

# FUSES



The Blow that Saves You Money!

by Ted Mann

**F**OR two bits or less you can protect \$500 when you consider that an inexpensive fuse protects a costly color TV set. Would you believe ten cents worth of electric protection saves \$35,000? Fuses also keep the house from burning down. The little zinc links can *pop* in picoseconds or broil hours before blowing. Hundreds of fuses and circuit breakers safeguard electronic equipment against shortcircuit damage, momentary surges or slow overload. Pick the right one and you'll never put a penny in the fuse box, wrap cigarette foil around a glass fuse, or jump wire across cartridge clips—all dangerous dodges of those who refuse to *re-fuse*.

**Thar' She Blows.** Edison made the first fuse before 1900 by enclosing a thin wire in a lamp base. As an intentionally weakened part of the circuit, the wire acted as a safety valve which melted from excessive current. Trouble was, early fuses were nearly as dangerous as the condition they were designed to prevent. Fuse wire fashioned from copper, had to reach dangerous temperature before blowing. This is now cured by changing to metal alloys of lower melting point.

You can see another problem by observing how a fuse blows. See Fig. 1. The link begins to overheat in the slim center region. Overheating begins at this point since the wider ends of the link are better able to

radiate heat. Soon the melted center drops away.

This supposedly ruptures the circuit, but a second effect takes over. Circuit voltage is still applied across the narrow gap in the link and it strikes an electrical arc. This burns back metal toward each end until increasing electrical resistance kills the arc. That happens during a simple overload. But everything's vastly speeded up for a dead short.

You can see in Fig. 1 that a total short circuit explodes the link. The whole center section, in fact, suddenly vaporizes. And the vapor itself becomes a good electrical conductor—so the arc keeps snapping dangerously across the gap. Is that a safety valve?

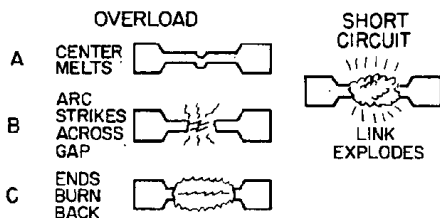
Today's fuses are not lethal weapons because of certain refinements in construction. The larger, cartridge-type fuses contain a powdery filler material that quenches the arc through cooling and condensing the metal vapor. In smaller fuses, sturdy, insulated tubes of glass or porcelain provide necessary protection. See Fig. 2. One manufacturer states (with a Gothic turn of phrase) that today's fuse won't "belch fire."

**Vengeful Volts.** Most talk about fuses concerns amperage and how various types respond to current flow. Yet all fuses are rated by volts. This relates to the explosive fury of a fuse gone wrong. Although a fuse may have a well-insulated holder, certain

# e/e FUSES

conditions may cause voltage to soar dangerously as the fuse blows.

If it's protecting a circuit that contains a coil, for example, sudden interruption may cause an "inductive" kick to feed back to the fuse terminals. It could be sufficiently high to shatter the holder. Voltage ratings assigned to fuses, though, are quite conservative.



**Figure 1. Major difference between overload, short circuit is amount of time it takes for fuse center link to melt apart.**

When a fuse is rated at 125 volts, for example, it refers to a standard test performed by the manufacturer. He assumes that the fuse will not shatter on this voltage when subjected to a short circuit with the colossal current of 10,000 amperes! Unless you're protecting a private power generating plant, your electronic equipment subjects the fuse to a piddling fraction of those ratings. Thus circuit voltages may usually be higher than fuse voltage rating without undue hazard.

**Twin Ratings.** The job of choosing a fuse would be simple if it merely meant measuring a circuit you wish to protect, then selecting a type to blow on slightly higher amperage. A hi-fi amplifier might operate with AC line current of 1.4 amps, but a 1.5-amp fuse would be a poor choice. It would cause much "nuisance" blowing. Whenever you turned on the amplifier, a sudden inrush of current (to charge big filter capacitors in the power supply, for example) might cause the fuse link to let go. And some devices, like an electric motor, draw starting currents far greater than normal running amperage.

