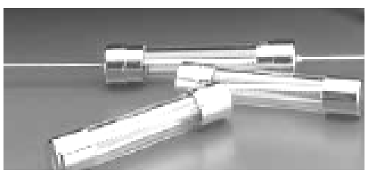
‘TECHNICAL SHORTS’

by Gerry O’Hara, G8GUH

‘TECHNICAL SHORTS’ is a series of (fairly) short articles prepared for the Eddystone User Group (EUG) website, each focussing on a technical issue of relevance in repairing, restoring or using Eddystone valve radios. However, much of the content is also applicable to non-Eddystone valve receivers. The articles are the author’s personal opinion, based on his experience and are meant to be of interest or help to the novice or hobbyist – they are not meant to be a definitive or exhaustive treatise on the topic under discussion…. References are provided for those wishing to explore the subjects discussed in more depth. The author encourages feedback and discussion on any topic covered through the EUG forum.

The Fuse – Simple Protection For Your Eddystone… ?



….or a waste of time and false sense of security?

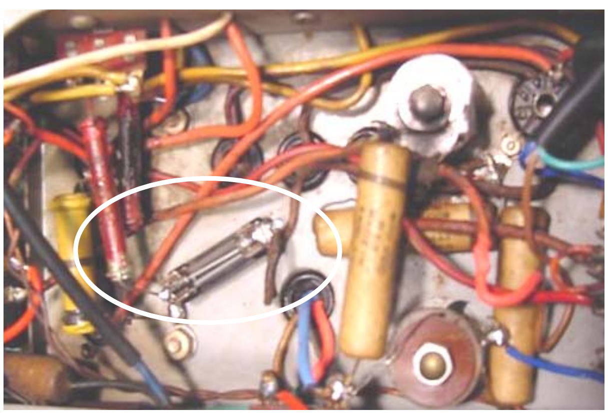
Fuses – come on, I hear you groan – we all know about fuses: a bit of thin wire in a glass tube that vapourises when too large a current is passed through it, thus protecting your electronic kit. Yes, we all know what fuses are, possibly having learned to fit fuses to those UK-style plugs as a kid as I did – usually fitting a 13 amp fuse as did your parents - because that is what those plugs are rated for aren’t they?…. a fat lot of protection that would afford electronic devices, when many draw less than 1 amp from a 115v supply when working correctly, never mind from a 240v supply (approximately half). Perhaps we should look into the use of fuses more closely if we are to have them afford even a semblance of protection to your precious Eddystone investment(s)…

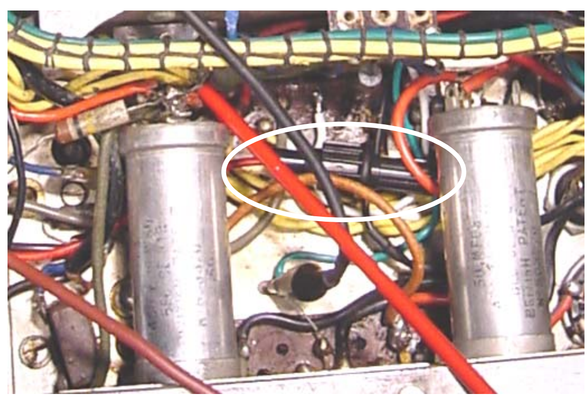
Many Eddystone models, along with other quality radios, have at least one fuse fitted, usually in the primary of the power transformer and/or between the centre tap of the power transformer HT secondary and ground. If your set does not have a fuse fitted in one of these positions, then I would recommend fitting one NOW – it can be done with the minimal of intrusion – I often fit an in-line $1^1/_4$ inch fuseholder between the live power connection (cord) and the on-off switch under the chassis in these circumstances. A few minutes fitting this simple and low-cost device can save the cost of a new power transformer, choke, rectifier valve or more… that of a house fire.... or even your life, for less than a couple of dollars.

