Littelfuse®

8 Technical Notes

This section is offered to help answer any questions not previously addressed in this data book regarding the *SIDACtor* device and its implementation.

Greentube™ Gas Plasma Arrester Construction and Operation

Littelfuse *Greentube* Gas Plasma Arresters (improved gas discharge tubes (GDTs)) are manufactured using totally non-radioactive processes.

Key Parameters

Gas plasma arrester technology involves three key parameters. (Figure 8.1)

The V_H (holdover voltage) is the most key parameter since the operating voltage of the protected system should be above this value to ensure that latch-up does not occur. Latch-up means the device stays in the low impedance state, and therefore the line is shorted. With the exception of 75 V and 90 V devices that have a holdover voltage of 50 V, all other devices have a holdover voltage of 135 V, which means they can be applied to virtually all telecom systems without any concern of latch-up.

The V_{SDC} (DC breakover (sparkover) voltage) is measured at a slow rate of rise, usually 100 V per second. In terms of design parameters, it is important to make sure that the lower (minimum) DC breakover voltage is above the system voltage.

The V_S (dynamic breakover (impulse sparkover) voltage) is a key feature since it determines the level of protection on offer. As with all protection devices, it is important that the transient is clamped to the lowest possible voltage—the lower the clamping voltage, the lower the level of potentially damaging energy let through to the system. It is important to note that the DC breakover (sparkover) voltage is not a guide to the dynamic breakover (impulse sparkover) voltage; for example, a 230 V dc device from various manufacturers will have various values of impulse sparkover—the lower this value, the better the level of protection. It is also important to make sure that the ramp speeds used to test this value are comparable. Typically, either 100 V/µS or 1 kV/µS is used. Values for 100 V/µS will be lower since these devices have sensitivity to ramp speeds. Good quality devices are less sensitive and, therefore, better.

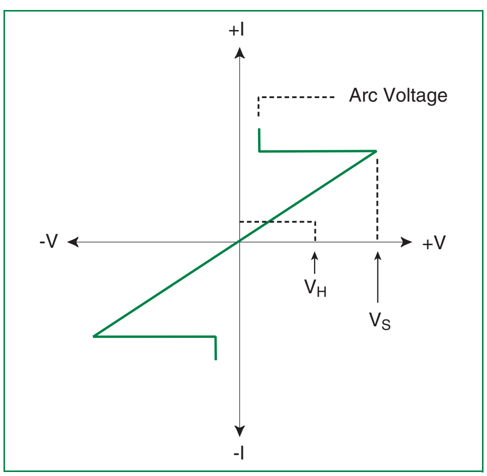


Figure 8.1 Gas Plasma Arrester V-I Characteristic Curve

Operation

The gas plasma arrester operates as a voltage-dependent switch. When a voltage appears across the device greater than its breakdown voltage, known as the sparkover (breakover) voltage, an arc discharge takes place within the tube, which creates a low impedance path by which the surge current is diverted.

When this arc discharge takes place, the voltage level is maintained irrespective of the discharge current. When the transient has passed, the gas plasma arrester resets to its non-conducting state if the voltage of the system is below the holdover voltage of the gas plasma arrester.

The gas plasma arresters can typically handle between 5 kA and 20 kA levels. This is defined as the Impulse Discharge capability, or maximum surge rating.

The very low capacitance (typically 1 pF to 2 pF) and very high insulation resistance (greater than 1 GΩ) of the gas plasma arrester ensures that it has virtually no effect on the protected system during normal operating conditions.

Somewhat related to the low capacitance, these devices have low insertion loss at high speeds and therefore will not degrade high-speed signal lines.

Physics

The functional operation of the gas plasma arrester is similar to the solid-state *SIDACtor*®. However, in the gas plasma arrester, the current flows through an inert gas, whereas in the *SIDACtor* it flows through silicon. The gas is contained in a ceramic envelope between metal electrodes. In its simplest form the device has two terminals. (Figure 8.2) The device operates as a voltage triggered switch, where the voltage applied between the two electrodes (after exceeding a certain value) causes the device to go from a high impedance state to a low impedance state. Figure 8.3 shows a gas plasma arrester with three terminals.

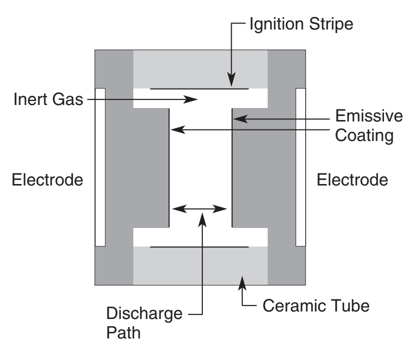


Figure 8.2 Two-terminal Gas Plasma Arrester

Technical Notes

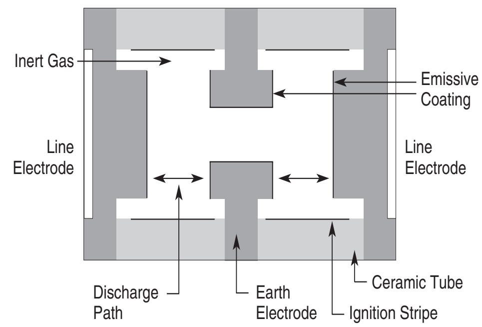


Figure 8.3 Three-terminal Gas Plasma Arrester

Up to a certain voltage, the device is essentially passive and high impedance. Beyond this point, the applied voltage causes the gas to ionize, causing electrons to flow. The voltage across the device then falls to the glow voltage, intrinsically linked to the holdover voltage and between 50 V and 130 V (depending on type) with a current of about 200 mA. A further increase in current (glow to arc transition current) causes the device to transition into the arc mode (on-state voltage). At this point, the device is at its lowest impedance and provides a path for unwanted electrical energy, such as that due to a transient.

The ignition stripes are used to aid the initial ignition and improve response to high-speed transients. The electrodes are coated with chemical compounds that impart certain characteristics to the device, in particular speed of response, current capability, and life characteristics.

A significant feature of these devices is not only that the capacitance value is low (typically 0.8 pF) but that the capacitance value does not vary with changes in voltage. This is particularly important on high-speed circuits. Littelfuse designs gas plasma arresters to provide better voltage limiting on high-speed transients and employs proprietary chemical and design techniques to achieve this.

The Littelfuse *Broadband Optimized™* range of gas plasma arresters incorporate all the features required for transparent operation on high-speed circuits.

Failsafe Devices

In normal operation or when conducting short duration transients (spikes) the gas plasma arrester does not generate any significant or detectable heat.

When conducting mains electricity (AC power) for extended periods (power fault), any arrester will generate excessive thermal energy, even to the point where its electrodes glow ‘cherry red.’ If an arrester is to be used in areas where connection with AC mains is a possibility, then a failsafe can be fitted. (Figure 8.4) These devices are spring-loaded switches held in the open position. When the arrester temperature rises, the device activates to create a short circuit between the arrester center (Ground) and line terminals (Tip or Ring). This short circuit is of low resistance and will conduct the fault current without generating any significant heat. The RG failsafe can be used in flow or re-flow solder processes without activating in response to the heat of the process. It is lead-free and can withstand long-term exposure to temperatures up to 100 °C.

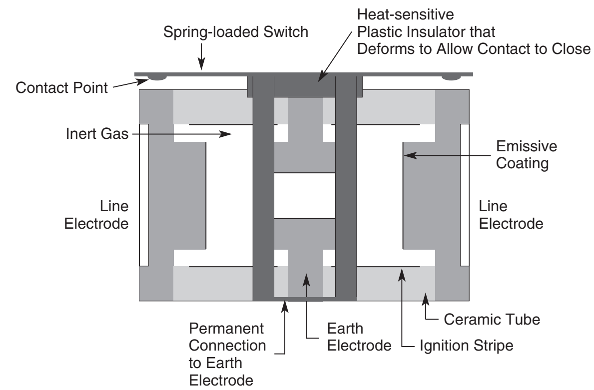


Figure 8.4 Three-terminal Gas Plasma Arrester with Failsafe

Classification of Gas Plasma Arresters

Littelfuse classifies gas plasma arresters in four range categories, based on response speed and performance.

Alpha Range (Super-fast, Premium)

Alpha gas plasma arresters provide extremely fast response to overvoltage transients, especially in the range from 1 kV/µs to 10 kV/µs. Alpha devices are appropriate for applications that are particularly sensitive to overvoltage events.

These devices are engineered to provide the best possible switching performance, responding rapidly to transient voltages. These devices keep transient voltages low and divert the transient current to Ground.

The Littelfuse gas plasma arrester included in this category is the SL1122A (hybrid series—gas plus SAD (Silicon Avalanche Diode))

Beta Range (Fast-response, Quality)

Beta gas plasma arresters are premium-quality devices offering high performance. The speed of these devices (which ultimately determines the effectiveness of a protector) is demonstrably better than traditional designs.

The Beta range includes mini devices which, although smaller, still offer very high surge-handling capabilities.

The following Littelfuse gas plasma arresters are included in this category:

- SL1002A (*Broadband Optimized*™ two-terminal, 6mm series available in SMT)
- SL1003A (three-terminal, 6mm series available in SMT)
- SL1011A (two-terminal, 8mm series)
- SL1011B (two-terminal, 8mm heavy duty series)
- SL1021A (three-terminal, 8mm series)
- SL1021B (three-terminal, 8mm heavy duty series)

The *Broadband Optimized*™ SL1002A series are especially developed for broadband equipment. Their off-state capacitance is compatible with bandwidths into the gigahertz range.