At the other extreme, a delicate test instrument might be destroyed if the fuse didn't speedily break the circuit. These variations introduce *time* as an element that's just as important as the number of amperes. Some fuses have a built-in mechanism that decides whether to blow fast or slow, de-

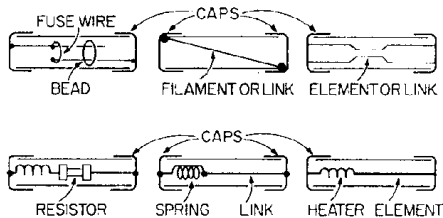
pending on circuit conditions.

But, first, what does a fuse rating actually mean? Simply saying that a fuse in a car radio is rated at 7½ amps doesn't tell the whole story. The 7½ amp figure means the fuse can carry that current indefinitely. Determining the current needed to melt the fuse must also reckon with overload time.

A typical automobile fuse might take fully four hours to blow when the fuse's rated current reaches 110 percent—which is amps times 1.1. This would happen as the radio drew 8¼ amps through the fuse (or 7.5 X 1.1). This is not a severe overload and the radio is still protected.

But if a short-circuit caused current to zoom to double the fuse rating—or 200 percent—the fuse promptly pops within 20 seconds. Higher percentages of overload would even speed up the process. Thus the radio continues to operate during minor surges. It won't blow the fuse unless overload current threatens irreversible damage to its components.

Not all devices need this brand of protection. To cope with a wide range of equipment, fuses are manufactured in three broad categories that relate to blowing times: *Medium Lag*, *Quick-Acting* and *Time Delay*. A look at these types reveals that fuses might have the same ampere rating but behave in quite different fashion.



**Figure 2. Construction variations between various fuse types gives each its own special set of characteristics.**

**Medium Lag.** This is the most common type you're apt to encounter. It also goes under the name "Normal Lag" or "Standard." This is the fuse for auto and other radios, amplifiers, TV sets heaters and lighting circuits. If you want an idea of how such a fuse behaves, check the curve marked "Medium" in Fig. 3. It reveals, for example, that at 200 percent of rated current (two times), the fuse typically blows in about 5 or 6 seconds. The greater the overload, the faster the action.

Common fuses in the medium category

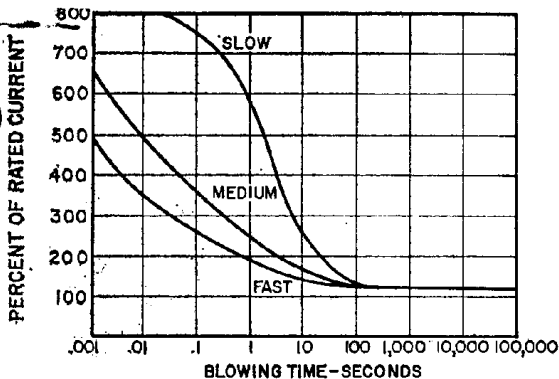
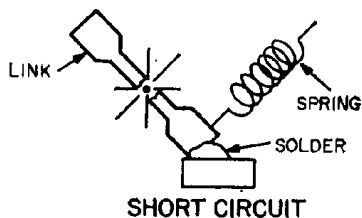


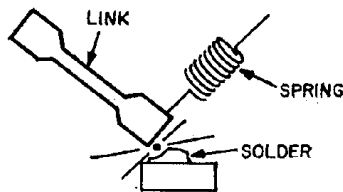
Figure 3. Note how slow-blow fuse takes considerably longer time for a current surge to open the circuit.

are the S.F.E. types (for automobiles) and 3AG by Littelfuse. There's also the AGC type made by Bussmann. The letters "AG", incidentally, originally meant "automotive glass".

As the "AG" number rose so did amperage rating and physical length. This was intended to foil any attempt to insert a fuse of excessive rating into a holder. So many new fuse types have appeared, however, that the system is all but abandoned. "AG" is no longer a reliable index of fuse size.



SHORT CIRCUIT



CONTINUOUS OVERLOAD

Figure 4. Dual-purpose mechanism of slo-blo fuse allows it to withstand momentary shorts, continuous overloads typically up to 400% of rated current in circuit.

