

Basic Fuse Technology

Fuses serve two main purposes:

- To protect components and equipment from costly damage caused by overcurrents.
- To isolate sub-systems from the main system once a fault has occurred.

Overcurrents

Overcurrents exist when the normal load for a circuit is exceeded. It can be either an overload or short circuit. An overload is any current flowing within the normal circuit path that is higher than the circuit normal full load current.

A short circuit is an overcurrent which greatly exceeds the normal full load current of the circuit. Also, as the name infers, a short circuit leaves the normal current carrying path of the circuit and takes a "short-cut" around the load and back to the power source. Components and equipment can be damaged by both types of overcurrents.

Selecting Overcurrent Protection

During normal conditions, the fuse must carry the load current of the circuit without nuisance openings. However, when an overcurrent occurs the fuse must interrupt the overcurrent, and withstand the voltage across the fuse after arcing. To properly select a fuse the following items must be considered:

- Voltage rating (AC or DC voltage)
- Full load currents (RMS Amperes)
- Available short circuit current
- In-rush characteristics
- Characteristics of equipment or components to be protected
- Ambient conditions
- Standards requirements

In addition consideration must be given to:

- Available board space
- Type of mounting
- Automatic or manual insertion
- Reliability
- Ease of field service

Electronic circuits frequently exhibit surges, caused by capacitors charging, motors being momentarily stalled, or high voltage components sparking over. It is important that designers take account of these temporary conditions during fuse selection. The ability to resist surges is a function of the fuse design relative to the surge pulse, duration, frequency etc. Comparison of a manufacturer's I^2t value alone is not sufficient, and Bussmann would be pleased to advise on specific applications.

Voltage Ratings

The voltage rating of the fuse must be greater than or equal to the circuit voltage. Because the fuse has such low resistance, the voltage rating becomes critical only when the fuse is trying to open. The fuse must be able to open quickly, extinguish the arc after the fuse element has melted and prevent the system open-circuit voltage from restriking across the open fuse element.

Current Ratings

Each fuse is marked with a nominal current rating.

Several factors can actually affect the ability of the fuse to carry this rated current. First the base material of the clip in which the fuse is mounted may greatly affect the performance of the fuse.

Another important factor is the conductor size used to connect the fuse to other circuit components. If the conductor is too small, it will generate a heat rise. That extra heat will be seen by the fuse, causing the fuse to open before it should. It is also important that the fuse be installed with clean and tight connections. If the connections are dirty or loose, they will cause increased resistance, generating extra heat. That heat will lead to a shortened fuse life.

Interrupting Rating (Breaking Capacity)

A fuse must be able to open the circuit under a short circuit without losing case integrity. The breaking capacity of a protective device is the maximum available current, at the rated voltage, that the device can safely open without rupturing.

Fuse Resistance

In most applications, the voltage drop across the fuse due to its internal and contact resistances is negligible. There are, however, certain critical applications where the fuse resistance must be considered, and it is important that the circuit designer understands the fuse characteristics in order to select the proper fuse.

Physical Sizes

There are numerous physical sizes of electronic small dimension fuses, including sub-miniature fuses. The most common are 5mm x 20mm and 1/4" x 1 1/4" (6.3mm x 32mm).

Sub-miniature fuses are designed for applications where board footprint usage is of critical concern.

Physical Sizes Of Fuses


5mm x 20mm	.2" x .79"
1AG*	1/4" x 5/8"
2AG (5mm x 15mm)	.2" x .59"
3AG	1/4" x 1 1/4"
4AG*	9/32" x 1 1/4"
5AG	13/32" x 1 1/2"
7AG*	1/4" x 7/8"
8AG*	1/4" x 1"

*Not popular for new designs

IEC Standards are very different from North American Standards. International Electrotechnical Commission (IEC) writes the standards followed by many European and Asian countries. Among the commission members are:

Australia	Japan	South Africa
Canada	Korea	Sweden
Denmark	Netherlands	Switzerland
Finland	Norway	Turkey
Germany	Poland	U.S.A.
Great Britain	Portugal	U.S.S.R.
Hungary	Romania	Yugoslavia
Israel		

Because the electrical characteristics of these fuses are so different, North American and IEC rated fuses are not interchangeable. When designing products to go "international", it is important to consider that world standards may require different fuses.

Some of these countries conduct their own testing, such as VDE, the German testing agency. However, most accept the testing of Svenska Elektriska Material Kontrollanstalten or Semko, the Swedish testing agency. Those products tested by Semko that pass the IEC requirements are marked with .

