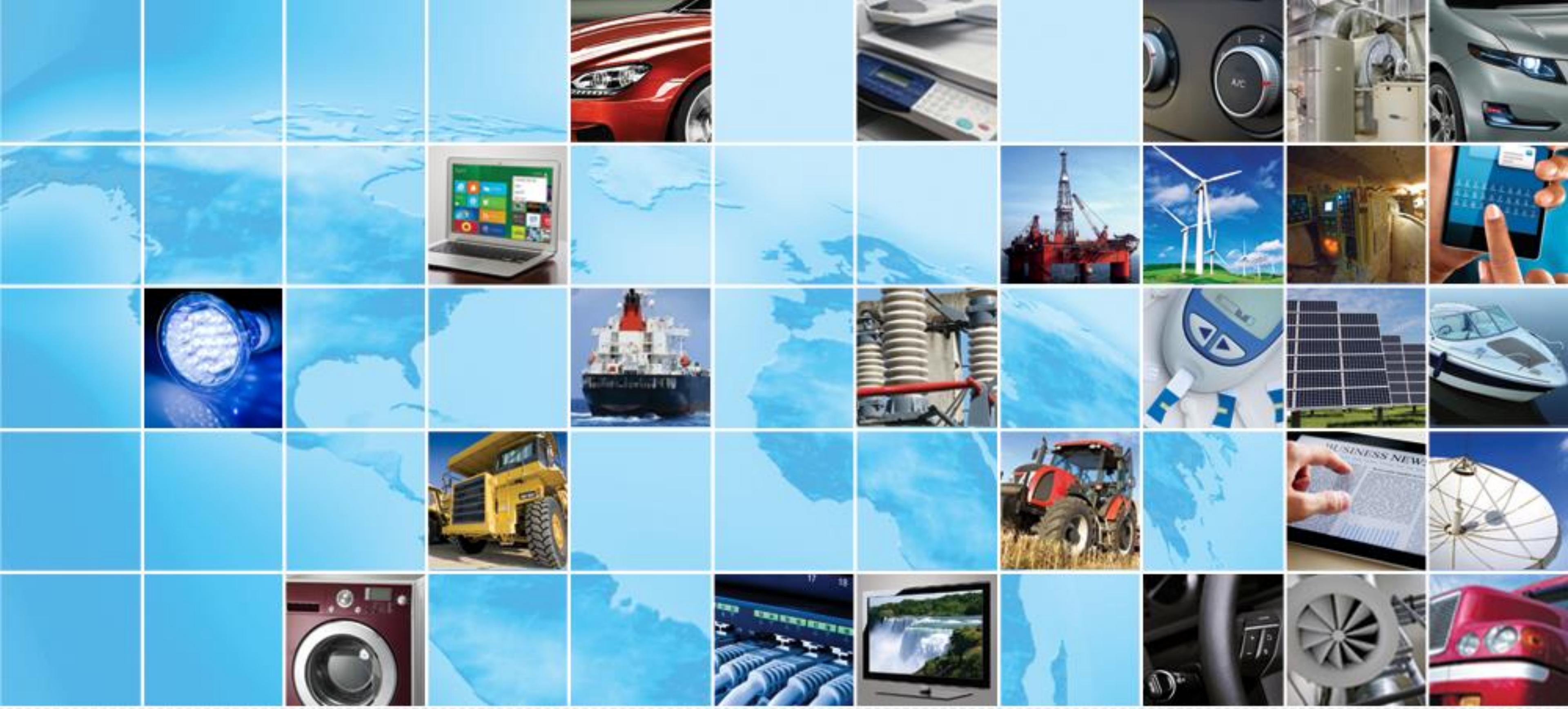


GDTs, MOVs & Fuses: Selecting the Appropriate Circuit Protection Component

Littelfuse®

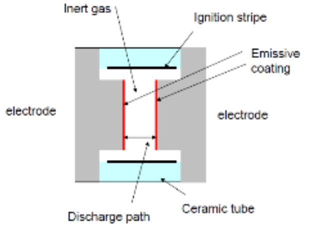
Expertise Applied | Answers Delivered

Introduction

- Selecting the appropriate circuit protection component is critical to a safe and robust design
- Sometimes, selecting the incorrect component can lead to catastrophic failures
- This presentation will show examples of proper and improper device selection and the consequences

Glowing Reviews of the (Wrong) GDT

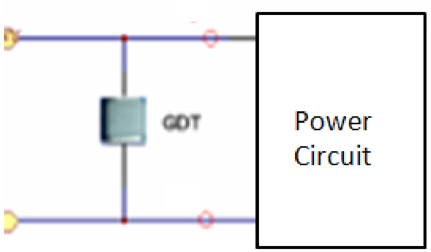
- **<u>Background</u>:**
  - Selecting the appropriate GDT for power line applications
    - Surge protection on AC or DC power lines is typically done by using MOVs
    - GDTs are typically used in signal applications or one N – PE leg due to minimal available currents



- **<u>Problem</u>:**
  - Upon seeing overvoltage surge, GDTs will break-over (crow-bar) by creating a sustained arc across the electrodes; surge current then shunted to ground, usually.
  - When surge event subsides, the GDT arc will be extinguished and system will return to normal
  - If power is applied to the line, the "follow current" will sustain the arc and the GDT may not be able to turn off.
  - GDT will then thermally fail due to sustained currents (glow red hot)
- **<u>Solution:</u>**
  - Littelfuse has AC power optimized GDTs (AC120/240 Series)

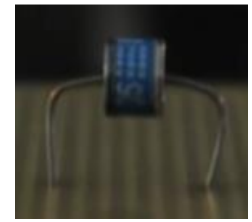
Glowing Reviews of the (Wrong) GDT

- **Test Set-up**:
  - 120V tube, AC coupled, 6KV/3KA, limited to 10A follow thru current
  - Littelfuse AC120 GDT (designed for power lines)
  - Littelfuse SL series GDT (designed for signal apps)



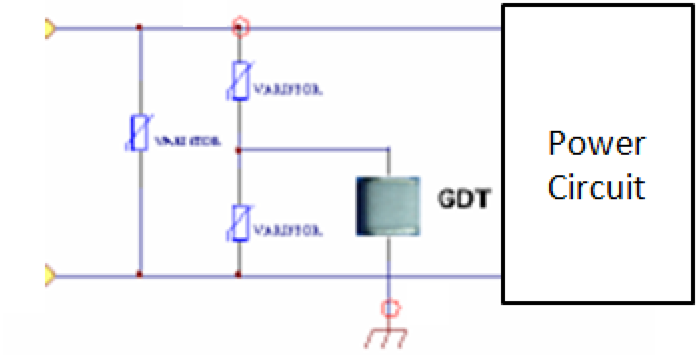
- **Images**:
  - 1. Littelfuse AC120 (GOOD) – see next slide
  - 2. Littelfuse SL series (BAD) – see next slide

Images Before, During and After

- Good
  - Before 
  - During 
  - After 
- Bad
  - Before 
  - During (longer glow, more heat) 
  - After 

Glowing Reviews of the (Wrong) GDT

- **<u>Additional Information</u>:**
  - MOVs can be placed in series with GDTs
  - MOV will help cut off the follow current and allow GDT to turn off
  - During surge event, MOV will clamp and conduct first into a low impedance state ; then GDT will break-over and create the arc.
  - When surge subsides, the MOV will go back to high impedance state and will quench the follow current and allow GDT arc to be extinguished



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MOV End of Life Failures are Really HOT!

- **Background**:
  - MOV (Metal Oxide Varistors) can degrade over lifetime due to surge events
  - MOV material can weaken due to multiple surges and develop “memory” path
  - MOV at end-of-life will start to leak current with nominal system voltage applied
- **Problem**:
  - Leakage will heat up the MOV and impedance will continue to drop leading to thermal run-away failure
  - MOV protection solutions needing to meet UL1449 3rd Ed which includes Abnormal Overvoltage testing which simulates this fault condition
- **Solution**:
  - Select Littelfuse TMOV series products to control MOV end-of-life (EOL) conditions.
  - TMOV™ MOVs have integrated thermal protector built inside the disc which will open upon thermal heating of MOV.
  - Use of TMOV will prevent catastrophic failure of MOV disc during EOL condition
  - TMOVs will help equipment makers pass UL1449 Abnormal Overvoltage Limited Current test requirements without the need for external fuse

MOV End of Life Failures are Really HOT!