**Quick-Acting.** This fuse category is also known as "Instrument" or "Fast-Acting." As the name implies, this kind of fuse blows faster than the medium type. It's useful for delicate instruments, meters and other devices that can't tolerate even small overload currents for any length of time. The fuse element is very fine and low mass causes it to melt at rates marked "Fast Blow" in Fig. 3. Note that at 200 percent rated current,

the fuse expires in less than a second.

**Slow-Blow.** Also known as the "slow-acting," "time-delay" or "time-lag" fuse, this type lets a strong surge through the circuit without blowing, but protects against shorts and overloads. It is especially useful for motors, switching circuits and TV receivers. Special dual construction enables the fuse to operate in two ways.

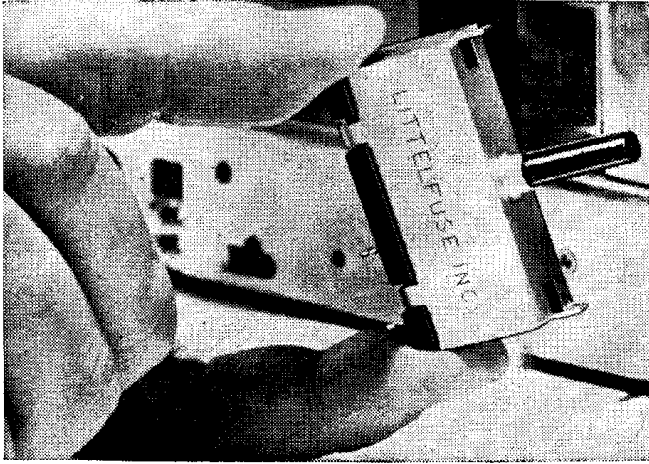
As shown in Fig. 4, the fuse contains the regular fusible link found in other types. It is designed to blow only during extreme short-circuit conditions. The second mode of operation occurs during a continuing overload condition, far longer than a temporary surge. This causes heat to build near the spring portion. If of sufficient duration, the heat softens the low-melting solder and the spring pulls the link to break the circuit. The slow-blow fuse is often applied in circuits that can tolerate currents of about 400 percent normal for 1 to 10 seconds.

**Specials.** As you can see in Fig. 5, there are many variations in fuses to meet special applications. (The fuses shown in Fig. 5 were available for photography at e/e's editorial office at the time this story was prepared for publication. There are many more types



Figure 5. Three different fuse styles are shown, but each has its own current rating. Hint: NEVER substitute like-styled fuse of higher amp rating for lower-amps-rated one.

state rectifiers occur in the TV power supply. When the set is first turned on, a heavy inrush of current must be limited by a small-value resistor (usually less than 10 ohms) to protect the rectifiers. By making a resistance element with fuse-like qualities a single component, the fusible resistor does the job of two parts. The component is often mounted with plug-in pins for convenient replacement.



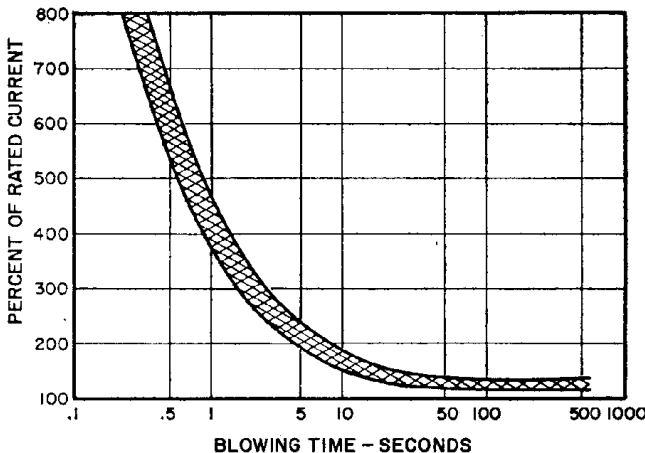
*Figure 6. Forget that box of spare fuses you keep at arms distance from your tv. Circuit breaker eliminates need for replaceable fuse, can be reset as often as needed. Press cylindrically-shaped button located on top of circuit breaker after you find fault; your tv is once again protected. Circuit breakers come in many ampere ratings.*

**Circuit Breakers.** A leading contender in the fuse field is the circuit breaker. See Fig 6. It's found on many major appliances and the newer TV sets. The attraction is obvious: you just press a red button after an overload. No need to hunt for a fuse.

