

FUSES: A SHORT PRIMER

Fuses are possibly the most misunderstood components in electronics, and often regarded as a 'nuisance'. In fact they play a very important role as a 'safety valve' in many circuits, protecting both the equipment from costly damage and the user from serious injury or possible loss of life.

A fuse is basically just a short piece of wire, carefully chosen in terms of its diameter and composition (and sometimes the physical tension applied to it as well) so that it will conduct current continuously up to a certain level, but melt or 'fuse' if the current rises significantly above that level. It's also designed to become an **open circuit** when it *does* 'blow' — automatically switching off the current before (hopefully) any serious damage is done. Thomas Edison first patented the concept of a wire fuse in 1880.

In most of the fuses used in electronic equipment, the fuse wire is mounted axially in a small glass or ceramic tube, fitted with metal end caps which form the electrical connections to the resulting fuse 'cartridge'. The glass tube forms a physical guard for the fuse, so that when it does blow the molten metal can't fly off and cause damage or injury. A glass tube also generally lets you see clearly when the fuse has blown — you can either see the actual gap in the wire, or at least a metallic smear on the inside of the glass.

Current Rating

Fuses are always marked with the current level they're designed to carry on a continuous basis before fusing will occur, at a standard temperature. However in many circuits a fuse is subjected to intermittent over-current surges in normal operation — for example when power is switched on each time and capacitors charge up, etc. Over time these 'normal surges' tend to cause **fatigue** in the fuse wire, which can result in the fuse blowing even when there is no fault condition. Partly because of this there are two different rating systems in common use: the European based **IEC system** and the US-based **UL** (Underwriters' Laboratories) system, which differ in terms of the ratio between the current which a fuse is rated to carry indefinitely without blowing, and the current which will cause it to blow. So a fuse with an IEC rating of 1A might have identical fusing characteristics to one with a UL rating of 1.4A.

Needless to say fuses take a finite time to 'blow', and this *fusing time* tends to vary inversely with the overload current level. So an overload causing say five times the usual current



Typical fuses of the type found in modern electronics equipment and electrical systems. Above are high current 5AG fuses; upper right, high current blade fuses; lower right, M205 and 3AG ceramic fuses; and below, a 'Slow Blow' 3AG fuse.

will produce much slower fusing than one which results in 20 times the usual current.

Fast and slow

Modern fuses are also made in versions which have different time-current relationships. The two most common types are the standard or 'fast acting' (F) type, and the 'Slow Blow' (T) type, designed to tolerate a large number of 'startup surge' type short-term and modest overloads without blowing.

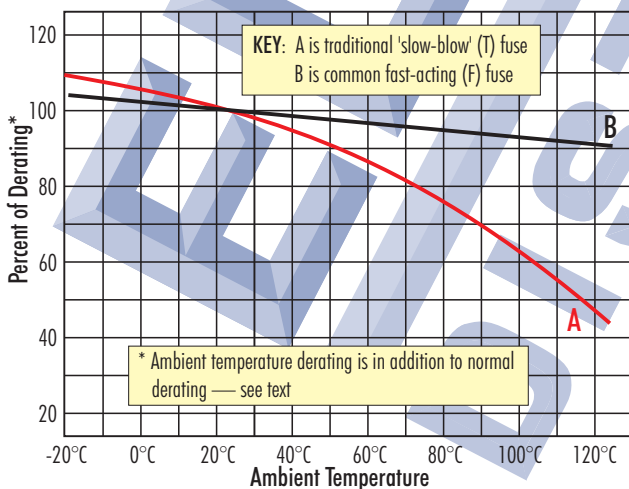
Ambient temperature also plays a key role in fuse behaviour — and we're talking here about the temperature of the air immediately surrounding the fuse wire itself. As a fuse is often mounted in a closed holder (i.e., preventing air flow past the fuse cartridge), which may also be near transformers or other heat-producing components, this means the fuse's ambient temperature may be significantly higher than 'room temperature'. Generally speaking the higher the fuse's operating temperature, the shorter its life carrying the rated current level.

Derating

Bearing these complications in mind, it's usual to operate most fuses at no more than 75% of their nominal rated current carrying capacity. So the correct fuse rating is found by dividing the operating current level by 0.75 — e.g. in a circuit normally carrying 750mA, a 1A fuse would be used. When this *derating* is done, fuses will generally operate almost indefinitely in equipment running at room temperatures of 25°C or lower.

For equipment running at *higher* temperatures, fuses should be further derated according to the graph shown. For example with an operating current of 1.5A and an ambient temperature of 70°C, a slow-blow fuse (curve A) would need to be rated at $1.5 / (0.75 \times 0.80) = 2.5A$.

Most fuses have a very low resistance and therefore introduce very little voltage drop in normal circuit operation. However when a fuse blows in high voltage, high current circuitry, an **arc** can be formed due to conduction by the vapourising metal. Fuses made for use in such circuits must therefore be made so



* Ambient temperature derating is in addition to normal derating — see text

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they don't allow an arc to be maintained — ensuring a safe and rapid switch-off. Fuses designed to break very high overload currents may have a special sand-filled ceramic case, to dampen the force of the exploding metal.

It's therefore very important to replace a blown fuse with one having the same voltage rating, as well as the same current carrying capacity.

Most of the fuse types used in modern electronic equipment were originally developed for use in cars. For example the letters 'AG' used in the physical size listing of common types shown in the table originally stood for 'automotive glass'. The 3AG and M205 sizes are most commonly used in electronics.

Ironically most modern motor vehicles use 'blade' type fuses, where the fusible link is inside a moulded plastic case with two thin blade-type electrodes designed to plug into a matching holder.

A final point: even though fuses do blow occasionally due to fatigue, most blown fuses draw attention to real and potentially very expensive equipment faults. So don't dismiss a blown fuse as a mere inconvenience. It may well be that a real fault has developed, and the blown fuse has done you a favour — by giving you the chance to find and fix the problem before any serious damage occurs.

Cylindrical Fuse Sizes

Package Size	Diameter		Length	
	Metric	Imperial	Metric	Imperial
1AG	6.35	0.25 (1/4")	16	0.625 (5/8")
2AG	4.5	0.177	15	—
3AG	6.35	0.25 (1/4")	32	1.25 (1 1/4")
4AG	7.1	0.281	32	1.25 (1 1/4")
5AG	10.3	0.406	38	1.5 (1 1/2")
7AG	6.35	0.25 (1/4")	22	0.875 (7/8")
8AG	6.35	0.25 (1/4")	25	1.0
M205	5.0	—	20	—

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