Delta Range (High-energy, Premium)

Delta gas plasma arresters provide very high current handling capability. They can divert up to 55 kA and 40 A ac (tested in accordance with ITU K.12) without loss of protection levels and so are ideally suited to outside plant applications. They are especially designed for high-energy, long-duration pulses (10/350 µs).

The Littelfuse gas plasma arrester included in this category is the SL1411A (two-terminal, 8mm series).

Omega Range (Cost-competitive)

Omega gas plasma arresters benefit from much of the technology used in the Beta range and are optimized for cost-conscious applications. Omega devices still offer performance advantages over many of the products available in the market from other sources.

The following Littelfuse gas plasma arresters are included in this category:

- SL1024A (three-terminal, 8mm series)
- SL1024B (three-terminal, 8mm heavy-duty series)

SIDACtor® Construction and Operation

SIDACtor devices are thyristor devices used to protect sensitive circuits from electrical disturbances caused by lightning-induced surges, inductive-coupled spikes, and AC power fault conditions. The unique structure and characteristics of the thyristor are used to create an overvoltage protection device with precise and repeatable turn-on characteristics with low voltage overshoot and high surge current capabilities.

Key Parameters

Key parameters for *SIDACtor* devices are V_{DRM}, I_{DRM}, V_S, I_H, and V_T, as shown in Figure 8.5. V_{DRM} is the repetitive peak off-state voltage rating of the device (also known as stand-off voltage) and is the continuous peak combination of AC and DC voltage that may be applied to the *SIDACtor* device in its off-state condition. I_{DRM} is the maximum value of leakage current that results from the application of V_{DRM}. Switching voltage (V_S) is the maximum voltage that subsequent components may be subjected to during a fast-rising (100 V/µs) overvoltage condition. Holding current (I_H) is the minimum current required to maintain the device in the on state. On-state voltage (V_T) is the maximum voltage across the device during full conduction.

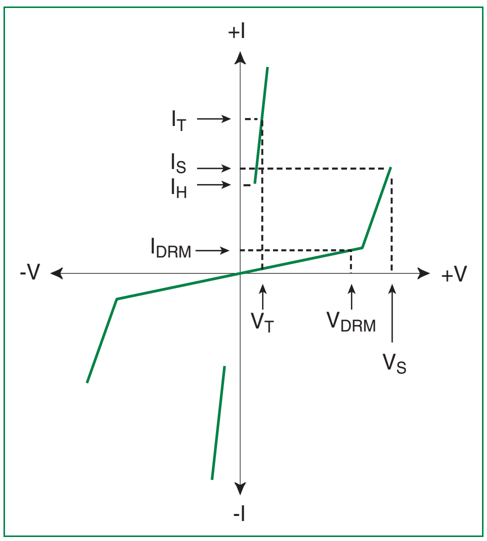


Figure 8.5 V-I Characteristics

Operation

The *SIDACtor* device operates much like a switch. In the off state, the device exhibits leakage currents (I_{DRM}) less than 5 µA, making it invisible to the circuit it is protecting. As a transient voltage exceeds the *SIDACtor* device's V_{DRM}, the device begins to enter its protective mode with characteristics similar to an avalanche diode. When supplied with enough current (I_S), the *SIDACtor* device switches to an on state, shunting the surge from the circuit it is protecting. While in the on state, the *SIDACtor* device is able to sink large amounts of current because of the low voltage drop (V_T) across the device. Once the current flowing through the device is either interrupted or falls below a minimum holding current (I_H), the *SIDACtor* device resets, returning to its off state. If the I_{PP} rating is exceeded, the *SIDACtor* device typically becomes a permanent short circuit.

Physics

The *SIDACtor* device is a semiconductor device characterized as having four layers of alternating conductivity: PNPN. (Figure 8.6) The four layers include an emitter layer, an upper base layer, a mid-region layer, and a lower base layer. The emitter is sometimes referred to as a cathode region, with the lower base layer being referred to as an anode region.

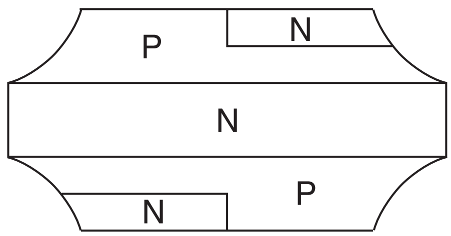


Figure 8.6 Geometric Structure of Bidirectional *SIDACtor* devices

As the voltage across the *SIDACtor* device increases and exceeds the device's V_{DRM}, the electric field across the center junction reaches a value sufficient to cause avalanche multiplication. As avalanche multiplication occurs, the impedance of the device begins to decrease, and current flow begins to increase until the *SIDACtor* device's current gain exceeds unity. Once unity is exceeded, the *SIDACtor* device switches from a high impedance (measured at V_S) to a low impedance (measured at V_T) until the current flowing through the device is reduced below its holding current (I_H).

Greentube™ Gas Plasma Arrester Selection Criteria

When selecting a *Greentube* gas plasma arrester, the following criteria is determined by the location and equipment in which it is installed and defines the robustness of the device.

Surge Rating (Impulse Discharge Rating or MAX I_{PP})

This parameter determines the peak pulse current the protector is able to withstand; it is expressed as kiloamps (kA) and relates to a double exponential waveform, typically an 8/20 µs duration (8 µs to peak value, 20 µs to half value). Gas plasma arresters are typically available in 2.5 kA, 5 kA, 10 kA, and 20 kA devices.

The location of the protector has a large influence on the choice of surge rating. Devices located outside of buildings (known as outside plant) need higher ratings because they will be nearer the source of the transient, and consequently, the surges will be of higher magnitude. Geography also plays a part since certain areas of the world get more lightning surges and of higher energy. Typically, a rating of 5 kA is the minimum for outside plant protectors, and the rating can be as high as 20 kA in areas of severe lightning conditions.

The Main Distribution Frame (MDF) is the first point of entry for external cables. Protectors in the MDF can be rated anywhere from 5 kA to 500 A, depending on the geographic area. Generally, the relevant Telecom authority defines the level of surge rating for a telecom circuit.

AC Surge Rating (AC Discharge Rating or Power Fault Rating)

This parameter determines the maximum AC current the protector is able to take without destruction; it is expressed as amps and usually relates to a number of cycles or a duration of exposure. Gas plasma arresters are typically available in 2.5 kA, 5 kA, 10 kA, and 20 kA devices. Normally, the AC rating of a gas plasma arrester is tied to the IPP surge rating (in other words, 5 A/5 kA, 10 A/10 kA, and so on).

SIDACtor® Device Selection Criteria

When selecting a *SIDACtor* device, use the following criteria:

Off-state Voltage (V_{DRM})

The V_{DRM} of the *SIDACtor* device must be greater than the maximum operating voltage of the circuit that the *SIDACtor* device is protecting.

Example 1:

For a POTS (Plain Old Telephone Service) application, convert the maximum operating Ring voltage (150 V_{RMS}) to a peak voltage, and add the maximum DC bias of the central office battery:

$150\ V_{RMS} \sqrt{2} + 56.6\ V_{PK} = 268.8\ V_{PK}$
$\therefore V_{DRM} > 268.8$ V

Example 2:

For an ISDN application, add the maximum voltage of the DC power supply to the maximum voltage of the transmission signal (for U.S. applications, the U-interface will not have a DC voltage, but European ISDN applications may):

$150\ V_{PK} + 3\ V_{PK} = 153\ V_{PK}$
$\therefore V_{DRM} > 153$ V

Switching Voltage (V_S)

The V_S of the *SIDACtor* device should be equal to or less than the instantaneous peak voltage rating of the component it is protecting.

Example 1:

$V_S \leq V_{Relay\ Breakdown}$

Example 2:

$V_S \leq$ SLIC V_{PK}

Peak Pulse Current (I_{PP})

For circuits that do not require additional series resistance, the surge current rating (I_{PP}) of the *SIDACtor* device should be greater than or equal to the surge currents associated with the lightning immunity tests of the applicable regulatory requirement (I_{PK}):

$I_{PP} \geq I_{PK}$

For circuits that use additional series resistance, the surge current rating (I_{PP}) of the *SIDACtor* device should be greater than or equal to the available surge currents associated with the lightning immunity tests of the applicable regulatory requirement ($I_{PK(available)}$):

$I_{PP} \geq I_{PK(available)}$

The maximum available surge current is calculated by dividing the peak surge voltage (V_{PK}) by the total circuit resistance (R_{TOTAL}):

$I_{PK(available)} = V_{PK}/R_{TOTAL}$

For longitudinal surges (Tip-Ground, Ring-Ground), R_{TOTAL} is calculated for both Tip and Ring:

$R_{SOURCE} = V_{PK}/I_{PK}$

$R_{TOTAL} = R_{TIP} + R_{SOURCE}$

$R_{TOTAL} = R_{RING} + R_{SOURCE}$

For metallic surges (Tip-Ring):

$R_{SOURCE} = V_{PK}/I_{PK}$

$R_{TOTAL} = R_{TIP} + R_{RING} + R_{SOURCE}$

Example 1:

A modem manufacturer must pass the Type A surge requirement of TIA-968-A without any series resistance.

I_{PK} = 100 A, 10x560 µs

$I_{PP} \geq$ 100 A, 10x560 µs

Therefore, either a “B” rated or “C” rated *SIDACtor* device would be selected.

Example 2:

A line card manufacturer must pass the surge requirements of GR 1089 with 30 Ω on Tip and 30 Ω on Ring.