As you can see by the curve in Fig. 7, the breaker behaves like a fuse, permitting brief

leased before the circuit breaker closes.

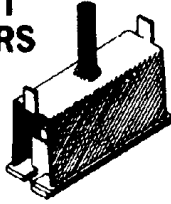
The chart in Fig. 8 shows typical ratings for several *Mallory* breakers. Note in all units that breaking the current is somewhat higher than operating current, but allowable surge current is much higher than either rating. Tripping time is ten seconds or less after breaking current is reached.



*Figure 7. Curve of circuit breaker looks like medium lag fuse characteristic curve as shown in Figure 3. Current rating tolerance of circuit breaker is wider than that of normal fuse; crosshatching for this particular circuit breaker shows about 20% overall tolerance.*

## MALLORY RESET CIRCUIT BREAKERS

- Just Reset
- Not A Fuse—  
A True  
Circuit Breaker



Exact replacement circuit breakers for television and industrial applications. Button must be pressed to reset. Tripping mechanism is temperature compensating for constant protection. Normal tripping time is 10 seconds or less. All values above 3-1 amps have special heavy-duty contacts to withstand heavy surge currents. Twist tab mounting lugs. Adapter for bushing mount listed below. Shpg. wt., 4 oz.

Stock No.	Mfrs. Type	Break Curr. Amps	Oper. Curr. Amps.	Surge Curr. Amps	Net Each
33 F 14606	CBT050	0.5	0.325	2	.81
33 F 14614	CBT075	0.75	0.49	3	.81
33 F 14622	CBT100	1.0	0.65	5	.81
33 F 14630	CBT150	1.5	0.975	12	.81
33 F 14648	CBT175	1.75	1.14	12	.81
33 F 14655	CBT200	2.0	1.3	12	.81
33 F 14663	CBT225	2.25	1.46	12	.81
33 F 14671	CBT250	2.5	1.63	12	.81
33 F 14689	CBT275	2.75	1.79	12	.81
33 E 14697	CBT300	3.0	1.95	12	.81
33 F 14705	CBT310	3.1	2.1	25	.88
33 F 14713	CBT325	3.25	2.11	25	.88
33 F 14721	CBT350	3.5	2.2	25	.88
33 F 14739	CBT375	3.75	2.44	25	.88
33 F 14747	CBT400	4.0	2.6	25	.88
33 F 14754	CBT450	4.5	2.92	25	.88
33 F 14762	CBT500	5.0	3.25	25	.88
33 F 14770	CBT600	6.0	3.9	25	.88
33 F 14788	CBT700	7.0	4.14	25	.88

Type CBB adapter for bushing mount. Bushing  $\frac{3}{8}$ "— $32 \times \frac{1}{4}$ " with nut.  
33 F 14796 ..... Net .16

Figure 8. Chart taken from page 328 of Lafayette's Catalog 710 gives brief listing of circuit breakers available from Mallory. Note three different amp ratings for each.

The circuit breaker is also replacing certain fuses in the automotive field. It's chiefly used in high-current circuits such as headlights, convertible top motors and window motors. The car breakers, however, automatically re-set themselves when the overload no longer exists. Not only is it convenient, but a bi-metal element of the breaker won't suffer a common fault of fuses in these circuits—fatigue. Fuses tend to fail when cycled repeatedly at high (though normal) on-off currents. (Fatigue also explains mysterious fuse failure in radio and TV sets when no circuit fault exists.)

**How Many Amps?** The equipment designer has already done the job of figuring the right fuse for his electronic gear. When the fuse blows—and the fault cured—the replacement fuse may merely duplicate the original. But if you home-brew equipment, you'll have to do some calculations to obtain the fuse rating. We've talked of *fuse* ratings but this is not the same as current consumed by the equipment being protected. To avoid nuisance blowing, the fuse almost always should be able to conduct more current than is drawn by the equipment.

It is considered good practice not to load a medium-blow fuse by more than 75 to 80 percent of its rating in amperes. To translate this into a practical value, you must know the number of amperes consumed by the

equipment during normal operation.

Let's say it is 4 amps. This number, therefore, should be 75 percent of the fuse rating. To find the answer, divide 4 by .75. The result is 5.3 amps, the fuse rating. This is an odd value, so select the next *highest* standard fuse size, which is 6 amps.