- **<u>Test Set-up</u>:**
  - 150V MOV with 240V/10A fault, AC coupled – simulating EOL condition
  - Side-by-side testing 150V TMOV (thermally protected MOV)

- **<u>Images</u>:**
  - Competitor MOV (Left) ; Littelfuse MOV (Middle) ; Littelfuse TMOV (Right)

See next slide for before, during & after pictures

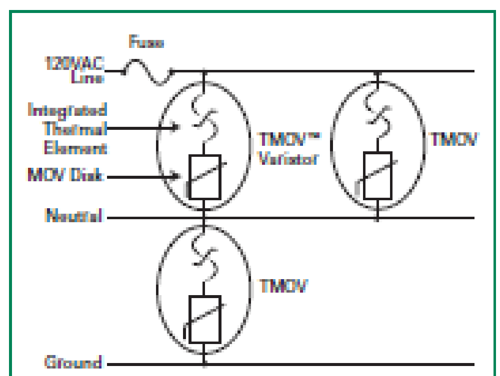
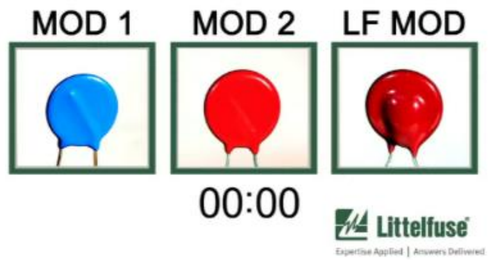


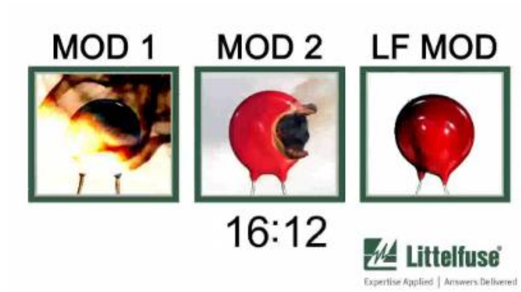
Figure 4. TMOV varistor offline protection scheme

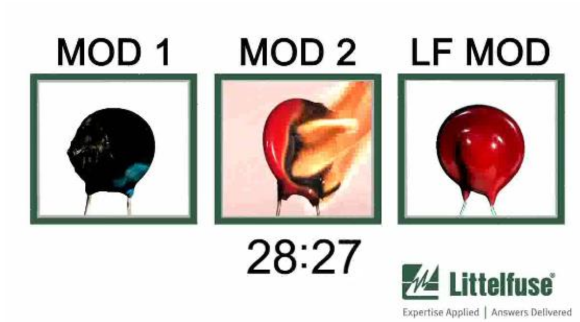
Images Before, During and After

– Before

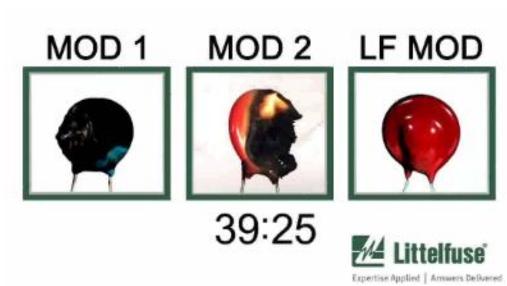


– During





– After



Don’t Let Your Diode Die an Untimely Death

- **Background**:
  - TVS diodes can be used for AC or DC input power protection
  - Caution to stay under the surge rating of the TVS diode
  - While TVS diodes offer fast and efficient clamping capability, they have limited surge robustness
  - IEC61000-4-5 and C.62.41-2002 are popular surge immunity standards
  - Maximum indoor surge condition typically is 6kV/3kA, 8/20us surge combo wave
- **Problem**:
  - TVS diodes can undergo catastrophic failure if over stressed beyond surge ratings
  - Traces need to be sized according or will open up as well!
- **Solution**:
  - Select the correct TVS diode surge rating for your application

Don’t Let Your Diode Die an Untimely Death

- **Test Set-up**:
  - SMCJ TVS diode, 1500W diode, bidirectional – 6kV/3kAa surge applied

- **Images**:

  See next slide for before, during & after pictures

Images Before, During and After

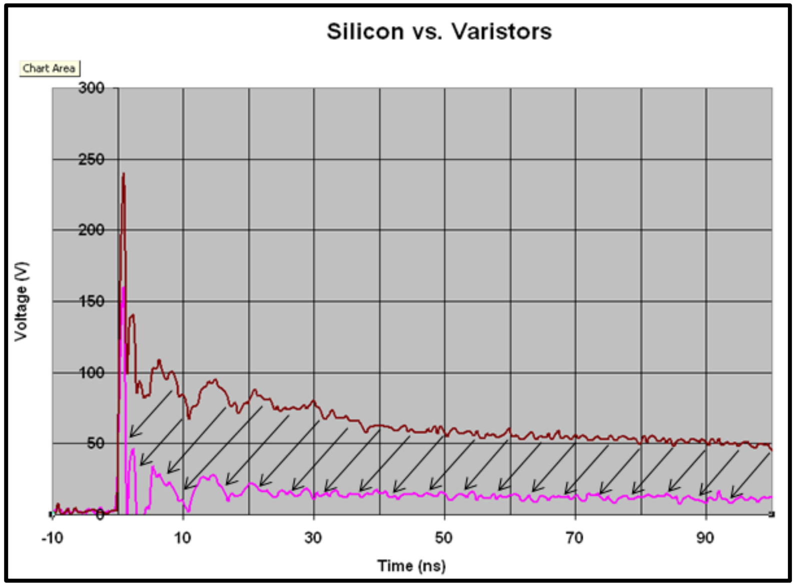
– Before

– During

– After

Don’t Let Your Diode Die an Untimely Death

- **<u>Additional Information</u>:**
  - Diodes should be selected for a given application by their:
    - Power Rating,
    - Maximum surge current,
    - Standoff Voltage, and
    - Breakdown Voltage
  - Though sometimes not as robust as a MOV, a TVS Diode will have the lowest dynamic resistance (the resistance between the I/O and ground); therefore, a TVS Diode will clamp better and reduce the overall amount of energy seen by the sensitive electronics downstream.
  - The area between the curves represents the amount of energy that DOES NOT get to the chip when an MLV was replaced by an equivalent TVS Diode.



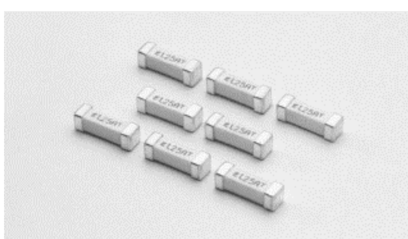
Ethernet Vs. Power Cross

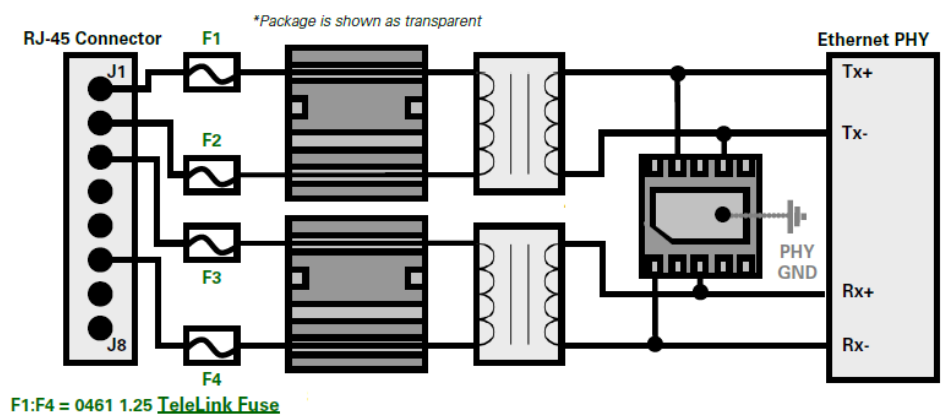
- **Background:**
  - Ethernet ports needing to meet GR-1089 Inter-Building Power Cross requirements need appropriate overcurrent protection
  - Typically, protection is a surge tolerant fuse that will open fast enough during Power cross testing
- **Problem:**
  - Prevent SEP SIDACtor (overvoltage protector) from getting damaged during power cross testing
  - Proper fusing required to comply with GR-1089 Power cross and prevent equipment damage/safety hazard
- **Solution:**
  - Use Littelfuse 461 Series Telelink fuse (typically 1.25A rating) at port input on cable side
  - Use low capacitance, C or D Rated, SIDACtor overvoltage protector (Littelfuse SEP series)

Ethernet Vs. Power Cross

- **<u>Test Set-up</u>:**
  - Littelfuse Ethernet demo board - Power cross 425V/40A GR-1089 fault – with and without fuse protection
  - SEP Series Ethernet surge protector on cable side
  - Fuse – Littelfuse 461 series, 1.25A Telelink fuse
- **<u>Images</u>:**
  - With fuse:
  - Without fuse:

See next slide for before, during & after pictures





Images Before, During and After

- With Fuse
  - Before

  - During

  - After

- Without Fuse
  - Before

  - During

  - After

"Fuse Interrupted" (the exploding DVD version)

- **Background**:
  - Fuse max voltage and max interrupt rating are safety critical specifications
  - When fuse opens during fault, the higher voltage applied will cause arc to form longer duration
  - Higher voltage and higher current faults will cause plasma formation and molten metal
  - Fuse body, fillers, and fuse element designed to quench arc and safely open fuse
- **Problem**:
  - Deviating from fuse max specs and over-stressing the device will cause catastrophic failures
- **Solution**:
  - Stay under the fuse voltage and interrupt ratings

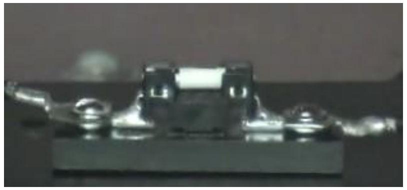
“Fuse Interrupted” (the exploding DVD version)

- **Test Set-up**:
  - Littelfuse 215 series, 5x20mm ceramic fuse ; 3.15A rating ; 250VAC/1500A Interrupt rating
  - We applied 250VAC/1500A short circuit fault
  - We applied 400VDC, 200A short circuit fault (above fuse voltage rating)
- **Images**:
  - Within fuse voltage rating:
  - Above fuse voltage rating:

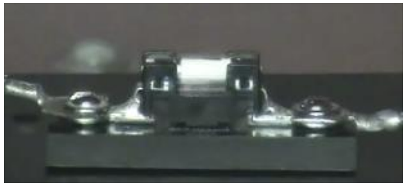
See next slide for before, during & after pictures

Images Before, During and After

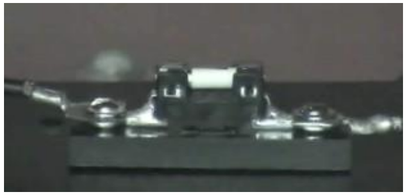
- Within Fuse Voltage Rating
  - Before



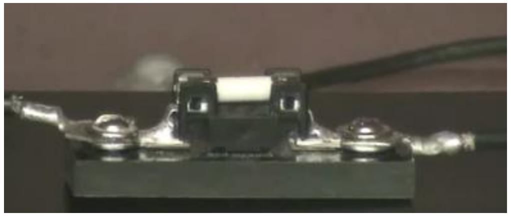
  - During



  - After



- Above Fuse Voltage Rating
  - Before

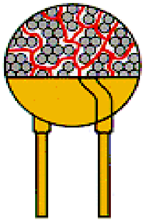


  - During

  - After

The Non-Resettable Resettable Fuse

- **Background:**
  - Just like fuses, PTC Resettable fuses can experience overvoltage stress and fail
  - PTC's most dangerous failure mode is overvoltage stress
  - The higher voltage causes damage to the polymer material and will damage the conductive carbon particles



- **Problem:**
  - Choosing wrong voltage rating can lead to catastrophic failure mode

- **Solution:**
  - Stay under the max voltage rating of your PTC

The Non-Resettable Resettable Fuse

- **Test Set-up**:
  - Littelfuse 16R series PTC Resettable fuse being used in 60VDC short circuit fault
  - 16R series has max voltage rating of 16VDC
  - Littelfuse 60R or 72R series is recommended for this application.

- **Images**:

  See next slide for before, during & after pictures

Images Before, During and After

– Before

– During

– After

Fusible Resistors are Irresistible (buyer beware!)

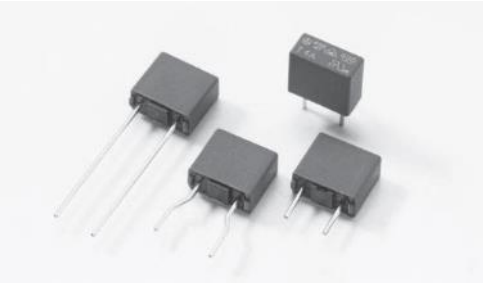
- **Background:**
  - Fusible resistors are poor alternatives to using a properly specified fuse.
  - These fusible resistors are frequently used in LED bulb or charger applications due to their low cost.
  - FusR will tend to get very hot during overload and burn open causing potential safety hazard.
  - Smoke will be generated from burning fusible resistor which is a customer satisfaction issue.
- **Problem:**
  - Unlike a fuse which is designed to open safely during overload condition, a fusible resistor (FusR) will not have a controlled and consistent opening mode.
- **Solution:**
  - Select a Littelfuse fuse designed to meet the specified requirements.

Fusible Resistors are Irresistible (buyer beware!)

- **Test Set-up:**
  - Fusible resistor vs. fuse during overload condition
  - 392 series TE fuse vs. 10ohm FusR
  - 240vac, 200% Overload over the fuse rating

- **Images:**
  - 392 series fuse – GOOD
  - 10 Ohm Fusible resistor – BAD

See next slide for before, during & after pictures



Images Before, During and After

- Fuse
  - Before

  - During

  - After

- Fusible Resistor
  - Before

  - During

  - After

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SMOV – The Superhero of MOVs

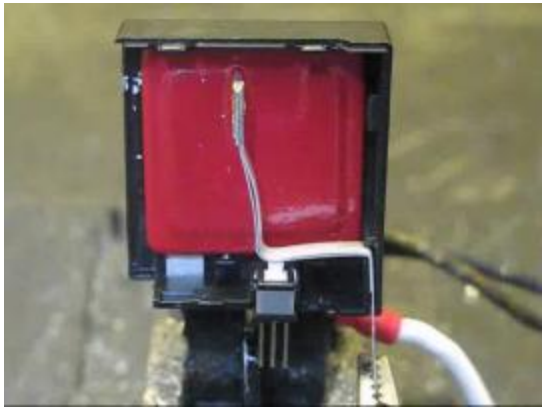
- **Background**:
  - UL1449 3rd Ed, Abnormal Overvoltage Intermediate current testing requires up to 150A fault current when testing MOVs
  - Intermediate current testing required for Type 3 SPDs and above.
- **Problem**:
  - Passing the UL1449 Intermediate current test standards typically requires an external fuse
  - Fuse will open before MOVs fail but difficult to select due to 6kv/3ka high surge withstand requirements
  - Integrated thermal protection inside Littelfuse TMOV is limited to max 10A fault current
- **Solution**:
  - Select Littelfuse SMOV Series instead of TMOV to pass UL1449 Intermediate current requirements

SMOV – The Superhero of MOVs

- **Test Set-up:**
  - 150V TMOV and SMOV tested at 240VAC/150A Intermediate current per UL1449

- **Images:**
  - TMOV failing at 150A – BAD
  - SMOV opening safely at 150A – GOOD

See next slide for before, during & after pictures



Expertise Applied | Answers Delivered

Images Before, During and After

- TMOV
  - Before

  - During

  - After

- SMOV
  - Before

  - During

  - After

Selecting a Fuse

Fuse Selection Process

Basics – definitions for selecting fuses

<u>Background selection information:</u>

Maximum operating current – the maximum current that the fuse will experience during normal operation of the application

Ambient temperature – the temperature in the area surrounding the fuse

Normal operating voltage – the voltage level of the line that the fuse is protecting; this is also the voltage that the fuse will have to safely support after it has opened

Current pulses – these are short duration pulses for which the fuse should not open

- In-rush and start-up currents are examples
- The shape, magnitude and quantity of the pulses is needed to ensure no nuisance tripping of the fuse

Maximum fault current – this determines the Interrupt Rating (Breaking Capacity) that the fuse must meet

Mounting requirements of fuse (surface mount, through hole) is considered secondary selection criteria (to meet mechanical needs)

Fuse Selection Process

Process for calculating minimum fuse current rating (Amps)

(This is explained in the Littelfuse Catalog starting on page 9)

Step 1) Collect information to calculate minimum fuse rating

- Maximum operating current
- Normal operating voltage
- Ambient temperature

Use the following equation to calculate the minimum fuse rating:

$$\text{Minimum fuse rating} = \frac{\text{Maximum operating current}}{\text{fuse re-rating factor} \times \text{thermal de-rating factor}}$$

Fuse Selection Process

Process for calculating minimum fuse rating (amperage)

<u>Fuse re-rating factor:</u>

- Use 0.75 if the fuse is UL or CSA Listed or Recognized
- Use 1.00 if the fuse is IEC Designed

<u>Thermal de-rating factor (TDR):</u>

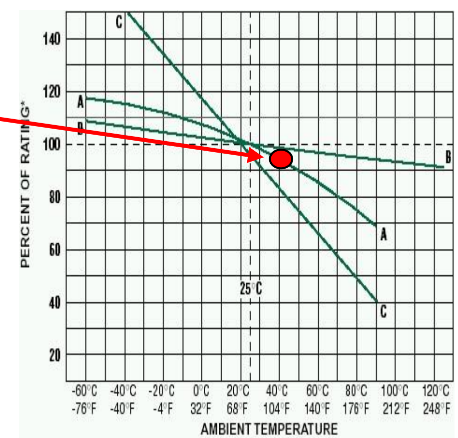
Determine the thermal de-rating factor by using the appropriate curve for the ambient temperature that the fuse will experience (found on page 9 of Fuse Catalog)

<u>For example:</u>

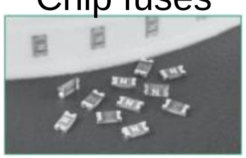
Thin Film Fuse → Use Curve A

If temp is 40ºC → Use TDR of **95%**

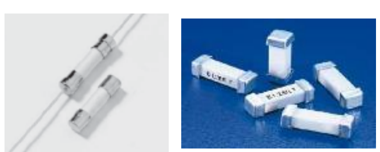
Curve A = Thin Film Fuses
Curve B = Wire-in-air Fuses
• (Cartridge, Nano²)
Curve C = Resettable PTCs



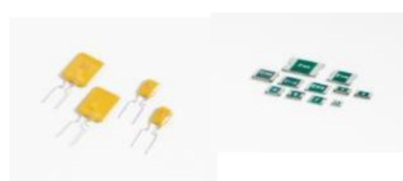
Chip fuses



Wire-in-air fuses



Resettable PTCs



Fuse Selection Process

Process for calculating minimum fuse rating (amperage)

Step 2) Calculate the minimum fuse rating

$$\text{Minimum fuse rating} = \frac{\text{maximum operating current}}{\text{fuse re-rating factor x thermal de-rating factor}}$$

For this example, it is given that a surface mount thin film fuse is desired, and that the maximum operating current is 0.50A and ambient temperature is 40° C:

Maximum operating current:	0.50A
Fuse re-rating factor:	0.75
Thermal de-rating factor:	0.95

$$\text{Then, minimum fuse rating} = \frac{0.50\text{ A}}{0.75 \times 0.95} = \mathbf{0.700\text{ A}}$$

Since this value is the minimum requirement, find the closest fuse rating that is higher.