Fuse Holders

Fuses, or ‘fuse cartridges’ to give the full title to the small glass (or ceramic) bodied types with metal caps we normally encounter in electronic equipment, usually need holders to allow them to be mounted in a circuit whilst allowing easy change-out in the event of the fuse blowing. Post WWII Eddystone receivers are usually fitted with at least one Belling-Lee (or similar) $1^{1}/_{4}$ inch chassis-mounted screw-in type fuseholder - see photos of those fitted to my S.750 (right) and S.770R (left) above. Depending on the model, the fuse may be fitted in the primary of the power transformer (as per my 830/4) or between the centre tap of the power transformer HT secondary and ground (as per my S.750). My S.770R had a fuse in each of the live and neutral lines to the transformer primary when it left the Bath Tub and I have now modified that arrangement to have one in the primary and one in the secondary circuits (using the same fuseholders). I also retro-fit additional fuseholders to sets fitted with only one (eg. my S.750) or none at all.

Retro-fitting chassis-mounted fuseholders normally necessitates difficult and irreversible 'surgery' of the radio chassis. I therefore opt for the much less intrusive in-line or surface mount types (to the left and right of the line-up above)– both work well and the most suitable of these may be selected for the particular application and location in the set (photos of some installations in Eddystone sets below).

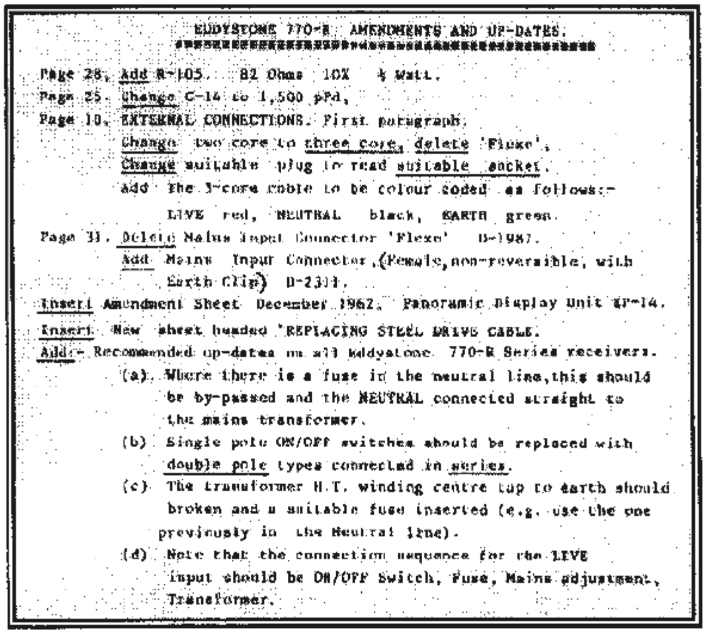




An in-line fuseholder retro-fitted to the power transformer primary in my S.750 (right) and a chassis-mount fuseholder retro-fitted in the secondary centre tap of my S.740 (left).

Location of a Fuse in a Typical Radio Circuit

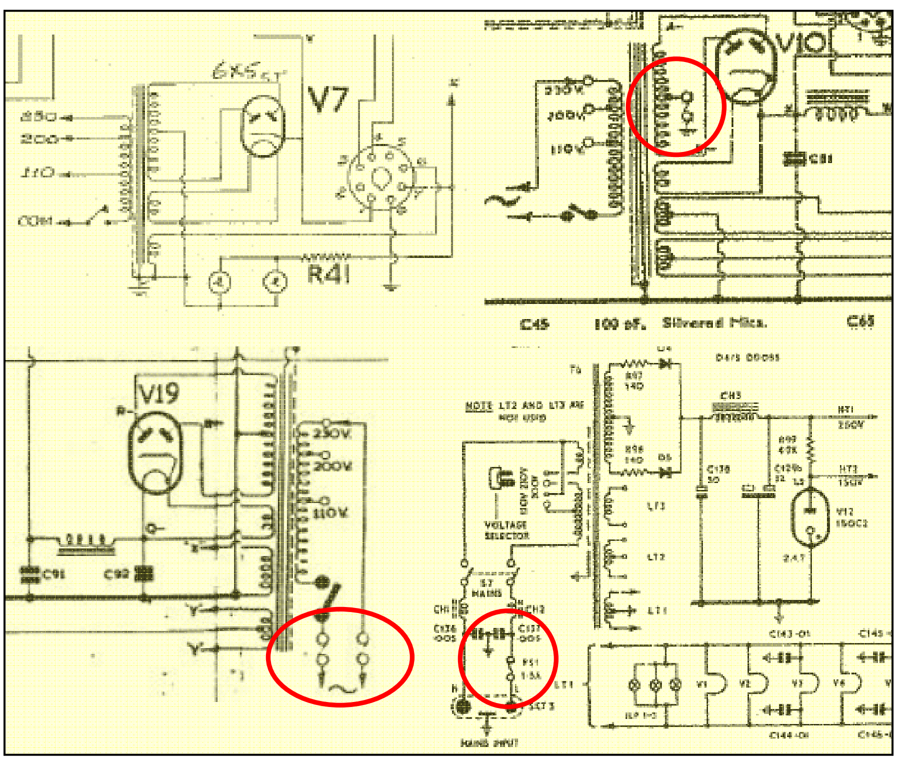
So, why do some circuits have fuses in the power transformer primary? (sometimes in both the live and neutral lines as in my S.770R – pre-modification, as noted above)