I_{PK} = 100 A, 10x1000 µs

V_{PK} = 1000 V

$R_{SOURCE} = V_{PK}/I_{PK} = 10\ \Omega$

$R_{TOTAL} = R_{SOURCE} + R_{TIP} = 40\ \Omega$

$I_{PK\ (available)} = V_{PK}/R_{TOTAL} = 1000\ V/40\ \Omega$

$\therefore I_{PP} \geq 25$ A

Holding Current (I_H)

Because TIA-968-A 4.4.1.7.3 specifies that registered terminal equipment not exceed 140 mA dc per conductor under short-circuit conditions, the holding current of the *SIDACtor* device is set at 150 mA.

For specific design criteria, the holding current (I_H) of the *SIDACtor* device must be greater than the DC current that can be supplied during an operational and short circuit condition.

Off-State Capacitance (C_O)

Assuming that the critical point of insertion loss is 70 percent of the original signal value, the *SIDACtor* device can be used in most applications with transmission speeds up to 30 MHz. For transmission speeds greater than 30 MHz, the new MC series is highly recommended.

Fuse Facts

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. In the absence of special requirements, Littelfuse reserves the right to make appropriate changes in design, process, and manufacturing location without notice.

The following fuse parameters or application concepts should be well understood in order to properly select a fuse for a given application.

Ambient Temperature

Ambient temperature refers to the temperature of the air immediately surrounding the fuse and is not to be confused with “room temperature.” The fuse ambient temperature is appreciably higher in many cases, because it is enclosed (as in a panel mount fuseholder) or mounted near other heat-producing components, such as resistors, transformers, and so on.

Breaking Capacity

See "Interrupting Rating" on page 8-14.

Current Rating

The current rating is the nominal amperage value of the fuse. The rating is established by the manufacturer as a value of current which the fuse can carry based on a controlled set of test conditions. (See *Rerating*.)

Catalog fuse part numbers include series identification and amperage ratings for guidance on making the proper choice.

Rerating

For 25 °C ambient temperatures, it is recommended that fuses be operated at no more than 75 percent of the nominal current rating established using the controlled test conditions. These test conditions are part of the UL/CSA/ANCE (Mexico) 248-14 “Fuses for Supplementary Overcurrent Protection,” whose primary objective is to specify common test standards necessary for the continued control of manufactured items intended for protection against fire, and so on. Some common variations of these standards include fully enclosed fuseholders, high contact resistances, air movement, transient spikes, and changes in connecting cable size (diameter and length). Fuses are essentially temperature-sensitive devices. Even small variations from the controlled test conditions can greatly affect the predicted life of a fuse when it is loaded to its nominal value, usually expressed as 100 percent of rating.

The circuit design engineer should clearly understand that the purpose of these controlled test conditions is to enable fuse manufacturers to maintain unified performance standards for their products, and the engineer must account for the variable conditions of the application. To compensate for these variables, the circuit design engineer designing for trouble-free, long-life fuse protection in equipment generally loads a fuse not more than 75 percent of the nominal rating listed by the manufacturer, keeping in mind that overload and short circuit protection must be adequately provided for.

The fuses under discussion are temperature-sensitive devices whose ratings have been established in a 25 °C ambient. The fuse temperature generated by the current passing through the fuse increases or decreases with ambient temperature change.

The ambient temperature will have an effect on the nominal current rating of a fuse. Most traditional *Slo-Blo*® Fuse designs use lower melting temperature materials and, therefore, are more sensitive to ambient temperature changes.

Dimensions

Unless otherwise specified, dimensions are in inches.

The fuses in this catalog range in size from the approximately 0402 chip size (0.041” L x 0.020” W x 0.012” H) up to the 5 AG, also commonly known as a “MIDGET” fuse (13/32” diameter x 1-1/2” length). As new products were developed throughout the years, fuse sizes evolved to fill the various electrical circuit protection needs. The first fuses were simple, open-wire devices, followed in the 1890s by Edison’s enclosure of thin wire in a lamp base to make the first plug fuse. By 1904, Underwriters Laboratories had established size and rating specifications to meet safety standards. The renewable type fuses and automotive fuses appeared in 1914, and in 1927 Littelfuse started making very low amperage fuses for the budding electronics industry.

The fuse sizes shown in Table 8.1 began with the early “Automobile Glass” fuses, thus the term “AG.” The numbers were applied chronologically as different manufacturers started making a new size; for example, “3AG” was the third size placed on the market. Other non-glass fuse sizes and constructions were determined by functional requirements, but they still retained the length or diameter dimensions of the glass fuses. Their designation was modified to AB in place of AG, indicating that the outer tube was constructed from Bakelite, fibre, ceramic, or a similar material other than glass. The largest size fuse shown in the chart is the 5AG, or “MIDGET,” a name adopted from its use by the electrical industry and the National Electrical Code range which normally recognizes fuses of 9/16” x 2” as the smallest standard fuse in use.

Table 8.1 Fuse Sizes

Size	Nominal Diameter (Inches)		Nominal Length (Inches)	
1AG	¼	0.250	5/8	0.625
2AG	—	0.177	—	0.588
3AG	¼	0.250	1¼	1.25
4AG	9/32	0.281	1¼	1.25
5AG	13/32	0.406	1½	1.50
7AG	¼	0.250	7/8	0.875
8AG	¼	0.250	1	1

Tolerances

The dimensions shown in this catalog are nominal. Unless otherwise specified, tolerances are applied as follows:

- ±0.010” for dimensions to two decimal places
- ±0.005” for dimensions to three decimal places

Contact the factory concerning metric system and fractional tolerances. Tolerances do not apply to lead lengths.

Fuse Characteristics

The characteristic of a fuse design refers to how rapidly the fuse responds to various current overloads. Fuse characteristics can be classified into three general categories: very fast-acting, fast-acting, or *Slo-Blo*® fuse. The distinguishing feature of *Slo-Blo*® fuses is that these fuses have additional thermal inertia designed to tolerate normal initial or start-up overload pulses.

Fuse Construction

Internal construction may vary depending on ampere rating. Fuse photos in this catalog show typical construction of a particular ampere rating within the fuse series.

Fuseholders

In many applications, fuses are installed in fuseholders. These fuses and their associated fuseholders are not intended for operation as a “switch” for turning power “on” and “off.”

Interrupting Rating

Also known as breaking capacity or short circuit rating, the interrupting rating is the maximum approved current which the fuse can safely interrupt at rated voltage. During a fault or short circuit condition, a fuse may receive an instantaneous overload current many times greater than its normal operating current. Safe operation requires that the fuse remain intact (no explosion or body rupture) and clear the circuit.

Interrupting ratings may vary with fuse design and range from 35 A ac for some 250 V metric size fuses (5x20 mm) up to 200,000 A ac for the 600 V KLK series. Information on other fuse series can be obtained from the factory.

Fuses listed in accordance with UL/CSA/ANCE 248 are required to have an interrupting rating of 10,000 A. Some exceptions, in many applications, provide a safety factor far in excess of the short circuit currents available.

Nuisance Opening

Nuisance opening is most often caused by an incomplete analysis of the circuit under consideration. Of all the selection criteria considered, special attention must be given to normal operating current, ambient temperature, and pulses. For example, one prevalent cause of nuisance opening in conventional power supplies is the failure to adequately consider the fuse’s nominal melting I^2t rating. The fuse cannot be selected solely on the basis of normal operating current and ambient temperature. In this application, the fuse’s nominal melting I^2t rating must also meet the inrush current requirements created by the input capacitor of the power supply's smoothing filter. For trouble-free, long-life fuse protection, it is good design practice to select a fuse so that the I^2t of the waveform is no more than 20 percent of the nominal melting I^2t rating of the fuse.

Resistance

The resistance of a fuse is usually an insignificant part of the total circuit resistance. Since the resistance of fractional amperage fuses can be several ohms, consider this fact when using them in low-voltage circuits. Actual values can be obtained from the factory. Most fuses are manufactured from materials which have positive temperature coefficients, and therefore, it is common to refer to cold resistance and hot resistance (voltage drop at rated current), with actual operation being somewhere in between. Cold resistance is the resistance obtained using a measuring current of no more than 10 percent of the fuse's nominal rated current. Consult with the factory if this parameter is critical to the design analysis. Hot resistance is the resistance calculated from the stabilized voltage drop across the fuse, with current equal to the nominal rated current flowing through it. Resistance data on all Littelfuse products are available on request. Fuses can be supplied to specified controlled resistance tolerances at additional cost.

Soldering Recommendations

Since most fuse constructions incorporate soldered connections, use caution when installing those fuses intended to be soldered in place. The application of excessive heat can reflow the solder within the fuse and change its rating. Fuses are heat-sensitive components similar to semi-conductors, and the use of heat sinks during soldering is often recommended.

Test Sampling Plan

Because compliance with certain specifications requires destructive testing, these tests are selected on a statistical basis for each lot manufactured.

Time-current Curve

The graphical presentation of the fusing characteristic, time-current curves are generally average curves which are presented as a design aid but are not generally considered part of the fuse specification. Time-current curves are extremely useful in defining a fuse, since fuses with the same current rating can be represented by considerably different time-current curves. The fuse specification typically will include a life requirement at 100 percent of rating and maximum opening times at overload points (usually 135 percent and 200 percent of rating). A time-current curve represents average data for the design; however, there may be some differences in the values for any one given production lot. Samples should be tested to verify performance once the fuse has been selected.