So, the minimum fuse rating that can be used is **0.750 A.**

Fuse Selection Process

Process for calculating minimum melting i^2t of fuse

Step 3) Calculate minimum nominal melting I^2t rating of fuse

1) Determine Pulse I^2t of the application (in-rush current, inductive load switching, etc.)
2) Calculate nominal melting I^2t of the fuse

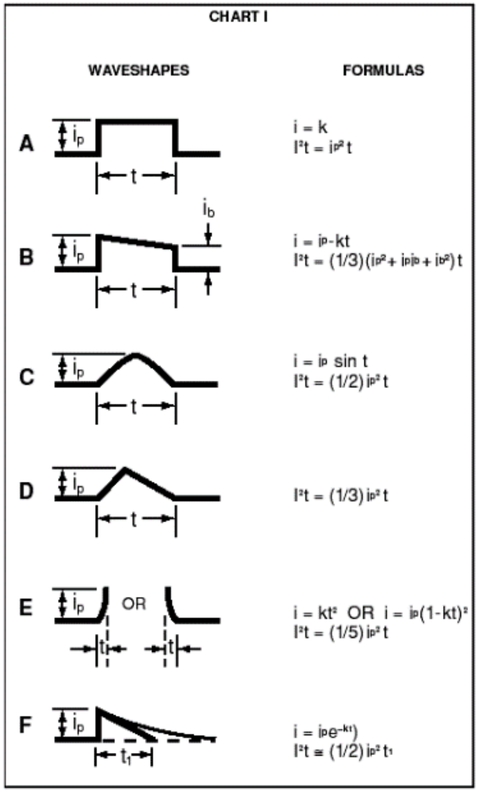
Pulse I^2t: use the waveshape chart to determine appropriate formula

For example:

- Assume that current measurements show Type A waveshape
- Peak current was measured to be 1.5A
- Duration of pulses are 1 millisecond.

Then,

Pulse I^2t = $Ip^2 \times t = (1.5)^2 \times 0.001s$ = 0.00225 A^2s



Fuse Selection Process

Process for calculating minimum melting i^2t of fuse

Step 4) Calculate minimum nominal melting I^2t rating of fuse

1) Determine Pulse I^2t of the application

2) Determine Rating Factor for the application

For example:

- Pulse Pulse I^2t was calculated to be 0.00225 A^2s
- Assume that the fuse needs to survive 100,000 pulses

Use Chart II to determine the Rating Factor

- For 100,000 pulses, Rating Factor is 22%

Then,

Minimum nominal melting **I^2t** rating = Pulse I^2t / rating factor

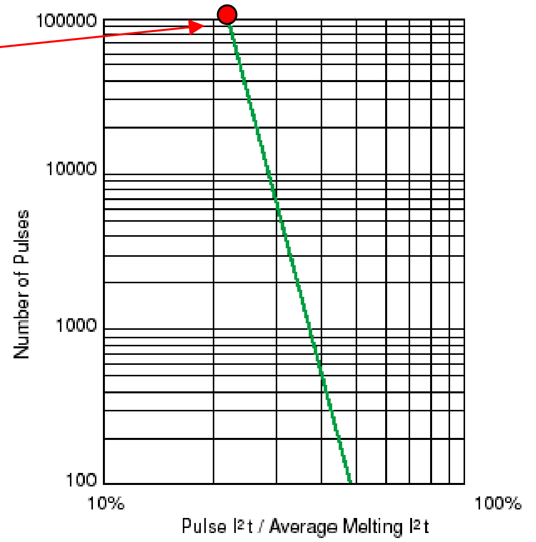
= 0.00225 A^2s / 0.22

= 0.0102 A^2s

CHART II

PULSE CYCLE WITHSTAND CAPABILITY

100,000 Pulses	Pulse I^2t = 22% of Nominal Melting I^2t
10,000 Pulses	Pulse I^2t = 29% of Nominal Melting I^2t
1,000 Pulses	Pulse I^2t = 38% of Nominal Melting I^2t
100 Pulses	Pulse I^2t = 48% of Nominal Melting I^2t



Note: Adequate time (10 seconds) must exist between pulse events to allow heat from the previous event to dissipate.

Fuse Selection Process

Process for calculating minimum melting i^2t of fuse

Step 5) Compare the calculated nominal melting I^2t to actual fuses:

Surface mount thin film fuses were specified earlier

So, compare Nominal melting **I^2t** value of 0.750A-rated thin film fuses to target value (0.0102 A^2s):

The information can be found on the product data sheet. The chart to the right is for the SlimLine 0402, 0435 series fuse.

Catalog Number	Ampere Rating	Voltage Rating	Nominal Resistance Cold Ohm[1]	Nominal Melting I^2t (A^2 Sec.)
0435.250	.25	24	0.220	0.0025
0435.375	.375	24	0.185	0.0035
0435.500	.5	24	0.150	0.0053
0435.750	**.75**	**24**	**0.105**	**0.0120**
0435 001.	1	24	0.072	0.020
0435 1.25	1.25	24	0.060	0.035
0435 01.5	1.5	24	0.047	0.056
0435 1.75	1.75	24	0.038	0.075
0435 002.	2	24	0.030	0.100

0433.750	1206, very fast acting	0.0170 A^2s	63VDC
0434.750	0603, very fast acting	0.0171 A^2s	32VDC
0435.750	0402, very fast acting	0.0120 A^2s	24VDC

Since the nominal melting **I^2t** value for all of these fuses is greater than the required value of the application (0.0102 A^2s), they are all valid for usage. The specific part can be chosen according the amount of board space available, the rated voltage, etc.

Fuse Selection Process

Summary of steps to select fuse

Understand the application and circuit parameters

→ Determine minimum current rating of fuse (fuse re-rating, thermal de-rating) — **0.750 A**

→ Determine **Pulse I^2t** value of the application — **0.00225 A^2s**

→ Determine minimum **Nominal melting I^2t** value of the Fuse — **0.0102 A^2s**

→ Compare calculated and actual nominal melting **I^2t** values to ensure fuse will not suffer nuisance opening. If there are multiple fuses qualified for the application, use secondary characteristics (size, voltage rating, etc.) to determine best solution

→ IMPORTANT!! Even though care may be used during the fuse selection process, it is recommended that application-level testing be performed to verify coordination of fuses to the circuit conditions

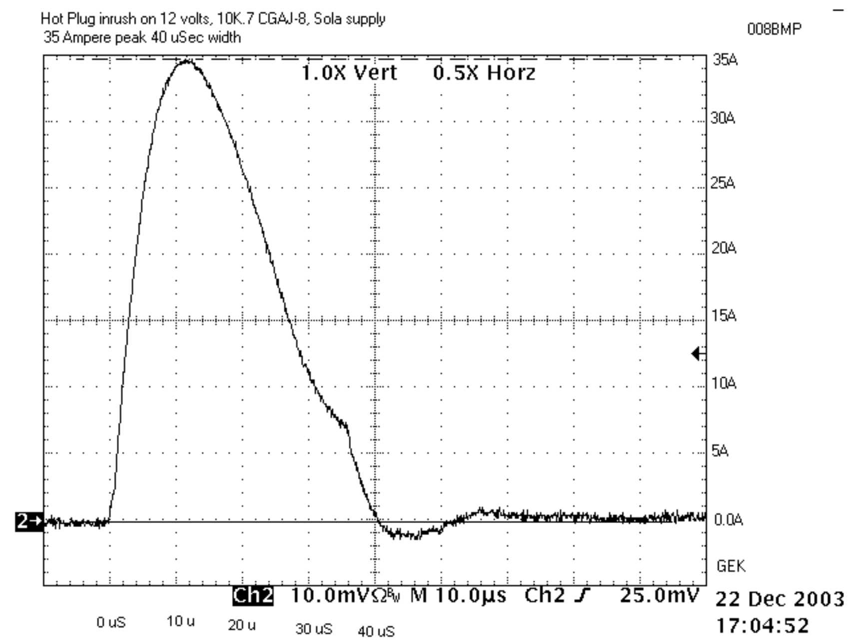
Fuse Selection Example

Verification of calculated melting i^2t

Screen shot is actual in-rush current from HDD hot-plug

Details of in-rush current

- System voltage = 12VDC
- Peak current = 35A
- t = 40 µs
- Number of pulses required = 70,000



Calculations:

$I^2t = (1/2)Ip^2\ t$

$I^2t = (1/2) \times (35A)^2 \times (.00004)$

Pulse $I^2t = 0.0245\ A^2s$

Nominal melting $I^2t = (0.0245 / 0.23) =$ **$0.1065\ A^2s$**

Catalog Number	Ampere Rating	Marking Code	Nominal Voltage Rating	Nominal Resistance[1] (Ω)	Melting I^2t (A^2 Sec.)[2]
0467.250	.25	D	32	0.435	0.0030
0467.375	.375	E	32	0.275	0.0053
0467.500	.5	F	32	0.180	0.0087
0467.750	.75	G	32	0.112	0.0171
0467 001.	1	H	32	0.062	0.0212
0467 1.25	1.25	J	32	0.050	0.0518
0467 01.5	1.5	K	32	0.040	0.0766
0467 1.75	1.75	L	32	0.028	0.0903
0467 002.	2	N	32	0.024	0.1103
0467 02.5	2.5	O	32	0.020	0.1440
0467 003.	3	P	32	0.016	0.2403
0467 03.5	3.5	R	32	0.013	0.4306
0467 004.	4	S	32	0.011	0.5760
0467 005.	5	T	32	0.0085	0.9000