EDDYSTONE 770-R AMENDMENTS AND UP-DATES.

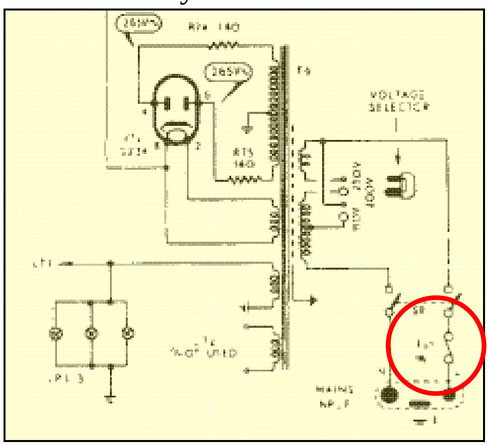
Page 28. Add R-105. 82 Ohms 10% ½ Watt.
Page 25. Change C-14 to 1,500 pFd,
Page 10. EXTERNAL CONNECTIONS. First paragraph.
Change two core to three core, delete 'Flexe'.
Change suitable plug to read suitable socket.
Add The 3-core cable to be colour coded as follows:-
LIVE red, NEUTRAL black, EARTH green.
Page 31. Delete Mains Input Connector 'Flexe' D-1987.
Add Mains Input Connector,(Female,non-reversible, with Earth Clip) D-2311.
Insert Amendment Sheet December 1962. Panoramic Display Unit EP-14.
Insert New sheet headed 'REPLACING STEEL DRIVE CABLE.
Add:- Recommended up-dates on all Eddystone 770-R Series receivers.
(a). Where there is a fuse in the neutral line,this should be by-passed and the NEUTRAL connected straight to the mains transformer.
(b) Single pole ON/OFF switches should be replaced with double pole types connected in series.
(c) The transformer H.T. winding centre tap to earth should broken and a suitable fuse inserted (e.g. use the one previously in the Neutral line).
(d) Note that the connection sequence for the LIVE input should be ON/OFF Switch, Fuse, Mains adjustment, Transformer.

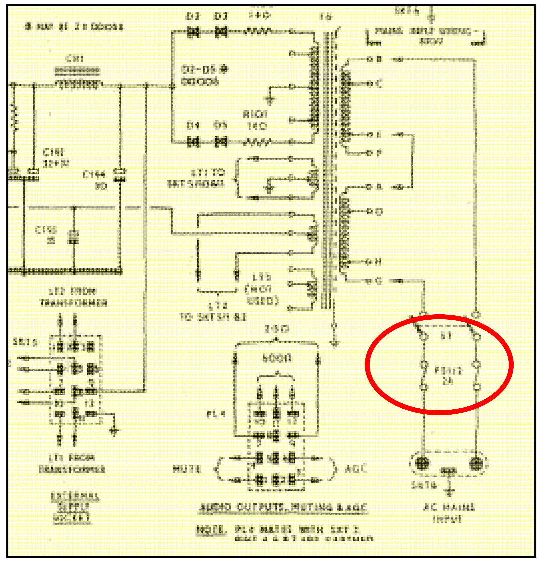
and some in the power transformer secondary (eg. in the S.750) whereas others have both? - even the folks at the Bath Tub appeared to change their mind after the sets were in production for a while (see 'amendments and updates' for the S.770, left). This is a really good question: a fuse in the primary circuit, in theory, should protect the whole radio in the event of an over-current fault developing, as any excess current draw in the transformer secondary, eg. due to a shorted power supply HT smoothing capacitor, should be reflected immediately by a surge in primary current also. However, in practice, damage can occur to the transformer secondary or in connected circuits, before the primary circuit fuse blows (indeed if it blows at all). This is an artefact of two things, 1) around half the set power is consumed by the valve heaters connected to two or more LT, high current, secondary windings. This reduces the differential between normal and HT (short) fault currents in the