The testing by European agencies revolves around voltage drop, time/current characteristics, breaking capacity and endurance tests. However, the biggest differences between North American and European standards are the time current characteristics. As shown on the next page, fuses built to North American Standards are not compatible with European standards.

IEC Versus North American Standards

Percent Of Fuse Rating		North American Listed or Certified Fuses Miscellaneous and Miniature Types*				International Electrotechnical Commission Fuses (Publication 127)					
		Fast-Acting Fuses		Time-Delay Fuses		Fast-Acting Fuses Sheet 1		Fast-Acting Fuses Sheet 2		Time-Delay Fuses Sheet 3	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
110%	0-30A	Cont.	—	Cont.	—						
135%	0-30A	—	1 hr.	—	1 hr.						
150%	32mA-6.3A	—	—	—	—	1 hr.	—	1 hr.	—	1 hr.	—
200%	0-3.0A	—	2 min.	5 sec.	2 min.						
	3.1-30A	—	2 min.	12 sec.	2 min.						
210%	32mA-6.3A					—	30 min.	—	30 min.	—	2 min.
275%	32mA-3.9A					.01 sec.	2 sec.	—	—	—	—
	4A-6.3A					.01 sec.	3 sec.	—	—	—	—
	32-100mA					—	—	.01 sec.	.5 sec.	.2 sec.	10 sec.
	125mA-6.3A					—	—	.05 sec.	2 sec.	.6 sec.	10 sec.
400%	32-100mA					.003 sec.	.3 sec.	.003 sec.	.1 sec.	.04 sec.	3 sec.
	125mA-6.3A					.003 sec.	.3 sec.	.01 sec.	.3 sec.	.15 sec.	3 sec.
1000%	32-100mA					—	.02 sec.	—	.02 sec.	.01 sec.	.3 sec.
	125mA-6.3A					—	.02 sec.	—	.02 sec.	.02 sec.	.3 sec.

*Does not include micro fuses

Notice that at 135% of its rated current a North American fuse must open within one hour while an IEC fuse must be able to carry 150% of its rated current for at least one hour.

The IEC uses symbols to denote fuse time/current characteristics, and breaking capacity.

Characteristics Symbol:

LETTER CODE	COLOR CODE	BREAKING CAPACITY SYMBOL
FF—Super Quick Acting	Black	L: Low Breaking Capacity
F—Quick Acting	Red	35A @ 250V AC or 10 x Rated Current
M—Medium Time Lag	Yellow	H: High Breaking Capacity
T—Time Lag	Blue	1500A @ 250V AC
TT—Super Time Lag	Grey	

Typical interrupting ratings of North American "Listed" electronic fuses is 10,000 amperes for all voltage levels except 250 volt AC fuses. 250 volt AC listed fuses are first tested as 125 volt AC fuses, in which case they must have a 10,000 ampere interrupting rating. However, at 250 volts, these fuses, as shown below, may have lower interrupting ratings.

Interrupting Ratings (Breaking Capacity) of North American Listed Fuses

Voltage Rating (AC)	Amp Rating of Fuse	Short Circuit Current UL Minimums
125V*	All	10,000A
	0-1A	35A
	1.1-3.5A	100A
250V	3.6-10A	200A
	10.1-15A	750A
	15.1-30	1,500A
300V	All	10,000A
500V	All	10,000A
600V	All	10,000A, 50,000A, or 100,000A

*Does not include micro fuses.

International Electrotechnical Commission (IEC)

Fuses designed to IEC standards must meet a breaking capacity test. The various breaking capacities for the four main IEC fuse types are shown below.

Interrupting Ratings (Breaking Capacity) Per IEC Standards

Type	Case Size	Breaking Capacity
Quick Acting High-Breaking Capacity	5mm x 20mm	1,500A
Quick-Acting Low-Breaking Capacity	5mm x 20mm	35A or 10 times rated current whichever is greater.
Time-Lag Low-Breaking Capacity	5mm x 20mm	35A or 10 times rated current whichever is greater.
Quick-Acting Low-Breaking Capacity	6.3mm x 32mm	35A or 10 times rated current whichever is greater.

Finally, both North American and IEC fuses' interrupting/breaking capacity are tested using AC. Their DC ratings could be different because of circuit time constant considerations. It is generally easier for a fuse to operate under AC than DC.

Ampere

The measurement of intensity of rate of flow of electrons in an electric circuit. An ampere is the amount of current that will flow through a resistance of one ohm under a pressure of one volt.

Ampere Rating

The current carrying capacity of a fuse. When a fuse is subjected to a current above its ampere rating, it will open the circuit after a predetermined period of time.