Underwriters Laboratories

Reference to "Listed by Underwriters Laboratories" signifies that the fuses meet the requirements of UL/CSA/ANCE 248-14 "Fuses for Supplementary Overcurrent Protection." Some 32 V fuses (automotive) in this catalog are listed under UL Standard 275. Reference to "Recognized under the Component Program of Underwriters Laboratories" signifies that the item is recognized under the component program of Underwriters Laboratories and application approval is required.

Voltage Rating

The voltage rating, as marked on a fuse, indicates that the fuse can be relied upon to safely interrupt its rated short circuit current in a circuit where the voltage is equal to or less than its rated voltage. This system of voltage rating is covered by National Electric Code (NEC) regulations and is a requirement of Underwriters Laboratories as a protection against fire risk. The standard voltage ratings used by fuse manufacturers for most small-dimension and midget fuses are 32 V, 63 V, 125 V, 250 V, and 600 V.

In electronic equipment with relatively low output power supplies, with circuit impedance limiting short circuit currents to values of less than ten times the current rating of the fuse, it is common practice to specify fuses with 125 V or 250 V ratings for secondary circuit protection of 500 V or higher.

As mentioned under *Rerating*, fuses are sensitive to changes in current, not voltage, maintaining their “status quo” at any voltage from zero to the maximum rating of the fuse. It is not until the fuse element melts and arcing occurs that the circuit voltage and available power become an issue. See *Interrupting Rating* for a discussion on the safe interruption of the circuit as it relates to circuit voltage and available power.

To summarize, a fuse may be used at any voltage that is less than its voltage rating without detriment to its fusing characteristics. Contact the factory for applications at voltages greater than the voltage rating.

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 eight 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 eight 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.

Electronic Fuse Selection Criteria

A fuse can be relied upon to operate safely at its rated current, at or below its rated voltage. This voltage rating is covered by the NEC regulations and is a requirement of UL as protection against fire risk. The standard voltage ratings used by fuse manufacturers for most small dimension fuses are 32 V, 63 V, 125 V, 250 V, and 600 V.

Fuses are not sensitive to changes in voltage; however, they are sensitive to changes in current. The fuse will maintain “steady-state” operation from zero volts to the maximum voltage rating. It is not until the fuse element melts and internal arcing occurs, that circuit voltage and available power become an issue. The interrupt rating of the fuse addresses this issue. Specifically, the voltage rating determines the ability of the fuse to suppress internal arcing that occurs after the fuse link melts.

For telecommunication applications, a voltage rating of 250 V is chosen because of the possibility of power line crosses. A three-phase voltage line will have voltage values up to 220 V. It is desirable for the voltage rating of the fuse to exceed this possible power fault event.

UL 60950 has a power fault test condition that requires a fuse to have an interrupt rating of 40 A at 600 V. GR 1089 contains a power fault test condition that requires a fuse to have an interrupt rating of 60 A at 600 V. A 125 V-rated part will not meet this requirement. **A 250 V part with special design consideration, such as Littelfuse’s 04611.25 *TeleLink*® fuse, does meet this requirement.**

Because fuses are rated in terms of continuous voltage and current-carrying capacity, it is often difficult to translate this information in terms of peak pulse current ratings. To simplify this process, Table 8.2 shows the surge rating correlation to fuse rating.

Table 8.2 Surge Rating Correlation to Fuse Rating

Fuse Rating mAmps	Equivalent I_{PP} Rating		
	10x160 µs Amps	10x560 µs Amps	10x1000 µs Amps
250	23	16.6	12.4
350	34	25.8	19.3
400	40	25.4	19
500	60	37.7	28.2
600	71	47.2	35.3
750	91	65.5	49
800	104	68.9	51.6
1000	130	88.6	66.3
1250	162	118.1	100

Peak Pulse Current (I_{PP})

For circuits that do not require additional series resistance, the surge current rating (I_{PP}) of the fuse should be greater than or equal to the surge currents associated with the lightning immunity tests of the applicable regulatory requirement (I_{PK}):

$$I_{PP} \geq I_{PK}$$

For circuits that use additional series resistance, the surge current rating (I_{PP}) of the fuse should be greater than or equal to the available surge currents associated with the lightning immunity tests of the applicable regulatory requirement ($I_{PK(available)}$):

$$I_{PP} \geq I_{PK(available)}$$

The maximum available surge current is calculated by dividing the peak surge voltage (V_{PK}) by the total circuit resistance (R_{TOTAL}):

$$I_{PK(available)} = V_{PK}/R_{TOTAL}$$

For longitudinal surges (Tip-Ground, Ring-Ground), R_{TOTAL} is calculated for both Tip and Ring:

$$R_{SOURCE} = V_{PK}/I_{PK}$$

$$R_{TOTAL} = R_{TIP} + R_{SOURCE}$$

$$R_{TOTAL} = R_{RING} + R_{SOURCE}$$

For metallic surges (Tip-Ring):

$$R_{SOURCE} = V_{PK}/I_{PK}$$

$$R_{TOTAL} = R_{TIP} + R_{RING} + R_{SOURCE}$$

Overvoltage Protection Comparison

The four most commonly used technologies for overvoltage protection are as follows:

- *SIDACtor®* devices
- Gas Plasma Arresters (GDTs)
- Metal Oxide Varistors (MOVs)
- TVS diodes

All four technologies are connected in parallel with the circuit being protected, and all exhibit a high off-state impedance when biased with a voltage less than their respective blocking voltages.

SIDACtor devices

A *SIDACtor* device is a PNPN device that can be thought of as a TVS diode with a gate. Upon exceeding its peak off-state voltage (V_{DRM}), a *SIDACtor* device will clamp a transient voltage to within the device's switching voltage (V_S) rating. Then, once the current flowing through the *SIDACtor* device exceeds its switching current, the device will crowbar and simulate a short-circuit condition. When the current flowing through the *SIDACtor* device is less than the device's holding current (I_H), the *SIDACtor* device will reset and return to its high off-state impedance.

Advantages

Advantages of the *SIDACtor* device include its fast response time (Figure 8.7), stable electrical characteristics, long term reliability, and low capacitance. Also, because the *SIDACtor* device is a crowbar device, it cannot be damaged by voltage and it has extremely high surge current ratings.

Restrictions

Because the *SIDACtor* device is a crowbar device, it cannot be used directly across the AC line; it must be placed behind a load. Failing to do so will result in exceeding the *SIDACtor* device's surge current rating, which may cause the device to enter a permanent short-circuit condition.

Applications

Although found in other applications, *SIDACtor* devices are primarily used as the principle overvoltage protector in telecommunications and data communications circuits. For applications outside this realm, follow the design criteria in "SIDACtor® Device Selection Criteria" on page 8-10.

Gas Plasma Arresters

Gas plasma arresters are either glass or ceramic packages filled with an inert gas and capped on each end with an electrode. When a transient voltage exceeds the DC breakdown rating of the device, the voltage differential causes the electrodes of the gas tube to fire, resulting in an arc, which in turn ionizes the gas within the tube and provides a low impedance path for the transient to follow. Once the transient drops below the DC holdover voltage and current, the gas tube returns to its off state.

Advantages

Gas plasma arresters have high surge current and low capacitance ratings. Current ratings can be as high as 500 A for 200 impulses, and capacitance ratings can be as low as 1 pF with a zero-volt bias.

Applications

Gas plasma arresters are typically used for primary protection due to their high surge rating. However, their low interference for high frequency components make them a candidate for high speed data links.

Metal Oxide Varistors

Metal Oxide Varistors (MOVs) are two-leaded, through-hole components typically shaped in the form of discs. Manufactured from sintered oxides and schematically equivalent to two back-to-back PN junctions, MOVs shunt transients by decreasing their resistance as voltage is applied.

Advantages

Since MOVs surge capabilities are determined by their physical dimensions, high surge current ratings are available. Also, because MOVs are clamping devices, they can be used as transient protectors in secondary AC power line applications.

Applications

Although MOVs are restricted from use in many telecom applications (other than disposable equipment), they are useful in AC applications where a clamping device is required and tight voltage tolerances are not.

TVS Diodes

Transient Voltage Suppressor (TVS) diodes are clamping voltage suppressors that are constructed with back-to-back PN junctions. During conduction, TVS diodes create a low impedance path by varying their resistance as voltage is applied across their terminals. Once the voltage is removed, the diode will turn off and return to its high off-state impedance.

Advantages

Because TVS diodes are solid state devices, they do not fatigue nor do their electrical parameters change as long as they are operated within their specified limits. TVS diodes effectively clamp fast-rising transients and are well suited for low-voltage applications that do not require large amounts of energy to be shunted.

Applications

Due to their low power ratings, TVS diodes are not used as primary interface protectors across Tip and Ring; they are used as secondary protectors that are embedded within a circuit.

dv/dt Chart

Figure 8.7 shows a peak voltage comparison between *SIDACtor* devices, gas discharge tubes, MOVs, and TVS diodes, all with a nominal stand-off voltage rating of 230 V. The X axis represents the dv/dt (rise in voltage with respect to time) applied to each protector, and the Y axis represents the maximum voltage drop across each protector.