Selection of fuse locations in Eddystone receivers, clockwise from top left: S.640 (none indicated), S.750 (secondary HT centre tap), EA12 (single fuse primary) and S770R (dual fuse primary)

transformer primary, and 2) current surge at power-on, due mainly to heavy current consumption of the cold valve heaters, resulting in a current surge in the transformer primary, hence the need to 'beef-up' the current rating of a fuse placed in this location to avoid frequent failure. By the same token, a fuse in this location may react (blow) if a short occurs on a LT (heater) winding, whereas a fuse in the secondary HT circuit would not. Somewhat better protection of the secondary HT winding and associated components (eg. rectifier tube and choke/filter resistor) is afforded by a fuse in the transformer HT secondary centre tap to ground connection. However, in cases where silicon rectifiers are used (eg. my 830/4), this is not necessarily the case – Peter Lankshear and Ron Brown note that if one diode in a two diode full-wave rectifier arrangement (as found in the EA12 and S.830 series of sets) develops a short, a fuse in the secondary centre tap will not protect the other diode as it will then have twice the normal voltage applied to it and this will (likely) also fail (usually a short). A heavy (AC) current will then pass through the entire secondary winding of the transformer and the two shorted diodes (but <u>not</u> through the centre tap fuse), resulting in an overheated or failed mains transformer. In summary, there is no ideal location for a fuse to protect a radio, but it is probably worth placing them in both primary and secondary transformer circuits to afford whatever protection they can…





Left - the S.940 has a single primary fuse, whereas the S.830/7 (above) has a double primary fuse fitted (other S.830 series models have different arrangements). Note the diode rectifiers used in the EA12 and S.830 series (see discussion in text)

What 'Size' (current rating) of Fuse Should be Used?

Selection of 'quick-blow' fuses – usually just a piece of thin wire, but sometimes the wire is shaped or patterned

So, by now you've installed the fuseholder(s) - good. That done, the most frequently asked questions about the fuses to place in them are "what size (current rating) will give good protection but will not blow under normal operation of the set?" (ie. give inconvenient and troublesome false alarms of a non-existent fault condition in the set) and " what type of fuse should I fit – quick or slow acting?". All types are readily-availably, ranging from really slow – they don't blow for several seconds, to really fast – ie, they blow in a few milliseconds (still not fast enough for many solid state devices – but who cares about that? - we are talking valve kit here…).

Selection of ‘slow-blow’ fuses – most are easily identified, but the type on the right can be mistaken for one of the ‘quick-blow’ variety

Generally, the MINIMUM fuse size should be based on 125% of the circuit’s full load current, with a MAXIMUM of 300% of the circuit’s full load current: 200% is typical. Time-delay type fuses, often termed ‘slow-blow’ should be used for inductive and large capacitive loads, such as in radio power supply circuits, where power-on current surges can occur, with fast-acting fuses, often termed ‘quick-blow’, used to protect non-inductive loads, in particular sensitive circuitry. I usually fit a ‘slow-blow’ type in the power transformer secondary centre tap, rated at 150% to 200% of the maximum HT current draw and a regular (‘quick blow’) type in the power transformer primary, rated at 200% to 300% of the expected operating current draw based on the manufacturers wattage rating of the set. If you find that fuses of these ratings blow frequently, then suspect a developing fault condition in the radio. It should be noted that fuses should be de-rated when used in high temperatures and/or close the their marked amperage rating – they are normally rated at 25C.

Closure

Well, that is about it on fuse ‘Lore’ – these much maligned and oft poorly understood devices could (with a bit of luck and good judgment combined), save that precious Eddystone from a nasty roasting… or much worse. To find out more about fuses, their characteristics and selection, check out some of the manufacturer’s websites and/or download a Product Catalogue – they are often full of good information.

As with my other articles, I hope readers will find one or two useful tips in the above musings, or that they stimulate thought and curiosity, or for others to submit additional material, either as an article or a post on the EUG forum.

