Extract from the "Sparks 'n' Arcs" column from Australian Model Engineering magazine number 169 – July-August 2013

Fuses

I flagged that I have been researching fuses in the March-April issue (167). Since then, I located several catalogue pages that listed fuses and characterized them only with physical size and with a single number "current rating". This was not good enough for the coverage I wanted to give the subject. Recently, a new JayCar catalogue has come out which lists some very interesting fuses manufactured by American manufacturer LittelFuse. These are not High Rupture Capacity (HRC) fuses, but from the datasheet appear to be suitable for use with the low voltages used in battery electric locomotives. Such a fuse, and holder are shown in Figure 154.

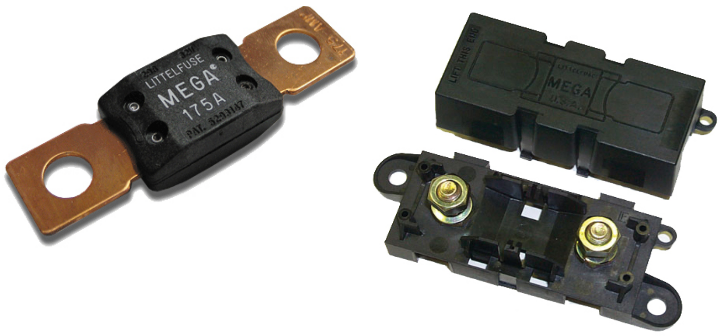

Figure 154 LittelFuse MEGA Fuse and holder.

There is more to a fuse than just carrying the current when the fuse is good, and not carrying the current when the fuse is "blown". Years ago, I was designing equipment for Telecom (Remember them? They were precursor to Telstra, but in community ownership.) The specification called for an alarm signal named "Fuse Fail". I argued that when a fuse has gone "open circuit", it has not failed to perform, but has indeed done just the opposite: it has succeeded in terminating a fault current. It reminded me of the old story about the lady who purchased a 3AG fuse (common size of fuse in a glass tube) for her vacuum cleaner from an electronics shop. She was back the next day complaining that the fuse was no good as it had blown as soon as the machine was switched on. She seemed to expect a replacement at no charge, and was not happy when she had to pay again. A week later, she met the electronics shop proprietor in the street and accosted him about the quality of his merchandise. "Your fuses are no good!" she said. "Your fuses blow as soon as the vacuum cleaner is switched on. I bought a fuse from the service station. When I switched the vacuum cleaner on, it burst into flames and was completely ruined. However, when I removed the service station fuse I found that it was still good, even when everything else in the vacuum cleaner had burned out!" Let us try to be slightly more sophisticated in our fuse use than that.

The designer of a fuse has to choose a compromise between two conflicting requirements. On one hand the user will want the resistance to be as low as possible to minimize volt drop. On the other hand it is energy dissipated in the resistance that raises the temperature of the element until it melts or vapourizes and opens the circuit. If this is to happen promptly, then that energy must accumulate at a high power. The power dissipation of a fuse element is related to the current thus:

$P = I^2.R$

Whatever the energy is that will open the fuse, it is determined by the product of the power by the time that power is applied.

$E_n = Pt$

$\quad = I^2 R\ t$

Where E_n is the energy required to open the fuse and t is the time it takes to open.

The resistance R is a parameter chosen by the manufacturer, and we, the user, are not concerned about the exact value as long as it is low enough to make the normal operational losses negligible. The important take away for us is that there is an "ideal" characteristic that I^2t is a constant. If the fault current is high, the fuse will open quickly. It will open before there is any appreciable heat loss from the element. If on the other hand, the fault current is only just above the rated current, the element will warm up slowly, and there will be a lot of heat loss. The heat loss means that the energy that must be totted up before opening will be much larger. A fuse then, will have a characteristic that is close to "I^2t is constant" for high currents, and "fuse will open (eventually) at a specified current".

Fuse characteristic curves are usually presented on a graph on which both axes have logarithmic scales. A characteristic of such a graph is that a power law, (such as I^2t = constant) is a straight line. Figure 155 shows characteristic curves for some of the MEGAfuse range, (green) with lines of constant I^2t added in red.

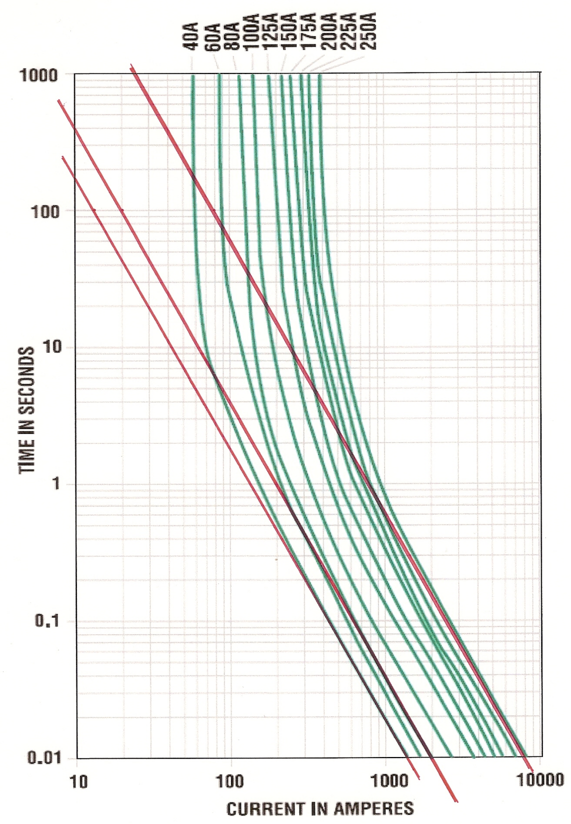

Figure 155. Fuse characteristic Curves.

It is seen that the fuse characteristic curves follow the lines of constant I^2t closely for high currents. This is important as the temperature rise in other components in the circuit will also be proportional to I^2t. This characteristic allows us to determine a maximum temperature rise in the elements of the circuit that are being protected by the circuit.

In S&A for Jan-Feb 2011, (162), I determined that a particular MOSFET could withstand 230 amps for 10 microseconds. This is an I^2t value of 0.529. If we were to have four of these in parallel in a controller (a realistic figure) the I^2t survival threshold for the combination would be about 2. The $I^2.t$ figure for the smallest fuse in range shown in Figure F2 is about 20. Thus the fuse could be relied on to protect motor windings or the heavy current wiring from a burn-out, but NOT the MOSFETs. It would be much too slow.

The LittelFuse datasheet for these fuses is at
http://www.littelfuse.com/data/en/Data_Sheets/Littelfuse-Automotive-Bolt-down-Fuse-MEGA-32V.pdf