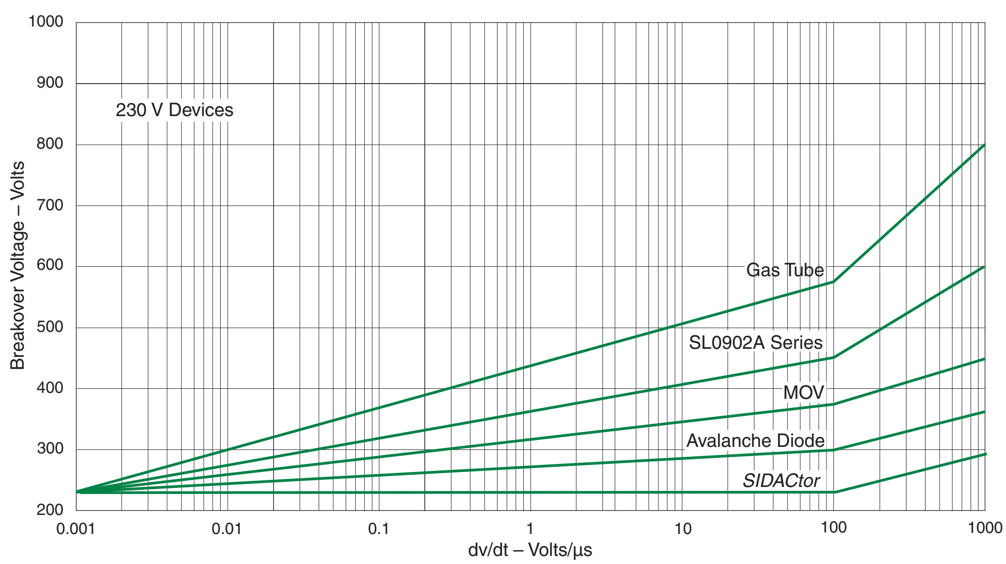


Figure 8.7 Overshoot Levels versus dv/dt

Technical Notes

Overcurrent Protection

In addition to protecting against overvoltage conditions, equipment should also be protected from overcurrent conditions using either PTCs, fuses, power/line feed resistors, or flameproof resistors. In all instances the overcurrent protector is a series element placed in front of the overvoltage protector on **either** Tip **or** Ring for metallic (closed loop) applications and on **both** Tip **and** Ring for longitudinal (grounded) applications.

PTCs

PTCs are positive temperature coefficient thermistors used to limit current. During a fault condition, heat is generated at a rate equal to I^2R. When this heat becomes sufficient, the PTC increases its resistance asymptotically until the device simulates an open circuit, limiting the current flow to the rest of the circuit. As the fault condition drops below the PTC's holding current, the device begins to reset, approximating its original off-state value of impedance.

Advantages

Because PTCs are resettable devices, they work well in a variety of industrial applications where electrical components cannot withstand multiple, low-current faults.

Applications

PTCs are used in a variety of applications. In addition to protecting telecommunications equipment, PTCs are also used to prevent damage to rechargeable battery packs, to interrupt the current flow during a motor lock condition, and to limit the sneak currents that may cause damage to a five-pin module.

Fuses

Due to their stability, fuses are one of the most popular solutions for meeting AC power fault requirements for telecommunications equipment. Similar to PTCs, fuses function by reacting to the heat generated due to excessive current flow. Once the fuses I^2t rating is exceeded, the center conductor opens.

Advantages

Fuses are available in both surface mount and through-hole packages and are able to withstand the applicable regulatory requirements without the use of any additional series impedance. Chosen correctly, fuses only interrupt a circuit when extreme fault conditions exist and, when coordinated properly with an overvoltage protector, offer a very competitive and effective solution for transient immunity needs.

Advantages include:

- Elimination of series line resistance enabling longer loop lengths
- Precise longitudinal balance allowing better transmission quality
- Robust surge performance which eliminates costly down time due to nuisance blows
- Greater surge ratings than resettable devices, ensuring regulatory compliance
- Non-degenerative performance
- Available in surface mount packaging which uses less Printed Circuit Board (PCB) real estate, eliminates mixed technologies, and reduces manufacturing costs

Weaknesses

Because a fuse does not reset, consideration should be given to its use in applications where multiple fault occurrences are likely. For example, AC strip protectors and ground fault interrupting circuits (GFIC) are applications in which an alternative solution might be more prudent.

Applications

Telecommunications equipment best suited for a fuse is equipment that requires surface mount technology, accurate longitudinal balance, and regulatory compliance without the use of additional series line impedance.

Selection Criteria

For circuits that do not require additional series resistance, the surge current rating (I_{PP}) of the *TeleLink*® SM fuse should be greater than or equal to the surge currents associated with the lightning immunity tests of the applicable regulatory requirement (I_{PK}).

$$I_{PP} \geq I_{PK}$$

For circuits that use additional series resistance, the surge current rating (I_{PP}) of the *TeleLink* SM fuse should be greater than or equal to the available surge currents associated with the lightning immunity tests of the applicable regulatory requirement ($I_{PK\ (available)}$).

$$I_{PP} \geq I_{PK\ (available)}$$

The maximum available surge current is calculated by dividing the peak surge voltage (V_{PK}) by the total circuit resistance (R_{TOTAL}).

$$I_{PP} \geq I_{PK\ (available)} = V_{PK}/R_{TOTAL}$$

For longitudinal surges (Tip-Ground, Ring-Ground), R_{TOTAL} is calculated for both Tip and Ring.

$$R_{TOTAL} = R_{TIP} + R_{SOURCE}$$

$$R_{TOTAL} = R_{RING} + R_{SOURCE}$$

For metallic surges (Tip-Ring):

$$R_{TOTAL} = R_{TIP} + R_{RING} + R_{SOURCE}$$

To select the most appropriate combination of *TeleLink* SM fuse and *SIDACtor*® device, decide the regulatory requirement your equipment must meet:

Regulatory Requirement	*TeleLink* SM Fuse	*SIDACtor* Device
GR 1089	04611.25	C Series
TIA-968-A, Type A	04611.25	B Series
TIA-968-A, Type B	04611.25	A Series
ITU K.20 Basic/Enhanced	04611.25	A Series / C Series
ITU K.21 Basic/Enhanced	04611.25	A Series / C Series
UL 60950	All	All
YD/T 950-1998	04611.25	A, B, or C Series *
YD/T 993-1998	04611.25	A, B, or C Series *
YD/T 1082-2000	04611.25	A, B, or C Series *

* Depends on the particular application

For applications that do not require agency approval or multiple listings, contact the factory.

Power/Line Feed Resistors

Typically manufactured with a ceramic case or substrate, power and line feed resistors have the ability to sink a great deal of energy and are capable of withstanding both lightning and power fault conditions.

Advantages

Power and line feed resistors are available with very tight resistive tolerances, making them appropriate for applications that require precise longitudinal balance.

Restrictions

Because power and line feed resistors are typically very large and are not available in a surface mount configuration, these devices are less than desirable from a manufacturing point of view. Also, because a thermal link is typically not provided, power and line feed resistors may require either a fuse or a PTC to act as the fusing element during a power fault condition.

Applications

Power and line feed resistors are typically found on line cards that use overvoltage protectors that cannot withstand the surge currents associated with applicable regulatory requirements.

Flameproof Resistors

For cost-sensitive designs, small (1/8 W – 1/4 W), flameproof metal film resistors are often used in lieu of PTCs, fuses, and power or line feed resistors. During a transient condition, flameproof resistors open when the resultant energy is great enough to melt the metal used in the device.

Advantages

Flameproof resistors are inexpensive and plentiful.

Restrictions

Flameproof resistors are not resistive to transient conditions and are susceptible to nuisance blows.

Applications

Outside of very inexpensive customer premise equipment, small resistors are rarely used as a means to protect telecommunications equipment during power fault conditions.

PCB Layout

Because the interface portion of a Printed Circuit Board (PCB) is subjected to high voltages and surge currents, consideration should be given to the trace widths, trace separation, and grounding.

Trace Widths

Based on the Institute for Interconnecting and Packaging Electronic Currents, IPC D 275 specifies the trace widths required for various current-carrying capacities. This is very important for grounding conditions to ensure the integrity of the trace during a surge event. The required width is dependent on the amount of copper used for the trace and the acceptable temperature rise which can be tolerated. Littelfuse recommends a 0.025-inch trace width with one ounce copper. (For example, a 38-AWG wire is equal to approximately 8 mils to 10 mils. Therefore, the minimum trace width should be greater than 10 mils.)

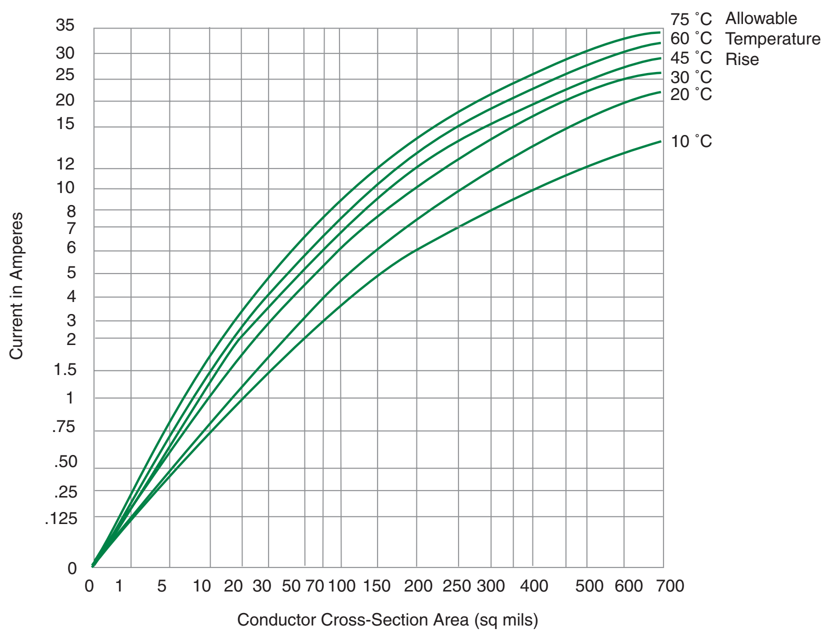


Figure 8.8 Current versus Area

The minimum width and thickness of conductors on a PCB is determined primarily by the current-carrying capacity required. This current-carrying capacity is limited by the allowable temperature rise of the etched copper conductor. An adjacent ground or power layer can significantly reduce this temperature rise. A single ground plane can generally raise the allowed current by 50 percent. An easy approximation can be generated by starting with the information in Figure 8.8 to calculate the conductor cross-sectional area required. Once this has been done, refer to Figure 8.9 for the conversion of the cross-sectional area to the required conductor width, dependent on the copper foil thickness of the trace.