Gerry O’Hara, G8GUH, Vancouver, Canada, October, 2006 (G8GUH@telus.net)

Some Useful References

- Radio Communications Handbook, RSGB (eg. 4th Ed, Chapter 17)
- Radio Amateurs Handbook, ARRL (eg. 57th Ed. Chapter 5)
- Radiotron Designers Handbook (Langford-Smith), 3rd and 4th Editions
- Various EUG Lighthouse articles, including:
  - Issue 74, page 18 (888 HT fuse blowing)
  - Issue 78, Page 15 (lack of fuse in model 556)
  - Issue 83, page 30 (Power Supplies in Eddystone Receivers by Ron Brown, with comments by Peter Lankshear), referencing Issue 78, page 37 (Silicon Diodes as Valve Substitutes – are they such a good idea? By Peter Lankshear)
  - Issue 84, page 37 (S.770R fuse mods)
- Manufacturers fuse selection guides (two examples appended to this article)
- Some web-based articles/resources on fuses include:
  - http://www.littelfuse.com/cgi-bin/r.cgi/en/know_content.html?ContentID=77&LFSESSION=URGuCpr3cO.
  - http://www.sunfuse.com
  - http://www.profuseinternational.com/pdfs/Newbery.pdf
  - http://www.allaboutcircuits.com/vol_1/chpt_12/4.html

Fuse Selection Guide

Fuse is a safety protection component for preventing fault current from causing hazards or serious damage in electric equipment. There are different types of fuses designed to meet different application requirements. To select an appropriate fuse for a particular application, several parameters should be considered.

1. Amperage rating (A)

Amperage rating indicates the current carrying capacity of a fuse. Normally, a fuse can hold continuously a current equal to or less than its amperage rating without blowing, at a standard environment specified by the relevant testing standards. However, since the actual current flows through the fuse may vary due to variations of other componenets and working environment, an allowance is usually provided when selecting the amperage rating of a fuse in order to avoid nuisance blowing. In other words, the amperage rating of a fuse should always be greater than the normal working current. An minimum allowance of around 20 to 25 percents is usually considered acceptable. The upper limit of amperage rating on the other hand is usually determined by the level of overload protection required. Although it is sometime difficult to obtain exact information, the amplitude of expected fault current and maximum allowed period within which a fuse must clear the fault current are very important in deciding the highest amperage rating to be used.

2. Voltage rating (V)

The voltage rating of a fuse states the maximum supply voltage that the fuse can safely clear. The most popular types of voltage ratings are 125V and 250V. A fuse should only be used at supply voltage less than or equal to its rated voltage. For example, a 125V fuse can be used at 110V supply voltage but not 220V while a 250V fuse can be used at both 110V and 220V supply voltages.

	110V equipment	220V equipment
125V fuse	Acceptable	Not acceptable
250V fuse	Acceptable	Acceptable