Ampere Squared Seconds, I²t

The measure of heat energy developed within a circuit during the fuse's clearing. It can be expressed as "melting I²t". "I" stands for effective let-through current (RMS), which is squared, and "t" stands for time of opening, in seconds.

Arcing Time

The amount of time from the instant the fuse link has melted until the overcurrent is interrupted, or cleared.

Breaking Capacity
(See Interrupting Rating)**Cartridge Fuse**

A fuse consisting of a current responsive element inside a fuse tube with terminals on both ends.

Class CC Fuses

600V, 200,000 ampere interrupting rating, branch circuit fuses with overall dimensions of 13/32" x 1 1/2". Their design incorporates rejection feature that allow them to be inserted into rejection fuse holders and fuse blocks that reject all lower voltage, lower interrupting rating 13/32" x 1 1/2" fuses. They are available from 1/10 amp through 30 amps.

Glass G Fuses

480V, 100,000 ampere interrupting rating branch circuit fuses that are size rejecting to eliminate overfusing. The fuse diameter is 13/32" while the length varies from 1 5/16" x 2 1/4". These are available in ratings from 1 amp through 60 amps.

Clearing Time

The total time between the beginning of the overcurrent and the final opening of the circuit at rated voltage by an overcurrent protective device. Clearing time is the total of the melting time and the arcing time.

Current Limitation

A fuse operation relating to short circuits only. When a fuse operates in its current limiting range, it will clear a short circuit in less than 1/2 cycle. Also, it will limit the instantaneous peak let-thru current to a value substantially less than that obtainable in the

same circuit if that fuse were replaced with a solid conductor of equal impedance.

Dual Element Fuse

Fuse with a special design that will utilize two individual elements in series inside the fuse tube. One element, the spring actuated trigger assembly, operates on overloads up to 5-6 times the fuse current rating. The other element, the short circuit section operates on short circuits up to their interrupting rating.

Fast Acting Fuse

A fuse which opens on overload and short circuits very quickly. This type of fuse is not designed to withstand temporary overload currents associated with some electrical loads.

Fuse

An overcurrent protective device with a fusible link that operates and opens the circuit on an overcurrent condition.

High Speed Fuses

Fuses with no intentional time-delay in the over-load range and designed to open as quickly as possible in the short circuit range. These fuses are often used to protect solid state devices.

Interrupting Capacity
See Interrupting Rating**Interrupting Rating**
(Breaking Capacity)

The rating which defines a fuse's ability to safely interrupt and clear short circuits. This rating is much greater than the ampere rating of a fuse. The National Electrical Code defines Interrupting Rating as "The highest current at rated voltage that an overcurrent protective device is intended to interrupt under standard test conditions."

Melting Time

The amount of time required to melt the fuse link during a specified overcurrent. (See Arcing Time and Clearing Time.)

Ohm

The unit of measure for electric resistance. An ohm is the amount of resistance that will allow one ampere to flow under a pressure of one volt.

Ohm's Law

The relationship between voltage, current, and resistance, expressed by the equation $E = IR$, where E is the voltage in volts, I is the current in amperes, and R is the resistance in ohms.

Overcurrent

A condition which exists on an electrical circuit when the normal load current is exceeded. Overcurrents take on two separate characteristics – overloads and short circuits.

Overload

Can be classified as an overcurrent which exceeds the normal full load current of a circuit. Also characteristic of this type of overcurrent is that it does not leave the normal current carrying path of the circuit – that is, it flows from the source, through the conductors, through the load, back through the conductors, to the source again.

Peak Let-Thru Current, Ip

The instantaneous value of peak current let-thru by a current limiting fuse, when it operates in its current limiting range.

Resistive Load

An electrical load which is characteristic of not having any significant inrush current. When a resistive load is energized, the current rises instantly to its steady state value, without first rising to a higher value.

R.M.S. Current

The R.M.S. (root-mean-square) value of any periodic current is equal to the value of the direct current which, flowing through a resistance, produces the same heating effect in the resistance as the periodic current does.

Semiconductor Fuses

Fuses used to protect solid state devices. See "High Speed Fuses".

Short Circuit

Can be classified as an overcurrent which exceeds the normal full load current of a circuit by a factor many times (tens, hundreds or thousands greater). Also characteristic of this type of overcurrent is that it leaves the normal current carrying path of the circuit — it takes a "short cut" around the load and back to the source.

Time-Delay Fuse

A fuse with a built in delay that allows temporary and harmless inrush currents to pass without opening, but is so designed to open on sustained overloads and short circuits.

Voltage Rating

The maximum open circuit voltage in which a fuse can be used, yet safely interrupt an over-current. Exceeding the voltage rating of a fuse impairs its ability to clear an overload or short circuit safely.