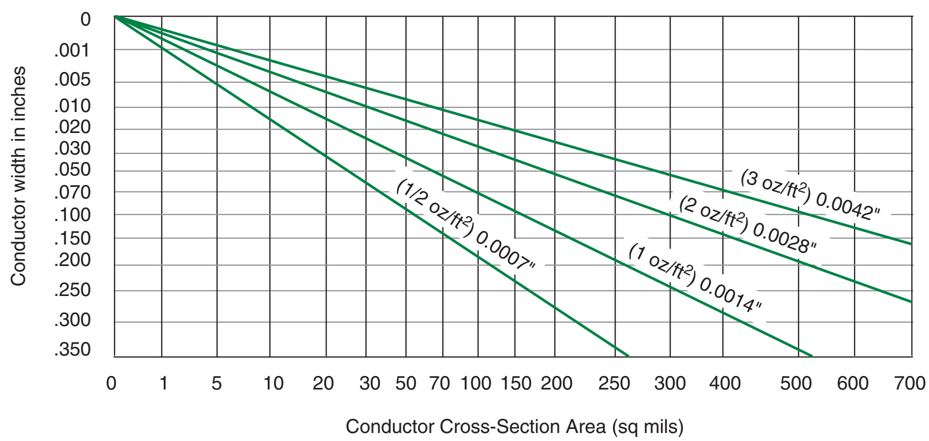


Figure 8.9 Conductor Width versus Area

Trace Separation

Tip and Ring traces are subjected to various transient and overvoltage conditions. To prevent arcing between traces, minimum trace separation should be maintained. UL 60950 provides additional information regarding creepage and clearance requirements, which are dependent on the Comparative Tracking Index (CTI) rating of the PCB, working voltage, and the expected operating environment. See "UL 60950 3rd Edition" on page 7-16 of this *Telecom Design Guide*.

A good rule of thumb for outside layers is to maintain a minimum of 18 mils for 1 kV isolation. Route the Tip and Ring traces towards the edge of the PCB, away from areas containing static sensitive devices.

Grounding

Although often overlooked, grounding is a very important design consideration when laying out a protection interface circuit. To optimize its effectiveness, several things should be considered in sequence:

1. Provide a large copper plane with a grid pattern for the Ground reference point.
2. Decide whether to use a single-point or a multi-point grounding scheme. A single-point (also called centralized) grounding scheme is used for circuit dimensions smaller than one-tenth of a wavelength (λ = 300,000/frequency) and a multi-point (distributed) grounding scheme is used for circuit trace lengths greater than one-fourth of a wavelength.
3. Because traces exhibit a certain level of inductance, keep the length of the ground trace on the PCB as short as possible in order to minimize its voltage contribution during a transient condition. In order to determine the actual voltage contributed to trace inductance, use the following equations:

$V = L\ (di/dt)$
$L = 0.0051\ \rho\ [\log_e 2\ \rho/(t+w) + ½ - \log_e G]$ in µH
where ρ = length of trace
G = function of thickness and width (as provided in Table 8.4)
t = trace thickness
w = trace width

For example, assume circuit A is protected by a P3100SC with a V_S equal to 300 V and a ground trace one inch in length and a self-inductance equal to 2.4 µH/inch. Assume circuit B has the identical characteristics as Circuit A, except the ground trace is five inches in length instead of one inch in length. If both circuits are surged with a 100 A, 10x1000 µs wave-form, the results would be as shown in Table 8.3:

Table 8.3 Overshoot Caused by Trace Inductance

	$V_L = L\ (di/dt)$	*SIDACtor* device V_S	Total protection level ($V_L + V_S$)
Circuit A	V_L = 2.4 µH (100 A/10 µs) = 24 V	300 V	324 V
Circuit B	V_L = 12 µH (100 A/10 µs) = 120 V	300 V	420 V

Other practices to ensure sound grounding techniques are:

1. Cross signal grounds and earth grounds perpendicularly in order to minimize the field effects of “noisy” power supplies.
2. Make sure that the ground fingers on any edge connector extend farther out than any power or signal leads in order to guarantee that the ground connection invariably is connected first.

Table 8.4 Values of Constants for the Geometric Mean Distance of a Rectangle

t/w or w/t	K	Log_eG
0.000	0.22313	0.0
0.025	0.22333	0.00089
0.050	0.22346	0.00146
0.100	0.22360	0.00210
0.150	0.22366	0.00239
0.200	0.22369	0.00249
0.250	0.22369	0.00249
0.300	0.22368	0.00244
0.350	0.22366	0.00236
0.400	0.22364	0.00228
0.450	0.22362	0.00219
0.500	0.22360	0.00211
0.500	0.22360	0.00211
0.550	0.22358	0.00203
0.600	0.22357	0.00197
0.650	0.22356	0.00192
0.700	0.22355	0.00187
0.750	0.22354	0.00184
0.800	0.22353	0.00181
0.850	0.22353	0.00179
0.900	0.22353	0.00178
0.950	0.223525	0.00177
1.000	0.223525	0.00177
0.000	0.0	0.0

Note: Sides of the rectangle are t and w. The geometric mean distance R is given by:
$\log_e R = \log_e(t+w) - 1.5 + \log_e G$. $R = K(t+w)$, $\log_e K = -1.5 + \log_e G$.

Technical Notes

Greentube™ Gas Plasma Arrester Soldering Recommendations

Reflow Soldering

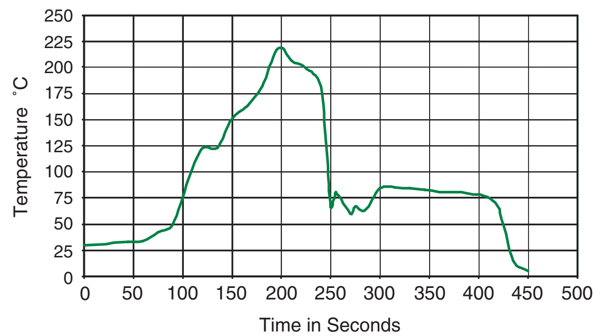
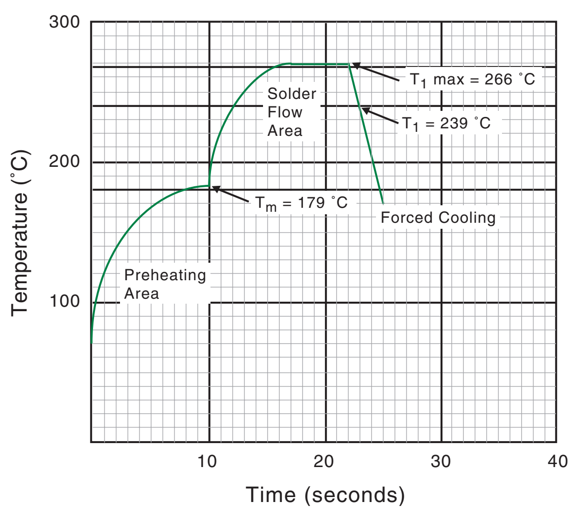


Figure 8.10 Profile for Reflow Soldering

Wave Soldering



Notes:
T_1 max (maximum tab temperature) = 266 °C
T_1 (flow temperature of solder) = 239 °C
T_m (melting point of solder) = 179 °C
T_{amb} = 25 °C

Maximum permissible rate of temperature change = °C/s

[Not for AF style SL1024 Series devices]

Figure 8.11 Profile for Wave Soldering

SIDACtor® Soldering Recommendations

When placing surface mount components, a good solder bond is critical because:

- The solder provides a thermal path in which heat is dissipated from the packaged silicon to the rest of the board.
- A good bond is less subject to thermal fatiguing and results in improved component reliability.

Reflow Soldering

The preferred technique for mounting the DO-214AA package is to reflow-solder the device onto a PCB-printed circuit board, as shown in Figure 8.12.

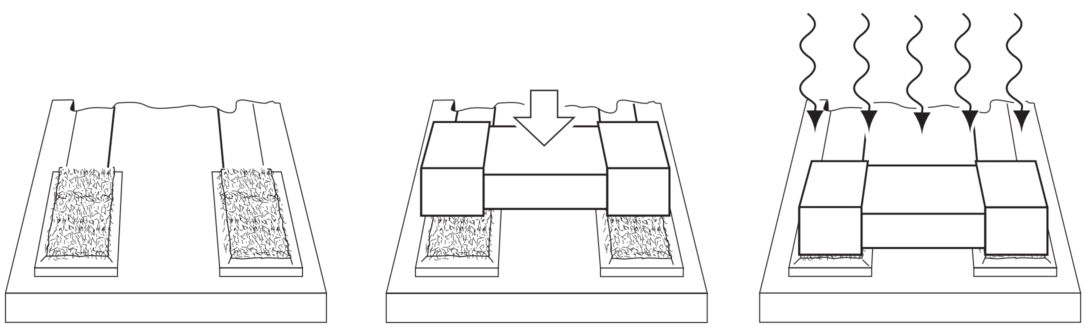


Figure 8.12 Reflow Soldering Procedure

For reliable connections, the PCB should first be screen printed with a solder paste or fluxed with an easily removable, reliable solution, such as Alpha 5003 diluted with benzyl alcohol. If using a flux, the PCB should be allowed to dry to touch at room temperature (or in a 70 °C oven) prior to placing the components on the solder pads.