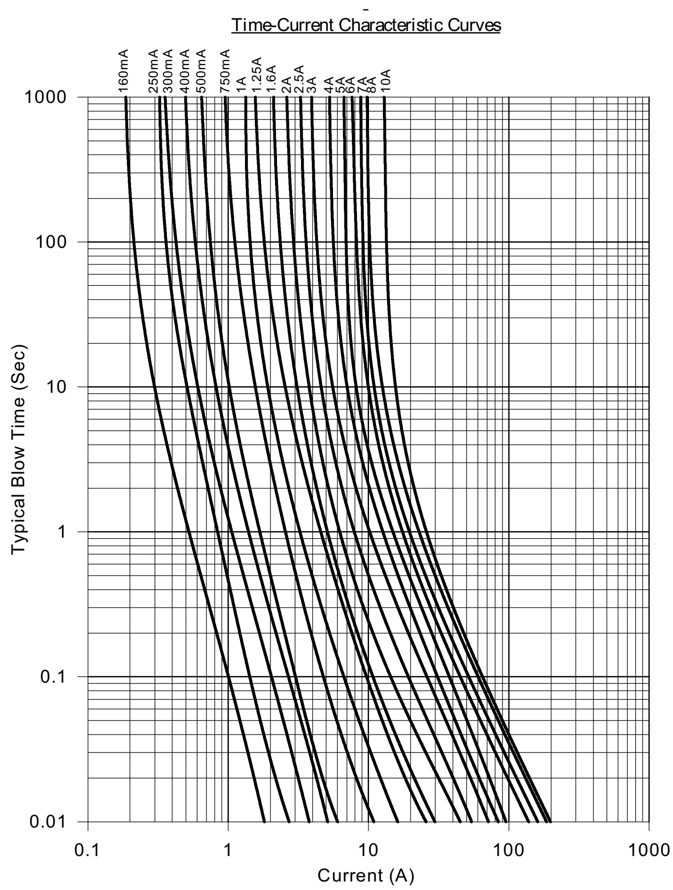
3. Blowing characteristics

Basically, fuses can be divided into two blowing characteristics, quick acting and slow blow. Quick acting fuses will react quickly to clear fault current for protecting delicate circuit. Slow blow fuses on the other hand can withstand surge current for a short period and blow when the overload current sustains. It is used mainly in applications where surge current is anticipated in normal operation, for example, the switch-on surge current of motors. A quick acting fuse may blow easily in those cases and require frequent replacement. Slow blow fuses are designed to solve this problem.
However, there is no universally accepted criteria for classifying quick acting/slow blow fuses. Different manufacturers may have different terminologies and specifications. Their products while have similar descriptions (slow blow or time lag), may have different degree of slow blow characteristics. The descriptions "quick acting" and "slow blow" only provide a rough indication of blowing characteristics. In order to get a more detail picture, the time-current characteristic curve and I^2t value should be studied.

Fuse Selection Guide

- **Time-Current Characteristic Curve**

It is a curve of blow time plotted against current, usually on a log-log scale graph paper. From this curve, the relationship between current and blow time of a fuse can be easily revealed. The typical blow times corresponding to different overload currents can be estimated from the curves. Slow blow fuses will have longer blow time especially at high current region (the lower right end of the curve will be higher compared with that of a quick acting fuse with same amperage rating). Slow blow fuses from different manufacturers may show different shapes of time-current characteristic curve. The appropriateness of using a fuse in a specific application should be justified by checking whether the corresponding time-current characteristic curve can fulfill both the overload protection and long term reliability requirements.



- **I^2t value**

The time-current characteristic curves usually only provide data down to 10 milliseconds. For blow time less than 8-10 msec (which is ½ cycle of 50Hz or 60Hz AC current), the actual blow time will be significantly affected by the phase angle at which the current is switched on. I^2t is a more meaningful value to represent the blowing characteristic of a fuse at such a short blow time. It is a value proportional to the let-through energy (the integral of square of current against time, with unit A^2sec) of a fuse before it blows at high overload current with blow time less than 8-10ms.

$$\int I^2 dt$$

where I is the current value at time t.

The I^2t value of a fuse should be greater than that of a surge current if the fuse is required to withstand the surge. The greater the I^2t value, the better the fuse surge resistance will be. However, unnecessarily great I^2t value may lead to safety problem if the fuse fails to clear a high fault current fast enough to avoid causing hazardous situation or damage to other more delicate components. A fuse chosen should have I^2t value between the desired surge resistance and maximum allowable fault current I^2t value.

I^2t value of surge current < I^2t value of fuse < Maximum allowable fault current I^2t

4. Safety approvals

Fuse is a safety protection component. Many countries require fuses to be approved by specified safety agencies. The most popularly accepted safety approval agencies are : Underwriters' Laboratories (UL) of U.S.A.; Canadian Standards Association (CSA) of Canada; Swedish Institute of Testing and Approvals of Electrical Equipment (SEMKO) of Sweden and VDE of Germany. UL and CSA have the same requirements which are stipulated in harmonized standards. The European approvals, like Semko and VDE basically follow the same relevant IEC standards.

- North America - UL, CSA
  The harmonized standards of UL and CSA for miniature and micro fuses are UL 248-1 and -14 (or CSA-C22.2 No. 248.1 and No. 248.14). Their fusing characteristic requirements are summarized at the table below.

Percentage of rated current	Blow time	
	Miniature fuses	Micro fuses
100%	Not blow	Not blow
135%	1 hour maximum	Not applicable
200%	2 minutes maximum	1 minute maximum

- Europe - SEMKO, VDE
  The European approvals follow the standards issued by International Electrotechnical Commission (IEC). The standard for miniature fuses is IEC127-2. There are different standard sheets in this standard for different fuse types. The fusing characteristic requirements of two of the standard sheets are summarized at the table below for comparison with that of UL/CSA.

