Application Note:
Subminiature Fuses for Primary Protection

By Chris Likely

Radial subminature fuses are commonly used in applications where PCB space is at a premium and component cost is critical, offering significant space savings over traditional 5 x 20mm ferrule fuses with only a small cost penalty. However, subminiature fuses use the same wire-in-air technology as more traditional fuses using a glass or ceramic tube construction and as such the criteria for selection are also the same.

Fuses serve two main purposes:

FIRST: to protect components, equipment and people from risk of fire and electric shock caused by overcurrents.

SECOND: to isolate sub systems from the main system once a fault has occurred. They are designed to be the 'weakest link' in a circuit, thus providing protection from sustained overload or short circuit faults in the system.

Fuses are thermally operated devices. When there is an overcurrent, the fuse element heats up and starts to melt. Once the heat has created a gap in the element, the current will start to 'arc' across the gap, causing it to burn back until the fault current has 'cleared'. The time from the start of the overcurrent event to the point where the fuse starts to arc in called the 'melting' or 'pre-arcing' time. The 'arcing' time is the time it takes for the fault to be cleared after the fuse has started to arc, and the total time from the start of the overcurrent event to the point where the arc is extinguished and the fault cleared is called the 'clearing' time.

Fuse Selection:

Under normal operating conditions, the operating voltage and current should not exceed the fuse ratings. For radial subminiature fuses, the nominal voltage rating is 250Vac, which, in practice, means the fuse can be used in conjunction with a nominal 250Vac supply where the maximum voltage can be up to 15% higher than nominal. When selecting the fuse current rating, a value at least 25% higher than the normal operating current should be selected in order to avoid nuisance opening. To obtain the correct current rating, the ambient air temperature around the fuse also needs to be taken into account. Typically, fuse ratings are validated at an ambient temperature of 25°C, both higher and lower temperatures will affect the fuse opening and current carrying characteristics. These effects are demonstrated in temperature re-rating curves, these curves should be consulted whenever a fuse is being used at temperatures significantly higher or lower than room temperature. See **Figure 1**.

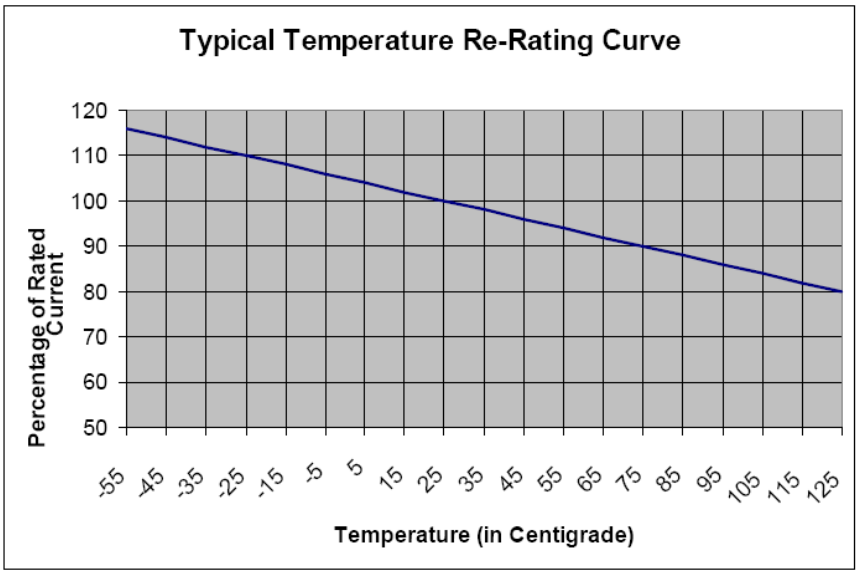

Figure 1 – Typical Re-Rating Curve for a Subminature Fuse

One of the areas where mistakes are commonly made in fuse selection is in choosing the correct value of I^2t in order to prevent nuisance opening due to surge currents that are part of the system's normal operation. First, the circuit pulse I^2t needs to be determined. **Figure 2** shows how this is achieved for a number of the most common surge current waveshapes. This value is then multiplied by a pulse factor to give the minimum fuse melting I^2t rating.