The 0467003.NR fuse had been selected

- **$0.2403\ A^2s$** is the listed value
- This value is greater than the calculated value, so the fuse should withstand 70,000 pulses
- Testing at Littelfuse confirmed that the fuse could indeed survive 70,000 of these pulses

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Fuse Selection Example (continued)

Using Ratio of Calculated Pulse I^2t to Melting I^2t of selected fuse to determine Pulse Cycle Withstand Capability

Pulse Energy vs. Fuse Melting Energy

Calculated Pulse I^2t = 0.0245 A^2s (previous page)

0467003 Fuse I2t = 0.2403 A^2s

Catalog Number	Ampere Rating	Marking Code	Nominal Voltage Rating	Nominal Resistance[1] (Ω)	Melting I^2t (A^2 Sec.)[2]
0467.250	.25	D	32	0.435	0.0030
0467.375	.375	E	32	0.275	0.0053
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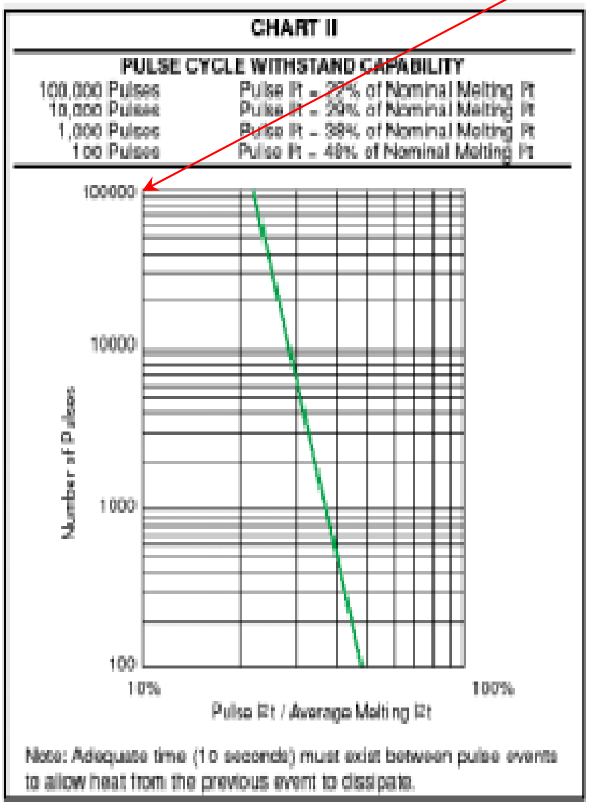
Ratio of Calculated Pulse I^2t / Fuse Melting I^2t
= 0.0245 A^2s / 0.2403 A^2s = ~10.2%

>100,000 pulses at 10.2% melting I^2t



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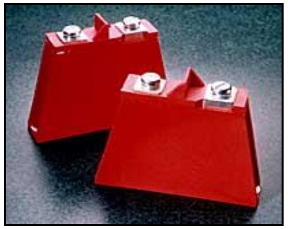
Surge Protection Selection

- Metal Oxide Varistor

Surge Protection Component
Overview of MOV product

Metal Oxide Varistor (MOV)

- **Shunts high pulse-current and high-energy transients to ground; thereby protecting the application**
- **Industry standard form factors**
- **Thermally-protected version is available (TMOV)**
- **<u>Key feature</u> is the durability to repeatedly handle high peak pulse current, high-energy surge transients**



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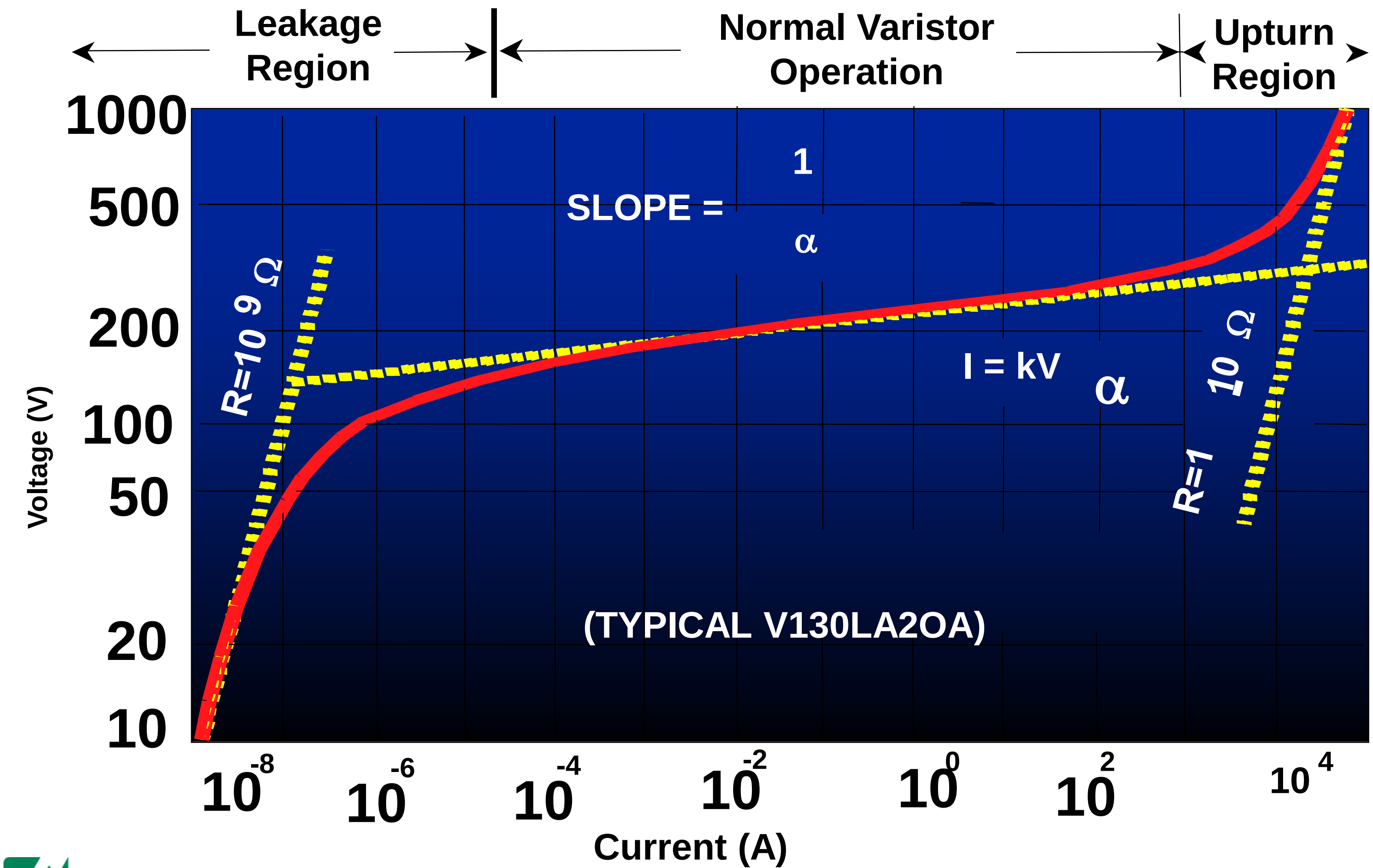
Surge protection component

Functional regions of MOV (based on V-I curve)



Surge Protection Selection

- Metal Oxide Varistor
- Example of selecting a MOV

MOV Selection Process

Example of selecting a MOV for lightning protection

Example of MOV selection

Circuit conditions and requirements:
-120VAC circuit
- Current waveform for surge is 8x20μs; voltage is 1.2x50μs
- Peak current during the surge is 3,000A
- Requirement is to survive 40 surges
- Other components (transformer, capacitors, etc.) are rated to withstand 1,000V maximum.

Approach to finding a solution:
- To find the voltage rating of the MOV, allow for 20% head room to take into account voltage swells.
    - 120VAC x 1.2 = 144VAC
    - So look at 150VAC rated MOVs
    - Determine which MOV disc size to use – identify those that minimally meet the 3,000A surge requirement

-Use *Pulse Rating Curves* to determine pulse capabilities of each series per the 40 pulses @ 3,000A requirement
- Use *V-I Curve* of selected MOV to verify that the peak voltage will be below the 1,000V ceiling.

