*

These organizations have been tasked with the harmonization of standards for the European Union. The most important of these are European Standards known by the letters "EN" which are published in the EC's Official Journal and the development of which can be tracked in a publication entitled the European Standards Bulletin. European Standards must be implemented at the national level and conflicting standards must be withdrawn.

#### *Verband Deutscher Elektronotechniker (VDE)*

Headquartered in Germany, VDE develops standards for Germany and provides testing of product. VDE is one of many agencies in Germany authorized by the government to issue the German "GS" mark for products complying to specific standards. The "GS" mark, short for Geprüfte Sicherheit roughly translated means Proved Safety.

#### *Technische Überwachungs Verein (TUV)*

TUV is composed of approximately 14 independent laboratories in Germany. Unlike VDE, the TUV's do not write standards. They are however, authorized by the German government to issue to "GS" mark for compliant equipment.<sup>9</sup>

<sup>1</sup> Source: *Overcurrent Circuit Protection...Fuse or PTC?*, page 1, Littlefuse web page, November 1998.

<sup>2</sup> Source: *Circuit Protection Basics*, page 2, Carlingswitch web site, November 1998.

<sup>3</sup> Source: *Total Circuit Protection*, page 9, Littlefuse web page, November 1998.

<sup>4</sup> Source: *Circuit Protection Basics*, page 1, Carlingswitch web page, November 1998.

<sup>5</sup> Source: *Fuseology*, pages 2-4, Littlefuse web page, November 1998.

<sup>6</sup> Source: Schurter, Inc., pages 104-105, Schurter web site, November 1998.

<sup>7</sup> Source: *Circuit Protection Basics*, page 1, Carlingswitch web site, November 1998.

<sup>8</sup> Source: *Thermal Series*, page 1, ETA web page, November 1998.

<sup>9</sup> Source: Safety and Regulatory Agencies, pages 1-4, Power-one Power Supplies web page, December 1998.