You'll find suitable types in the catalogs to fit into clips, an extractor post or to be soldered directly into the circuit with pig-tail leads. Most common physical size for electronic gear is the glass 3AG or AGC type ( $\frac{1}{4}$ "X $\frac{1}{4}$ ").

If you check commercial circuits, chances are you'll find that the fuse is operated at 50 (not 75 or 80) percent of its rating. This is another way of saying the fuse rating is double the load current. A car radio, for example, might draw 3 to 4 amperes, but the fuse is usually  $7\frac{1}{2}$  or 9 amps.

You can also follow this practice, especially if your circuit is subject to temporary surges. This may seem like overfusing the circuit but the fuse should melt before anything is damaged (and it is less subject to nuisance blowing).

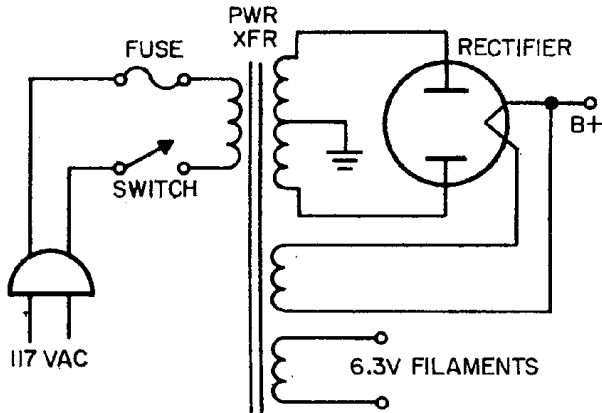
When equipment will certainly cause temporary overloads several times normal circuit current, then choose a time-lag or slow-blow fuse. Recall that it has a dual element to cope with this condition. It withstands brief overloads of several times normal

current. With this kind of surge protection, it is common practice to select the rating of a slow-blow at a somewhat higher figure than the medium type. It should be about 80 to 90 percent. To convert this into a slow-blow fuse rating, measure the circuit's normal current and divide it by .8 or .9 for the fuse amperage.

tors in the process. The expensive power transformer, however, gets a reasonable degree of protection with this system.

More sensitive fusing occurs in Fig. 10. With the fuse in the centertap of the transformer, it responds only to changes in the B+ current. Since this bypasses high currents consumed by tube filaments, the fuse can be much smaller and is responsive to partial shorts in the remaining circuits. A variation of this is in Fig. 11; a half-wave supply that might be found in an AC-DC ta-

**Figure 9. Fuse in power transformer primary circuit protects entire power supply including 6.3 VAC filament source. However, it's possible that short circuit in device, while not of sufficiently high amperage to blow fuse, will damage components in power supply like filter capacitor or choke.**

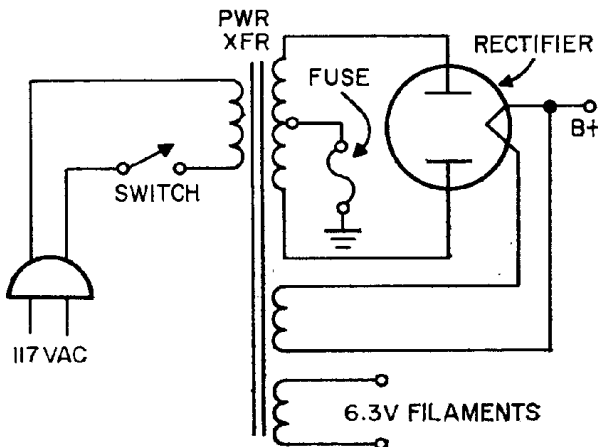


**Where to Fuse.** There's some compromise in where to locate a fuse for maximum circuit protection. Fig. 9, a typical full-wave power supply, shows why. The fuse is inserted in one leg of the incoming AC power line. Since the fuse is situated at the closest point to the power source, it provides overall protection. If a defect develops in some circuit, however, there's a chance the fuse will not blow for say, a shorted bypass capacitor that doesn't create enough excess fuse current. It could burn out a few resis-

ble radio. Only here there's a fusible resistor of the type described earlier. Since you can obtain a fusible resistor locally or from electronic part houses, why not modify your table radio instead!