MOV Selection Process

Determine which disc size is needed (see page 112 of MOV Catalog)

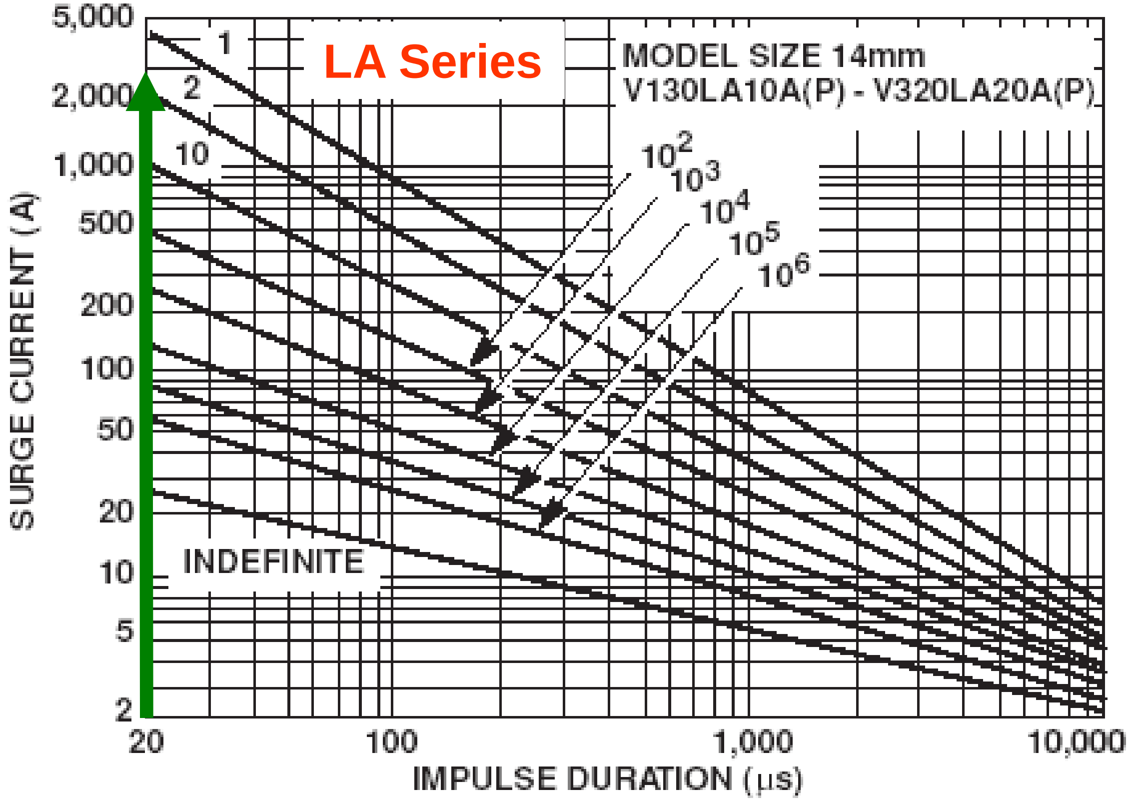
RoHS Pb LEAD-FREE AND RoHS COMPLIANT MODELS		STANDARD MODELS		MODEL SIZE DISC DIA. (mm)	MAXIMUM RATING (85°C)				SPECIFICATIONS (25°C)				
					CONTINUOUS		TRANSIENT						
					V_{RMS}	V_{DC}	ENERGY 10 x 1000µs	PEAK CURRENT 8 x 20µs	VARISTOR VOLTAGE AT 1mA DC TEST CURRENT		MAXIMUM CLAMPING VOLTAGE 8 x 20µs		TYPICAL CAPACITANCE f = 1MHz
PART NUMBER	BRANDING	PART NUMBER	BRANDING		$V_{M(AC)}$ (V)	$V_{M(DC)}$ (V)	W_{TM} (J)	I_{TM} (A)	V_{NOM} MIN (V)	V_{NOM} MAX (V)	V_C (V)	I_{PK} (A)	C (pF)
V130LA1P	P1301	V130LA1	1301	7	130	175	11	1200	184	255	390	10	180
V130LA2P	P1302	V130LA2	1302	7	130	175	11	1200	184	228	340	10	180
V130LA5P	P1305	V130LA5	1305	10	130	175	20	2500	184	228	340	25	450
V130LA10AP	P130L10	V130LA10A	130L10	14	130	175	38	4500	184	228	340	50	1000
V130LA20AP	P130L20	V130LA20A	130L20	20	130	175	70	6500	184	228	340	100	1900
V130LA20BP	P130L20B	V130LA20B	130L20B	20	130	175	70	6500	184	220	325	100	1900
V140LA2P	P1402	V140LA2	1402	7	140	180	12	1200	198	242	360	10	160
V140LA5P	P1405	V140LA5	1405	10	140	180	22	2500	198	242	360	25	400
V140LA10AP	P140L10	V140LA10A	140L10	14	140	180	42	4500	198	242	360	50	900
V140LA20AP	P140L20	V140LA20A	140L20	20	140	180	75	6500	198	242	340	100	1750
V150LA1P	P1501	V150LA1	1501	7	150	200	13	1200	212	284	430	10	150
V150LA2P	P1502	V150LA2	1502	7	150	200	13	1200	212	268	395	10	150
V150LA5P	P1505	V150LA5	1505	10	150	200	25	2500	212	268	395	25	360
V150LA10AP	P150L10	V150LA10A	150L10	14	150	200	45	4500	212	268	395	50	800
V150LA20AP	P150L20	V150LA20A	150L20	20	150	200	80	6500	212	268	395	100	1600
V150LA20BP	P150L20B	V150LA20B	150L20B	20	150	200	80	6500	212	243	360	100	1600

Data sheet review – Peak Current rating

- From the problem statement, need > 3,000A capability for 150VAC disc
- Per the table, the 14mm disc can pass at least one 3,000A surge pulse
- Since the LA series is the least robust, we'll start the evaluation there

MOV Selection Process

Determine if 14mm LA Series is suitable (see page 117, Fig 11 of the MOV Catalog)

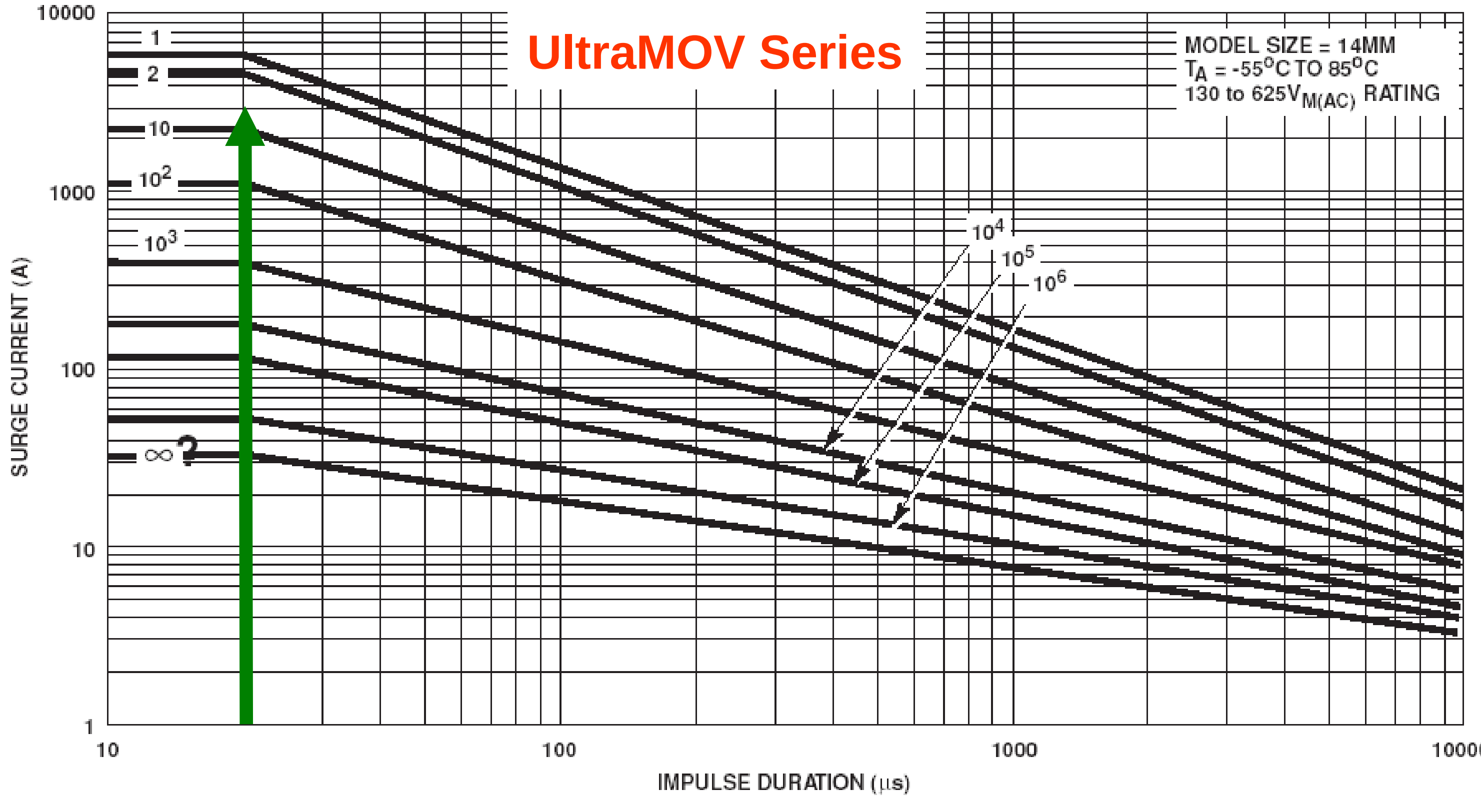


Pulse Rating Curves for 14mm LA series

- Locate pulse width (20µs) on the x-axis
- Find where vertical line intercepts 3,000A point
- In this case, we find that the LA MOV can survive 1 to 2 pulses

MOV Selection Process

Determine if 14mm UltraMOV Series is suitable (see page 88, Fig 9 of the MOV Catalog)