Percentage of rated current	**IEC127-2, Standard sheet II** 5x20mm, quick acting, Low breaking capacity	**IEC127-2, Standard sheet III** 5x20mm, time lag, Low breaking capacity
150%	1 hour minimum	1 hour minimum
210%	30 minutes maximum	2 minutes maximum
275%	50ms minimum, 2 sec maximum	600ms minimum, 10 sec maximum
400%	10ms minimum, 300ms maximum	150ms minimum, 3 sec maximum
1000%	20ms maximum	20ms minimum, 300ms maximum

Note : The specification of UL/CSA and IEC127-2 stipulated above is just a brief representation. The corresponding standards should be referred for the exact details.

Fuse Selection Guide

5. Mounting methods

Depending on the fuse construction and other installation constrains or requirements, fuses can be installed for use by different mounting methods.

Fuse construction	Cartridge	Leaded	SMD
Mounting methods	- Fuse clip - Fuse holder	- Direct soldering - Crimping	- Surface mount

Cartridge fuses installed in fuse clips or fuse holders offer the advantage of easy replacement but the material and installation cost will be higher. The leaded fuses can be directly inserted into printed circuit board and soldered by automated soldering processes to reduce assembly labor cost. Crimping connection allows leaded fuses to be installed in some areas where other mounting methods will not be feasible. SMD fuses are specially designed for SMD assembly and soldering processes, usually of smaller size comparing with cartridge and leaded fuses.

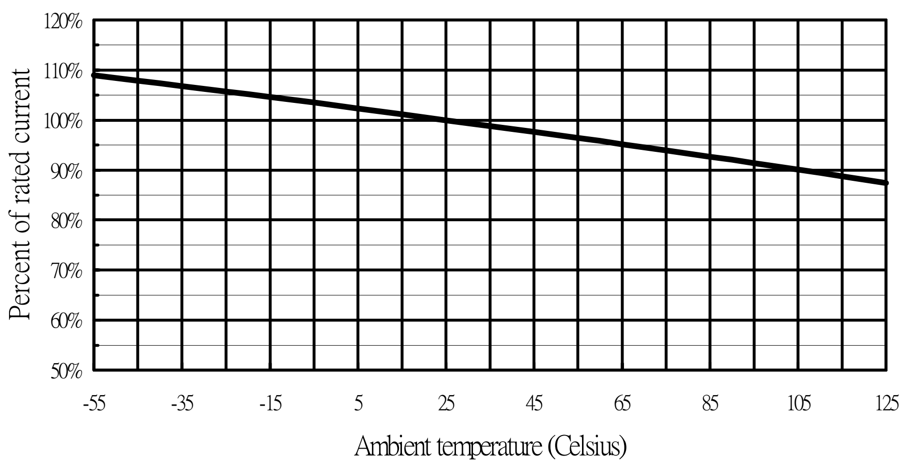
6. Size

There are two most popular sizes of miniature fuses - 5mm diameter x 20mm length and 1/4" diameter x 1-1/4" length. Appropriate size should be selected to match the fuse clips/holders or the space available. If only limited space is available, micro fuse can be considered.

7. Derating characteristic

Fuse is a thermal sensitive device. The ambient temperature will affect heat transfer from the fuse to the surrounding and hence the current carrying capacity of the fuse. The nominal amperage rating of a fuse is usually established at ambient temperature of 25°C. The higher the ambient temperature, the lower the current carrying capacity will be. Appropriate allowance should be given when deciding the amperage rating of a fuse used at temperature significantly higher or lower than 25°C. Fuses of different constructions and materials may be affected differently by the ambient temperature. The typical relationship of ambient temperature and current carrying capacity is illustrated below.