This leaves the problem of fusing filaments. Although a conventional fuse can be used to protect the filaments you might borrow a trick used in some circuits.

Shown in Fig. 12 is the system used in some color TV sets, one of the more thoroughly protected home-entertainment de-



**Figure 10. Secondary of power transformer is fused. Protection is for high voltage circuit only; filament supply's unfused.**

vices. There are no less than three techniques to guard against overcurrent. In one leg of the primary lead is a thermistor. Although it is not a breaker-type device, it prolongs the life of the circuit by slowing the inrush of current when the set is first turned on. It might present 120 ohms when cold, thus limiting current, but electrically disappears when hot since it sinks to just 1.5 ohms after circuit warmup.

Next site of protection is a circuit breaker in the power transformer secondary. It trips during overload anywhere along the B+ leg in the receiver. (This is equivalent to the centertap fuse shown in Fig. 10.) The filament circuit has completely separate protection. It is merely a short link of No. 26 wire that melts when a short exists along the filament supply. There's little hazard since voltage is only 6.3VAC and serious arcing won't occur.

**Fusing Transistors.** There have been attempts to protect transistors by fusing, but fuses generally will not react fast enough. Techniques which use additional semiconductors (such as diodes) provide a better

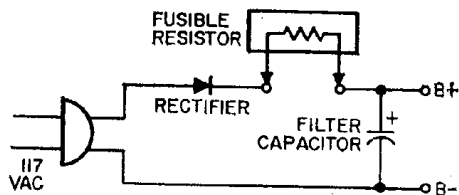


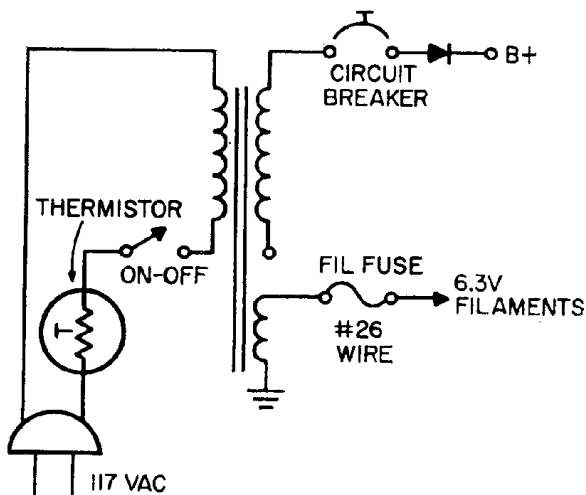
Figure 11. Fusible resistor combines surge-limiting resistor, fuse in one package shown here in AC/DC rig's power supply.

117 volts of Alternating Current.

**Getting Clipped.** How a fuse mounts is more important than is generally believed. Much trouble with nuisance blowing has been traced to defective fuse clips or holders. Poor contact between clips and fuse produces hot spots that blow the fuse prematurely. It may also introduce electrical resistance that upsets the circuit being protected.

One manufacturer suggests the following: you should hear a resounding "snap" when inserting a fuse into clips—it signals good grip strength. And you should have to pry a defective fuse from its clips. Since

Figure 12. Three points of protection on color tv power supply are thermistor in transformer primary circuit to limit surges, circuit breaker in B+ secondary circuit, wire-type fuse for filament.



solution. There is, though, some consideration in fusing the power supply of solid-state equipment. Since transistor circuit voltages are significantly lower than those encountered in tube circuits, the resistance of the fuse becomes increasingly important. It may be an ohm or less, but this introduces a new element that might affect the operation of a delicate circuit. Two solutions are possible: use the largest fuse size consistent with circuit protection (since this reduces resistance) or install the fuse in the primary side of the power transformer where voltages are over

dirty clips are a frequent cause of trouble, shine them with contact cleaner. Just be sure to remove the AC plug from the wall outlet before touching any contact with your fingers. It helps reduce the con-fusion.

Always remember, fuses protect valuable equipment from going up in smoke and eliminate dangers to human life. By overriding an existing fuse circuit with a penny, jumper, or oversized fuse, you may be putting a hole in your pocketbook—or one in the ground. ■