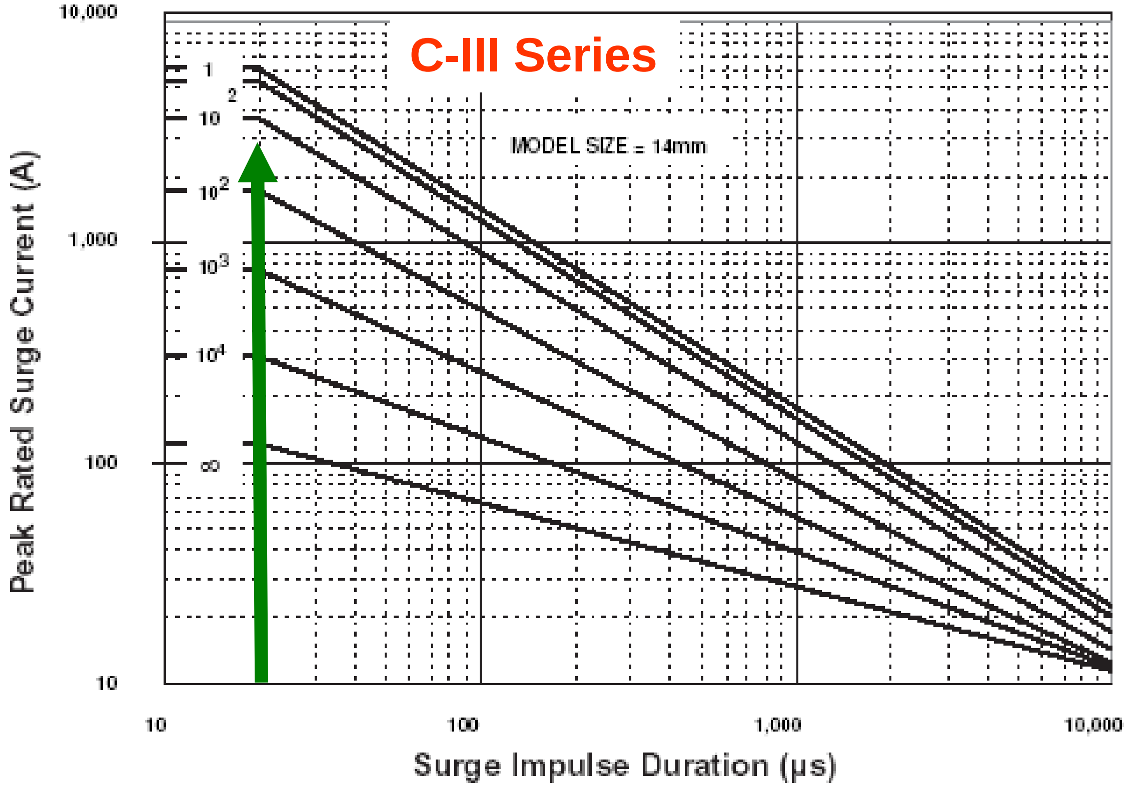


Pulse Rating Curves for 14mm UltraMOV series

- Locate pulse width (20µs) on the x-axis
- Find where vertical line intercepts 3,000A point
- In this case, we find that the UltraMOV can survive 2 to 10 pulses

MOV Selection Process

Determine if 14mm C-III Series is suitable (see page 105, Fig 6 of the MOV Catalog)



Pulse Rating Curves for 14mm C-III series

- Locate pulse width (20µs) on the x-axis
- Find where vertical line intercepts 3,000A point
- In this case, we find that the C-III can survive 10 to 100 pulses

MOV Selection Process

So, how many pulses can 14mm C-III varistor take? (see page 103 of the MOV Catalog)

LEAD-FREE AND RoHS COMPLIANT MODELS PART NUMBER	STANDARD MODELS PART NUMBER	MODEL SIZE DISC DIAMETER (mm)	SPECIFICATIONS (25°C)					
			VARISTOR VOLTAGE AT 1mA DC TEST CURRENT		MAXIMUM CLAMPING VOLTAGE (8/20µs)		DUTY CYCLE SURGE RATING	
			V_N MIN (V)	V_N MAX (V)	V_C (V)	I_P (A)	3kA (8/20µs) # PULSES	750A (8/20µs) # PULSES
V130LA5CP	V130LA5C	10	184	228	340	25	2	100
V130LA10CP	V130LA10C	14	184	228	340	50	40	600
V130LA20CP	V130LA20C	20	184	228	340	100	80	1600
V130LA20CPX325	V130LA20CX325	20	184	220	325	100	80	1600
V140LA5CP	V140LA5C	10	198	242	360	25	2	100
V140LA10CP	V140LA10C	14	198	242	360	50	40	600
V140LA20CP	V140LA20C	20	198	242	360	100	80	1600
V140LA20CPX340	V140LA20CX340	20	198	230	340	100	80	1600
V150LA5CP	V150LA5C	10	212	268	395	25	2	100
V150LA10CP	V150LA10C	14	212	268	395	50	40	600
V150LA20CP	V150LA20C	20	212	268	395	100	80	1600
V150LA20CPX360	V150LA20CX360	20	212	243	360	100	80	1600

Pulse Rating Curves for 14mm C-III series

- Consult the data sheet for verification of surge pulse capabilities
- From the table, the 14mm disc can survive 40 pulses
- So, the V150LA10C(P) is the best part for the requirements

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MOV Selection Process

Determine the peak voltage that the 3,000A surge will create

(see page 105 of the MOV Catalog)

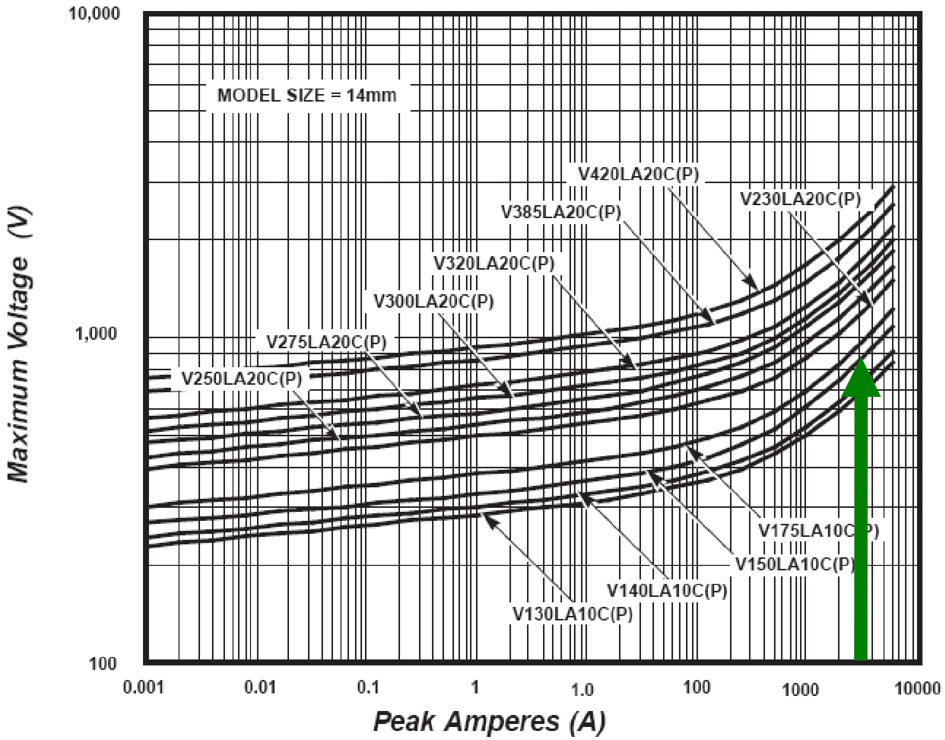

Figure 4. Maximum Clamping Voltage for 14mm Parts

V-I Curves for 14mm C-III series

- Consult the data sheet for verification of surge pulse capabilities
- From the table, locate the peak current on the x-axis (3,000A)
- Find where it intercepts the curve for V150LA10C(P) product
- In this case, the maximum voltage is found to be 850V

MOV Selection Process

Compare V150LA10C(P) to requirements

Example of MOV selection

Circuit conditions and requirements:

-120VAC circuit

- Current waveform for surge is 8x20µs; voltage is 1.2x50µs
- Peak current during the surge is 3,000A
- Requirement is to survive 40 surges
- Other components (transformer, capacitors, etc.) are rated to withstand 1,000V maximum.

Approach to finding a solution:

- To find the voltage rating of the MOV, allow for 20% head room to take into account voltage swells.
  - 120VAC x 1.2 = 144VAC
  - So look at 150VAC rated MOVs → Voltage rating of 150VAC
  - Determine which MOV disc size to use – identify those that minimally meet the 3,000A surge requirement → Disc size of 14mm

-Use *Pulse Rating Curves* to determine pulse capabilities of each series per the 40 pulses @ 3,000A requirement → Can meet 40 surge pulses

- Use *V-I Curve* of selected MOV to verify that the peak voltage will be below the 1,000V ceiling. → Peak voltage of 850V

Compare requirements to V150LA10C(P)

- Voltage rating of 150VAC
- Disc size of 14mm
- Can meet 40 surge pulses
- Peak voltage of 850V

iDesign™ Online Fuse Design and Selection Tool Registration page

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iDESIGN™

Welcome to Littelfuse Fuse Design & Selection Tool

iDesign™ Online Fuse Design and Selection Tool, a robust, web-based tool to help circuit designers identify the optimal electronic fuses for their products.