Typical Derating Characteristic



Fuse Facts and Fuse Selection Guide

DERIVATION OF NOMINAL MELTING I^2t: Laboratory tests are conducted on each fuse design to determine the amount of energy required to melt the fusing element. This energy is described as nominal melting I^2t and is expressed as "Ampere Squared Seconds" (A^2 Sec.). A pulse of current is applied to the fuse, and a time measurement is taken for melting to occur. If melting does not occur within a short duration of about 8 milliseconds (0.008 seconds) or less, the level of pulse current is increased. This test procedure is repeated until melting of the fuse element is confined to within about 8 milliseconds. The purpose of this procedure is to assure that the heat created has insufficient time to thermally conduct away from the fuse element. That is, all of the heat energy (I^2t) is used, to cause melting. Once the measurements of current (I) and time (t) are determined, it is a simple matter to calculate melting I^2t. When the melting phase reaches completion, an electrical arc occurs immediately prior to the "opening" of the fuse element. Clearing I^2t = Melting I^2t + arcing I^2t. The nominal I^2t values given in this publication pertain to the melting phase portion of the "clearing" or "opening".

FUSE SELECTION GUIDE

The application guidelines and product data in this guide are intended to provide technical information that will help with application design. Since these are only a few of the contributing parameters, application testing is strongly recommended and should be used to verify performance in the circuit/application.

Many of the factors involved with fuse selection are listed below:

Selection Factors

1. Normal operating current
2. Application voltage (AC or DC)
3. Ambient temperature
4. Overload current and length of time in which the fuse must open.
5. Maximum available fault current
6. Pulses, Surge Currents, Inrush Currents, Start-up Currents, and Circuit Transients
7. Physical size limitations, such as length, diameter, or height
8. Agency Approvals required, such as UL, CSA, VDE, METI, MITI or Military
9. Considerations: mounting type/form factor, ease of removal, axial leads, visual indication, etc.
10. Fuseholder features: clips, mounting block, panel mount, p.c. board mount, R.F.I. shielded, etc.

NORMAL OPERATING CURRENT: The current rating of a fuse is typically derated 25% for operation at 25°C to avoid nuisance blowing. For example, a fuse with a current rating of 10A is not usually recommended for operation at more than 7.5A in a 25°C ambient. For additional details, see RERATING in the previous section and AMBIENT TEMPERATURE below.

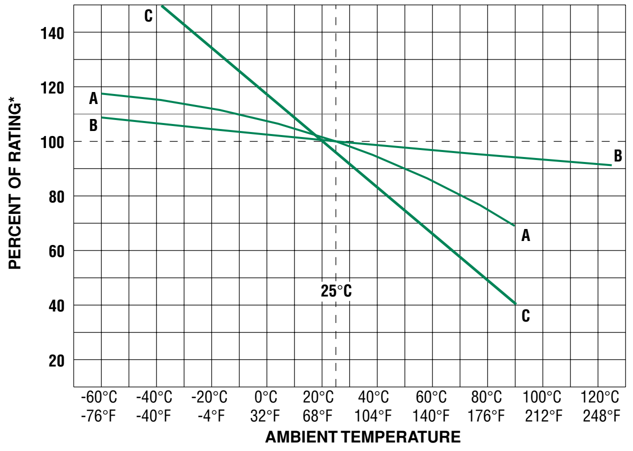
VOLTAGE: The voltage rating of the fuse must be equal to, or greater than, the available circuit voltage. For exceptions, see VOLTAGE RATING.

AMBIENT TEMPERATURE: The current carrying capacity tests of fuses are performed at 25°C and will be affected by changes in ambient temperature. The higher the ambient temperature, the hotter the fuse will operate, and the shorter its life will be. Conversely, operating at a lower temperature will prolong fuse life. A fuse also runs hotter as the normal operating current approaches or exceeds the rating of the selected fuse. Practical experience indicates fuses at **room temperature** should last indefinitely, if operated at no more than 75% of catalog fuse rating.

CHART SHOWING EFFECT OF AMBIENT TEMPERATURE ON CURRENT-CARRYING CAPACITY (TYPICAL)

KEY TO CHART:

Curve A: Thin-Film Fuses and 313 Series (.010 to .150A)
Curve B: Very Fast-Acting, Fast-Acting, and Spiral Wound Slo-Blo® Fuses
Curve C: Resettable PTC's



*Ambient temperature effects are in addition to the normal rerating, see example.

Example: Given a normal operating current of 2.25 amperes in an application using a Very Fast Acting fuse at room temperature, then:

$$\text{Catalog Fuse Rating} = \frac{\text{Normal Operating Current}}{0.75}$$

or

$$\frac{2.25 \text{ Amperes}}{0.75} = 3 \text{ Amp Fuse (at 25°C)}$$