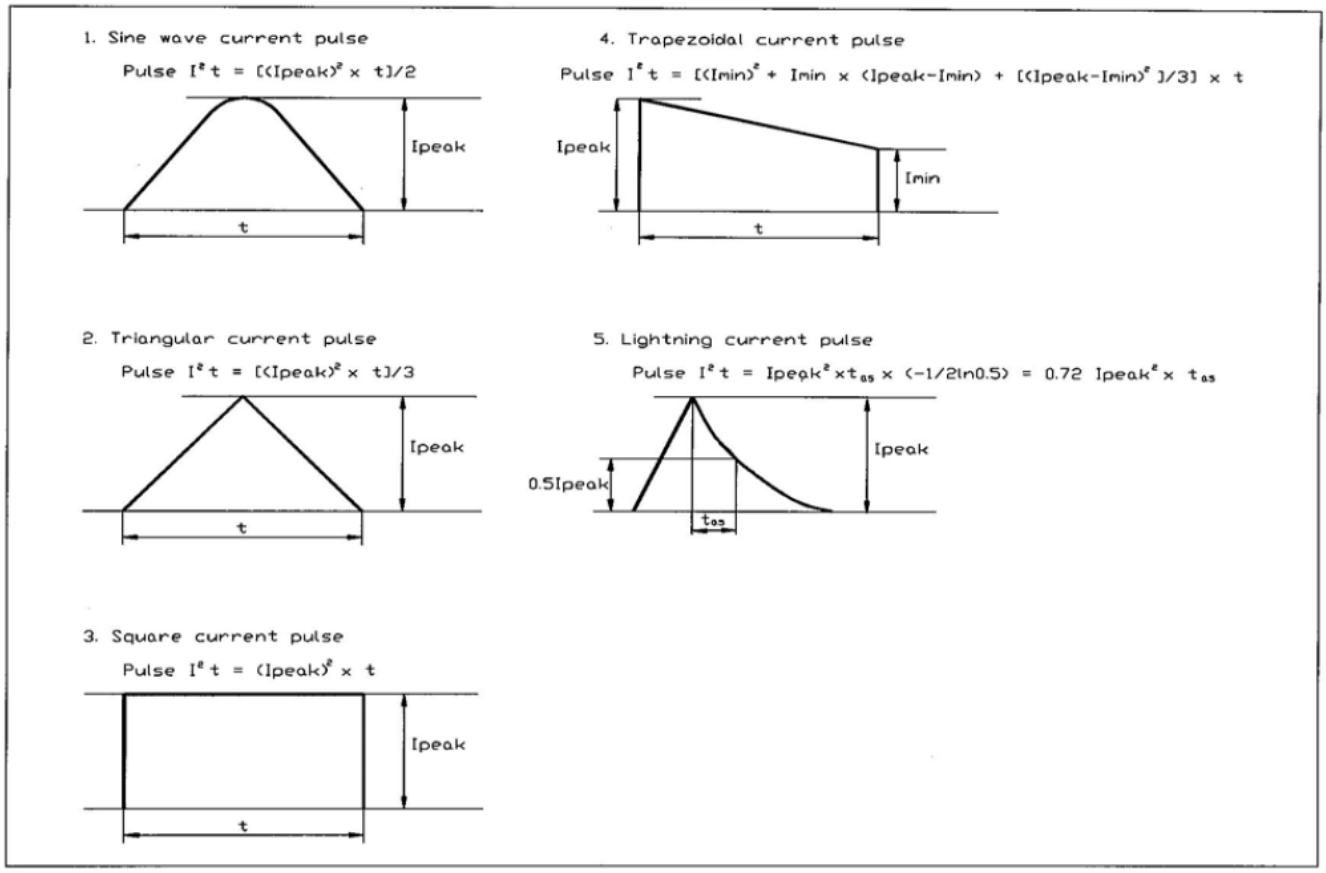

Figure 2 - Pulse Waveshapes and I^2t Calculations

The pulse factor is dependent, primarily, on the construction of the fuse element. The most commonly used construction is wire-in-air. This type of construction is affected by the number and frequency of surge pulses over the lifetime of the fuse. Normally, wire-in-air construction utilizes low melting point metal plating, or deposits, on the element to cause the element to melt at a lower temperature. This is referred to as the 'M' effect. If the fuse is sized incorrectly, low level pulse currents may cause the low melting point metals to alloy to the element without completely opening it. After a series of pulse currents, this will result in an increase in fuse resistance and, eventually, the fuse will open. **It is important to note** that the value for fuse melting I^2t must be tested at the same peak current as the circuit pulse current. **Figure 3** shows a guide to pulse factor based on fuse type and number of pulses.

Solid Matrix Construction

Number of Surge Pulses	Pulse Factor, F_p
1 to 100,000	1.25

Wire-in-Air Construction

Number of Surge Pulses	Pulse Factor, F_p
100	2.1
1,000	2.6
10,000	3.4
100,000	4.5

Figure 3 - Pulse Factor

If the circuit is not normally subject to surge currents, then a fast acting fuse can be selected. The fast acting fuse will offer greater protection as, under a fault condition, less energy is 'let through' the fuse before it opens. For circuits that are subject to surge currents, a time delay fuse is normally required. In most electronic equipment, the fuse is selected to provide short circuit protection. This is protection against a fault in the equipment that allows current to flow outside the normal path. Under this type of fault condition, the current levels can be several times larger than the normal operating current. When specifying a fuse for short circuit protection, it is important to have the correct fuse breaking capacity or interrupt rating. This is the maximum available current that the fuse can, at rated voltage, safely open without rupturing. The breaking capacity of the fuse must be equal to or greater than the available short circuit current of the system. **It is also important** to be aware of the different fuse standards, as there are significant differences between European and American regulations.

European standards tend to follow international requirements laid down in IEC60127 for electronic fuses.

In America, UL standards are applied, which in practice, means that European approved fuses are not suitable for use in America, and vice versa. However, European designed fuses can be UL Recognized and used in accordance with the UL Recognition program guidelines.

The SR-5 series of radial subminiature fuses from **Cooper Bussmann** offers a low cost solution to primary circuit protection requirements for applications such as electric shavers, lighting ballast, televisions, battery chargers and telecommunication equipment. With current ratings up to 5A and a small 8.4mm diameter footprint and 7.6mm height, the SR-5 is available in either bulk or ammo pack.