The iDesign™ tool, the first of its kind available from a circuit protection device supplier, offers a fast, intuitive way to identify the best component for an application, find parts documentation, and order part samples for prototyping... all in one convenient package!

The iDesign tool currently supports only electronic, board mounted, fuses used in a wide variety of applications, excluding system level, power fuses or automotive-style fuses. The iDesign tool's flexibility will allow Littelfuse to incorporate additional circuit protection devices in the future, so be sure to check back often!

Welcome to Littelfuse. The world's #1 brand in circuit protection solutions.

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Free to register now !!!

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Additional Literature

Design and Selection Guides

- **Electronic Products Selection Guide**
  - Available on the Littelfuse website
  - Includes all Littelfuse technologies
  - Quick reference for all product specifications and applications

- **System Level Design Guide**
  - Available on the Littelfuse website
  - Discusses multiple applications such as:
    - USB1.1/2.0/3.0
    - HDMI/DVI
    - 10/100/1000 Ethernet
    - eSATA
    - Audio (Speaker/Microphone)
    - Keypad/Push button
    - And many more…

- **Ethernet Design Guide**
  - Includes both TVS Diode Arrays, SIDACtor Devices, and TVS Diodes (for PoE)

Additional Literature
Sample Kits

- **TVS Diode Arrays**
  - Contains over 55 products and includes all 2012 new product releases

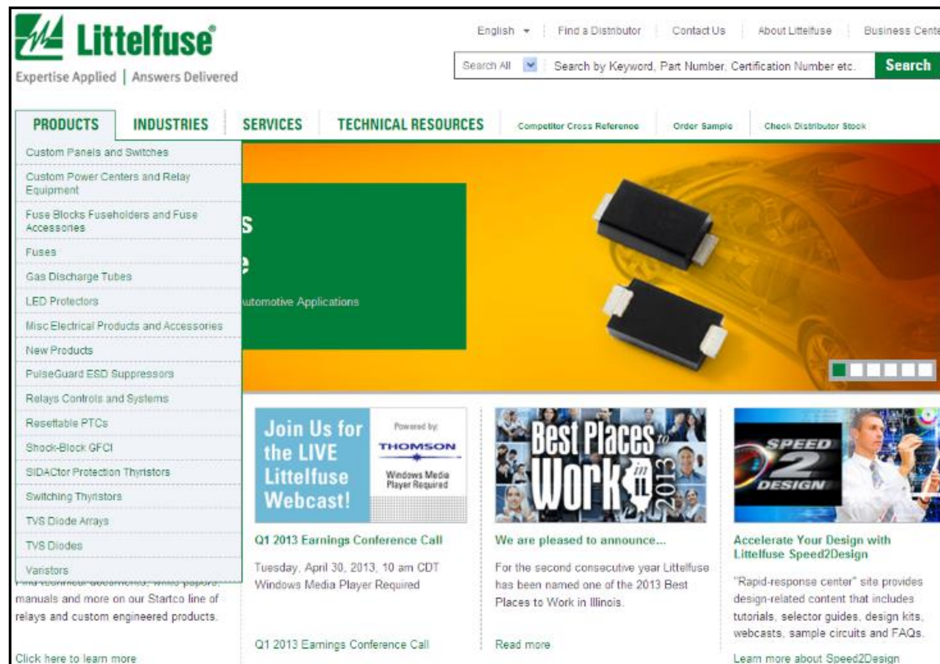
- **TVS Diodes**
  - Axial Lead 400-1500W
    - SA5.0A, SA12CA, SAC5.0, P6KE27CA, P6KE200A, 1.5KE91A, 1.5KE440A, LEC28A
  - Surface Mount 400-1500W
    - SMAJ5.0A, SMAJ58A, P4SMA20CA, P4SMA200CA, SMBJ15A, SMBJ33CA, P6SMB36A, P6SMB200CA, 1KSMB47CA, 1KSMB160A, SMCJ24CA, SMCJ64A, 1.5SMC6.8A, 1.5SMC550CA

Additional Literature

Miscellaneous

- [TVS Diode Array App]
  - Only for the iPhone/iPad
  - Help in finding the right product for your application

- **Product Catalogs**
  - Found on Littelfuse.com
  - Catalogs are available under the respective product category



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About Littelfuse

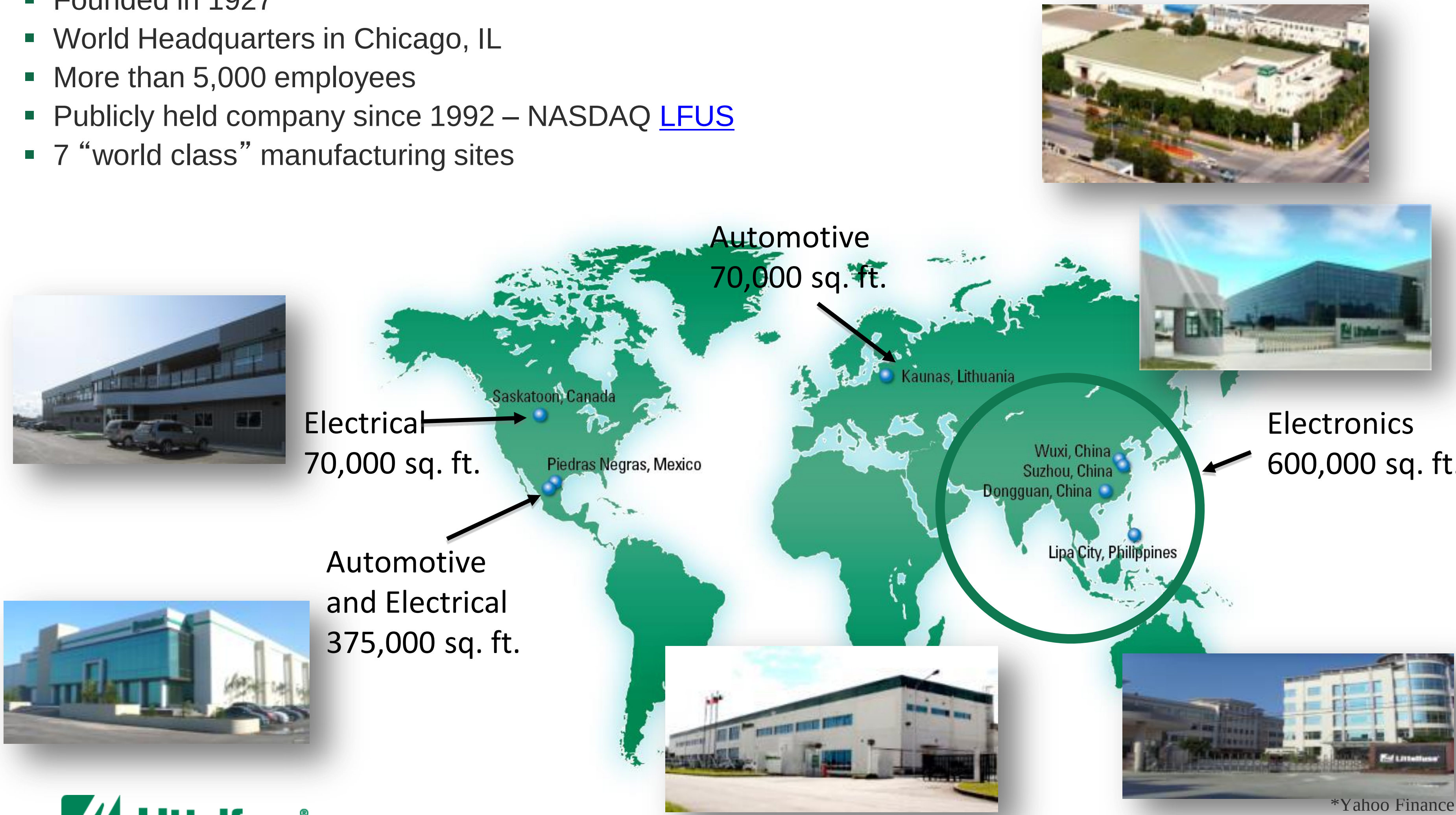
Who is Littelfuse?

- **Founded 1927 in Chicago, Ill., USA**
- **Traded on the U.S. NASDAQ; Symbol: LFUS**
- **6,300 employees**
- **35 facilities worldwide:**
  - Americas
  - Europe
  - Asia

Littelfuse Products

Global Presence – Local Resources

- Founded in 1927
- World Headquarters in Chicago, IL
- More than 5,000 employees
- Publicly held company since 1992 – NASDAQ LFUS
- 7 “world class” manufacturing sites



*Yahoo Finance

The #1 Brand in Circuit Protection — Emerging Player in Power Control and Sensing

Electronics (49%)

- Passives
- Semis
- Sensors

Automotive (35%)

- Auto Fuse
- Commercial Vehicle
- Sensors

Electrical (16%)

- Power Fuse
- Relay/Custom

Littelfuse has the broadest and deepest portfolio of circuit protection products serving three major market segments.

Littelfuse Protects Against Common Threats to Electrical Circuits and Components

Overcurrent Protection

Power Cross

Overloads & Short Circuits

Overvoltage Protection

ESD Protection

Lightning Protection

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Equipment Protection

Power Distribution and Control

Power Distribution Centers

Mining Control Consoles

Every product that uses electrical energy needs circuit protection to ensure safety, reliability and performance.