Relying on the adhesive nature of the solder paste or flux to prevent the devices from moving prior to reflow, components should be placed with either a vacuum pencil or automated pick and place machine.

With the components in place, the PCB should be heated to a point where the solder on the pads begins to flow. This is typically done on a conveyor belt which first transports the PCB through a pre-heating zone. The pre-heating zone is necessary in order to reduce thermal shock and prevent damage to the devices being soldered, and should be limited to a maximum temperature of 165 °C for 10 seconds.

After pre-heating, the PCB goes to a vapor zone, as shown in Figure 8.13. The vapor zone is obtained by heating an inactive fluid to its boiling point while using a vapor lock to regulate the chamber temperature. This temperature is typically 215 °C, but for temperatures in excess of 215 °C, care should be taken so that the maximum temperature of the leads does not exceed 275 °C and the maximum temperature of the plastic body does not exceed 260 °C. (Figure 8.14)

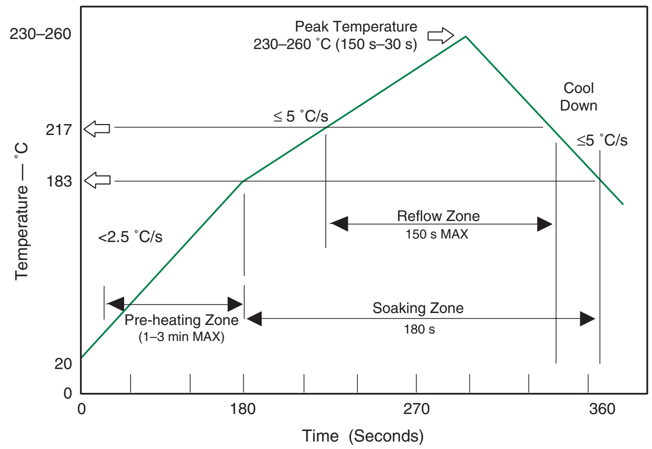


Figure 8.13 Reflow Solder Profile for RoHS-compliant Devices or Non-RoHS-compliant Devices

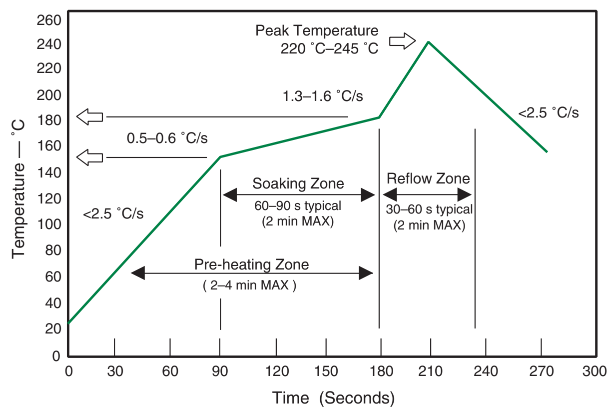


Figure 8.14 Reflow Soldering Profile for Non-RoHS-compliant Devices Only

During reflow, the surface tension of the liquid solder draws the leads of the device towards the center of the soldering area, correcting any misalignment that may have occurred during placement and allowing the device to set flush on the pad. If the footprints of the pad are not concentrically aligned, the same effect can result in undesirable shifts as well. Therefore, it is important to use a standard contact pattern which leaves sufficient room for self-positioning.

After the solder cools, connections should be visually inspected and remnants of the flux removed using a vapor degreaser with an azeotrope solvent or equivalent.

Wave Soldering

Another common method for soldering components to a PCB is wave soldering. After fluxing the PCB, an is adhesive applied to the respective footprints so that components can be glued in place. Once the adhesive cures, the board is pre-heated and then placed in contact with a molten wave of solder with a temperature between 240 °C and 260 °C and permanently affixes the component to the PCB. (Figure 8.15 and Figure 8.16)

Although a popular method of soldering, wave soldering does have drawbacks:

- A double pass is often required to remove excess solder.
- Solder bridging and shadows begin to occur as board density increases.
- Wave soldering uses the sharpest thermal gradient.

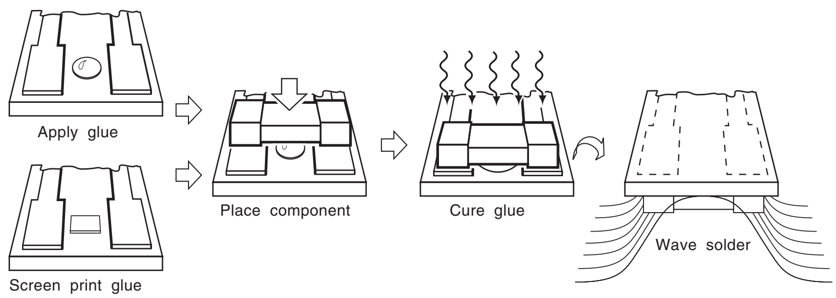


Figure 8.15 Wave Soldering Surface Mount Components Only

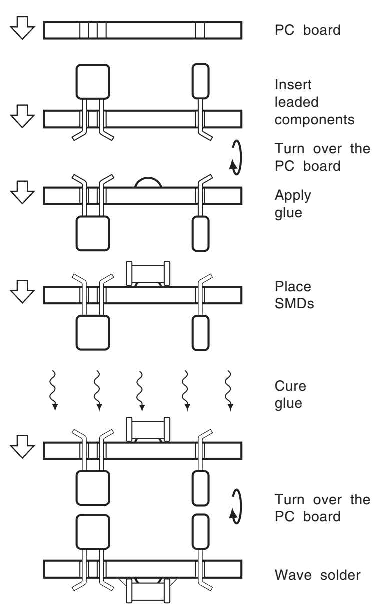


Figure 8.16 Wave Soldering Surface Mount and Leaded Components

Technical Notes

TeleLink® Fuse Soldering Recommendations

For wave soldering a *TeleLink* fuse, the following temperature and time are recommended:
- Reservoir temperature of 260 °C (500 °F)
- Time in reservoir—three seconds maximum

For infrared, the following temperature and time are recommended:
- Temperature of 260 °C (464 °F)
- Time—30 seconds maximum

Hand soldering is not recommended for this fuse because excessive heat can affect the fuse performance. Hand soldering should be used only for rework and low-volume samples.

Note the following recommendations for hand soldering:
- Maximum tip temperature of 240 °C (464 °F)
- Minimize the soldering time at temperature to achieve the solder joint. Measure the fuse resistance before and after soldering. Any fuse that shifts more than ±3% should be replaced. An increase in resistance above this amount increases the possibility of a surge failure, and a decrease in resistance may cause low overloads to exceed the maximum opening times.
- Inspect the solder joint to ensure that an adequate solder fillet has been produced without any cracks or visible defects.

Sn-Pb Wave Soldering Recommendations

Table 8.5 Sn-Pb Soldering Parameters

Sn-Pb Wave Parameter	Recommendation
Equipment	NU/ERA wave solder machine by Technical Devices
Solder Alloy	Alpha Metals Sn36Pb37
Flux Type	NC130 No-Clean flux by Florida CirTech, Inc.
Belt Speed	3.8 ft/min
Parameters	Pre Heater Temp Setting = 296 °C Solder Pot Temp = 249 °C Dwell Time = 1.5 seconds

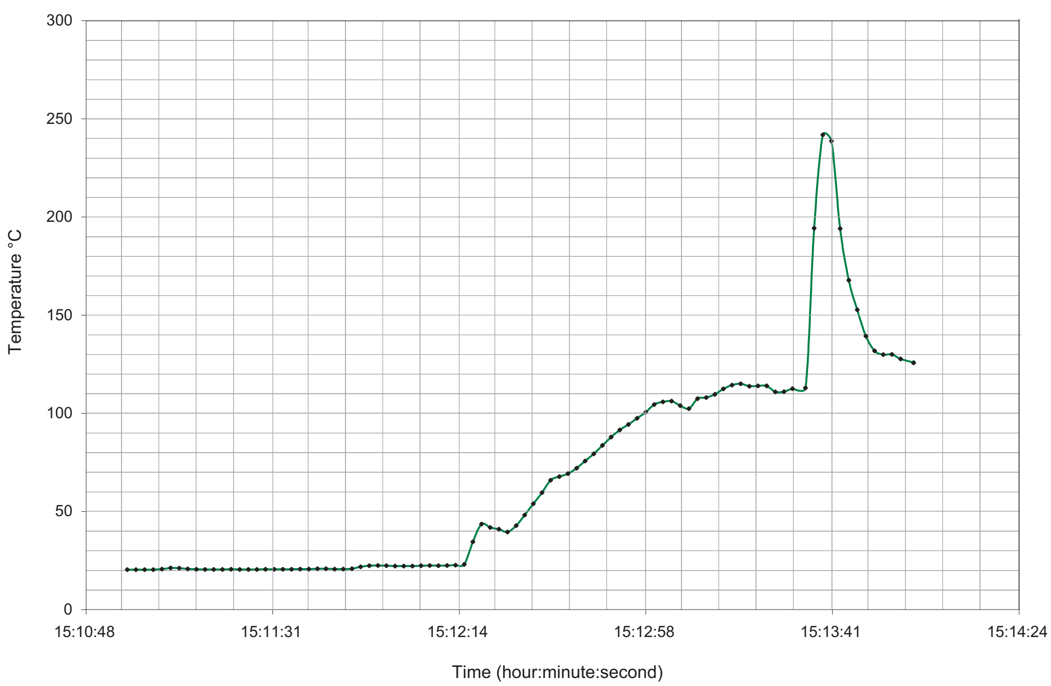


Figure 8.17 Profile for Sn-Pb Wave Soldering

Technical Notes

Lead-free Soldering Recommendations

As the electronics industry undergoes conversion from SnPb to lead-free soldering processes, Littelfuse will develop lead-free replacements or RoHS-compliant replacements for all electronic products. This conversion will require our customers to change established board-mounting process parameters for two reasons:

- The wettability (how well the molten solder flows on solderable surfaces) is degraded for Sn-Ag-Cu alloys (industry-preferred lead-free solder) as compared to Sn-Pb eutectics.
- The melting point for Sn-Ag-Cu alloys is typically around 220 °C (varying slightly among different alloys), much higher than the 183 °C melting point of conventional Sn-Pb eutectic solder.

Increasing profile temperatures and/or dwell times typically overcomes these issues.

This board-mounting standard serves as a design guideline for the electronics business unit relative to lead-free or RoHS-compliant product development across all Littelfuse facilities worldwide. This design guideline is applicable to all new product development programs as well as modifications of existing products.

Convection Reflow (SMD)

Table 8.6 defines the reflow parameter and lead-free requirements for convection reflow (SMD) soldering.

Table 8.6 Convection Reflow (SMD) Parameters and Lead-free Requirement

Reflow Parameter	Lead-free Requirement
Preheat Temperature Min Temperature Max Time (Min to Max)	 150 °C 200 °C 60–180 seconds
Thermal Ramp-up Rate	3 °C/second (Max)
Time above 217 °C	60–120 seconds
Peak Temperature	255 +5/-0 °C
Time within 5 °C of Peak Temperature	10–30 seconds
Thermal Ramp-down Rate	-6 °C/second (Max)

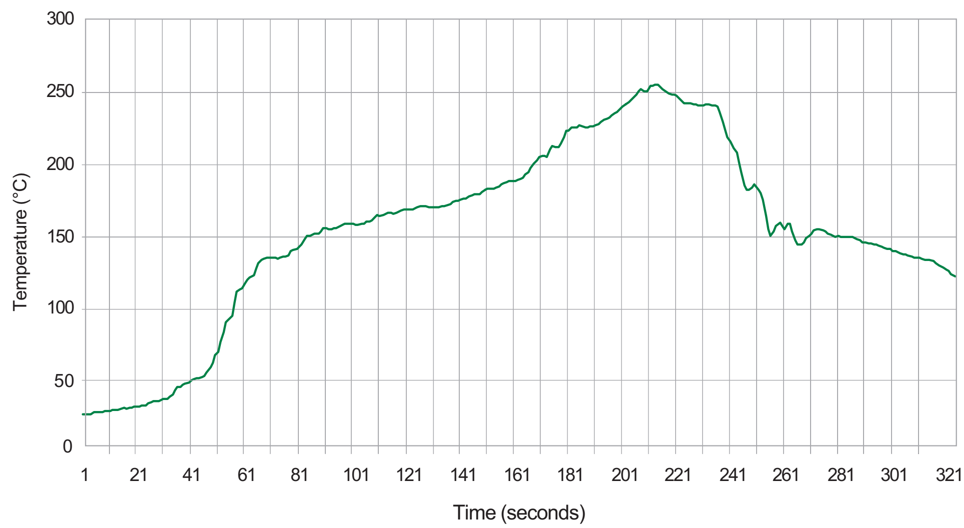


Figure 8.18 Profile for Lead-free Reflow Soldering

Wave Solder (THD)

Table 8.7 defines the wave parameter and lead-free requirements for wave (THD) soldering.

Table 8.7 Wave Solder (THD) Parameters and Lead-free Requirement

Reflow Parameter	Lead-free Requirement
Preheat (depending on flux only) Temperature Min Temperature Max Time (Min to Max)	 100 °C 150 °C 60–180 seconds
Solder Pot Temperature	260–265 °C (Max)
Solder Dwell Time	2–3.5 seconds
Cooling	-6 °C/second (Max)

Telecommunications Protection

Because early telecommunications equipment was constructed with components such as mechanical relays, coils, and vacuum tubes, it was somewhat immune to lightning and power fault conditions. But as cross bar and step-by-step switches have given way to more modern equipment such as digital loop carriers, repeater amplifiers, and multiplexers, an emphasis has been put on protecting this equipment against system transients caused by lightning and power fault conditions.

Lightning

During an electrical storm, transient voltages are induced onto the telecommunications system by lightning currents which enter the conductive shield of suspended cable or through buried cables via ground currents.

As this occurs, the current traveling through the conductive shield of the cable produces an equal voltage on both the Tip and Ring conductors at the terminating ends. Known as a longitudinal voltage surge, the peak value and waveform associated with this condition is dependent upon the distance the transient travels down the cable and the materials with which the cable is constructed.

Although lightning-induced surges are always longitudinal in nature, imbalances resulting from terminating equipment and asymmetric operation of primary protectors can result in metallic transients as well. A Tip-to-Ring surge is normally seen in terminating equipment and is the primary reason most regulatory agencies require telecom equipment to have both longitudinal and metallic surge protection.

Power Fault

Another system transient that is a common occurrence for telecommunications cables is exposure to the AC power system. The common use of poles, trenches, and ground wires results in varying levels of exposure which can be categorized as direct power fault, power induction, and ground potential rise.

Direct power fault occurs when a power line makes direct contact to telecommunications cables. Direct contact is commonly caused by falling trees, winter icing, severe thunderstorms, and vehicle accidents. Direct power fault can result in large currents being present on the line.

Power induction is common where power cables and telecommunications cables are run in close proximity to one another. Electromagnetic coupling between the cables results in system transients being induced onto the telecommunications cables, which in turn can cause excessive heating and fires in terminal equipment located at the cable ends.

Ground potential rise is a result of large fault currents flowing to Ground. Due to the varying soil resistivity and multiple grounding points, system potential differences may result.

Lightning

Lightning is one of nature's most common and dangerous phenomena. At any one time, approximately 2,000 thunderstorms are in progress around the globe, with lightning striking the earth over 100 times per second. According to IEEE C.62, during a single year in the United States lightning strikes an average of 52 times per square mile, resulting in 100 deaths, 250 injuries, and over 100 million dollars in damage to equipment property.

The Lightning Phenomenon

Lightning is caused by the complex interaction of rain, ice, up drafts, and down drafts that occur during a typical thunderstorm. The movement of rain droplets and ice within the cloud results in a large build up of electrical charges at the top and bottom of the thunder cloud. Normally, positive charges are concentrated at the top of the thunderhead while negative charges accumulate near the bottom. Lightning itself does not occur until the potential difference between two charges is great enough to overcome the insulating resistance of air between them.

Formation of Lightning

Cloud-to-ground lightning begins forming as the level of negative charge contained in the lower cloud levels begins to increase and attract the positive charge located at Ground. When the formation of negative charge reaches its peak level, a surge of electrons called a stepped leader begins to head towards the earth. Moving in 50-meter increments, the stepped leader initiates the electrical path (channel) for the lightning strike. As the stepped leader moves closer to the ground, the mutual attraction between positive and negative charges results in a positive stream of electrons being pulled up from the ground to the stepped leader. The positively charged stream is known as a streamer. When the streamer and stepped leader make contact, it completes the electrical circuit between the cloud and ground. At that instant, an explosive flow of electrons travels to ground at half the speed of light and completes the formation of the lightning bolt.

Lightning Bolt

The initial flash of a lightning bolt results when the stepped leader and the streamer make connection resulting in the conduction of current to Ground. Subsequent strokes (3-4) occur as large amounts of negative charge move farther up the stepped leader. Known as return strokes, these subsequent bolts heat the air to temperatures in excess of 50,000 °F and cause the flickering flash that is associated with lightning. The total duration of most lightning bolts lasts between 500 millisecond and one second.

During a lightning strike, the associated voltages range from 20,000 V to 1,000,000 V while currents average around 35,000 A. However, maximum currents associated with lightning have been measured as high as 300,000 A.

10 Key Facts about Lightning

1. Lightning strikes the earth on an average of 100 times per second.
2. Lightning strikes can affect computers and other electronic equipment as far as a kilometer away.

3. Lightning causes transient overvoltages (very fast electrical surges) on power, data communication, and signal and telephone lines. These surges then carry to and affect vulnerable equipment.
4. At-risk electronic equipment includes computers, building management systems, PABX telephone exchanges, CCTV equipment, fire and burglar alarms, uninterruptible power supplies, programmable logic controllers, and data acquisition equipment.
5. Transient overvoltages can cause instant damage to equipment and its circuitry, leading to costly and lengthy stoppages to operation and latent damage, and can result in breakdowns weeks or months later.
6. Even equipment in a building with structural lightning protection is still at great risk, as structural protection is designed to prevent damage to the building and to prevent loss of life.
7. While most businesses are at risk, campus or multi-building sites tend to be especially vulnerable.
8. Lightning can and does strike in the same place and can strike the same place multiple times. Sites that have suffered once are proven vulnerable and often suffer again within a matter of months.
9. Protecting electronic systems from transient overvoltage damage costs only a fraction of the cost of damage.
10. Littelfuse designs and manufactures quality lightning protection equipment.