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

- **Background:**
  - 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

- **Problem:**
  - 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)

- **Solution:**
  - 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

**Additional Information:**

- 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
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!

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

- **Images:**
  - Competitor MOV (Left) ; Littelfuse MOV (Middle) ; Littelfuse TMOV (Right)

See next slide for before, during & after pictures
Images Before, During and After

– Before

MOD 1  MOD 2  LF MOD

00:00

MOD 1  MOD 2  LF MOD

MOD 1  MOD 2  LF MOD

16:12  28:27

39:25
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

### Additional Information:
- 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

- **Test Set-up:**
  - 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

- **Images:**
  - With fuse: See next slide for before, during & after pictures
  - Without fuse:
Images Before, During and After

- **With Fuse**
  - Before
  - During
  - After

- **Without Fuse**
  - Before
  - During
  - After
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: See next slide for before, during & after pictures
  - Above fuse voltage rating:
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
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
Images Before, During and After

- **TMOV**
  - Before
  - During
  - After

- **SMOV**
  - Before
  - During
  - After
Selecting a Fuse
Fuse Selection Process
Basics – definitions for selecting fuses

Background selection information:

**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)

**Fuse re-rating factor:**
- Use 0.75 if the fuse is UL or CSA Listed or Recognized
- Use 1.00 if the fuse is IEC Designed

**Thermal de-rating factor (TDR):**
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)

For example:

- Thin Film Fuse: Use Curve A
- If temp is 40°C: Use TDR of 95%

Chip fuses, Wire-in-air fuses, Resettable PTCs

Curves:
- Curve A = Thin Film Fuses
- Curve B = Wire-in-air Fuses (Cartridge, Nano²)
- Curve C = Resettable PTCs
Step 2) Calculate the minimum fuse rating

Minimum fuse rating = \( \frac{\text{maximum operating current}}{\text{fuse re-rating factor} \times \text{thermal de-rating factor}} \)

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

Then, minimum fuse rating = \( \frac{0.50 \text{ A}}{0.75 \times 0.95} \) = 0.700 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 \text{ A}^2\text{s}**
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 $i^2t$ was calculated to be $0.00225 \text{ A}^2\text{s}$
- 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

\[
= 0.00225 \text{ A}^2\text{s} / 0.22 \\
= 0.0102 \text{ A}^2\text{s}
\]
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$^2$s):

<table>
<thead>
<tr>
<th>Catalog Number</th>
<th>Ampere Rating</th>
<th>Voltage Rating</th>
<th>Nominal Resistance Cold Ohm$^1$</th>
<th>Nominal Melting $I^2t$ (A$^2$ Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0435.250</td>
<td>0.25</td>
<td>24</td>
<td>0.220</td>
<td>0.0025</td>
</tr>
<tr>
<td>0435.375</td>
<td>0.375</td>
<td>24</td>
<td>0.185</td>
<td>0.0035</td>
</tr>
<tr>
<td>0435.500</td>
<td>0.50</td>
<td>24</td>
<td>0.150</td>
<td>0.0053</td>
</tr>
<tr>
<td>0435.750</td>
<td>0.75</td>
<td>24</td>
<td>0.105</td>
<td>0.0120</td>
</tr>
<tr>
<td>0435 001.</td>
<td>1</td>
<td>24</td>
<td>0.072</td>
<td>0.020</td>
</tr>
<tr>
<td>0435 1.25</td>
<td>1.25</td>
<td>24</td>
<td>0.060</td>
<td>0.035</td>
</tr>
<tr>
<td>0435 01.5</td>
<td>1.5</td>
<td>24</td>
<td>0.047</td>
<td>0.056</td>
</tr>
<tr>
<td>0435 1.75</td>
<td>1.75</td>
<td>24</td>
<td>0.038</td>
<td>0.075</td>
</tr>
<tr>
<td>0435 002.</td>
<td>2</td>
<td>24</td>
<td>0.020</td>
<td>0.100</td>
</tr>
</tbody>
</table>

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

1. Understand the application and circuit parameters

2. Determine minimum current rating of fuse (fuse re-rating, thermal de-rating) - 0.750 A

3. Determine Pulse $I^2t$ value of the application - 0.00225 A²s

4. Determine minimum Nominal melting $I^2t$ value of the Fuse - 0.0102 A²s

5. 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
- $t = 40 \mu s$
- Number of pulses required = 70,000

Calculations:

\[ i^2t = \frac{1}{2}Ip^2 t \]

\[ i^2t = \frac{1}{2} \times (35A)^2 \times 0.00004 \]

Pulse $i^2t = 0.0245 A^2s$

Nominal melting $i^2t = (0.0245 / 0.23) = 0.1065 A^2s$

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
Pulse Energy vs. Fuse Melting Energy

Calculated Pulse $I^2t = 0.0245 \text{ A}^2\text{s}$ (previous page)

0467003 Fuse $I^2t = 0.2403 \text{ A}^2\text{s}$

<table>
<thead>
<tr>
<th>Catalog Number</th>
<th>Ampere Rating</th>
<th>Marking Code</th>
<th>Nominal Voltage Rating</th>
<th>Nominal Resistance (Ω)</th>
<th>Melting $I^2t$ (A' Sec.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0467 250</td>
<td>0.25</td>
<td>D</td>
<td>32</td>
<td>0.435</td>
<td>0.0030</td>
</tr>
<tr>
<td>0467 375</td>
<td>0.375</td>
<td>E</td>
<td>32</td>
<td>0.275</td>
<td>0.0053</td>
</tr>
<tr>
<td>0467 500</td>
<td>0.5</td>
<td>F</td>
<td>32</td>
<td>0.180</td>
<td>0.0087</td>
</tr>
<tr>
<td>0467 750</td>
<td>0.75</td>
<td>G</td>
<td>32</td>
<td>0.112</td>
<td>0.0171</td>
</tr>
<tr>
<td>0467 001</td>
<td>1</td>
<td>H</td>
<td>32</td>
<td>0.062</td>
<td>0.0212</td>
</tr>
<tr>
<td>0467 125</td>
<td>1.25</td>
<td>J</td>
<td>32</td>
<td>0.050</td>
<td>0.0518</td>
</tr>
<tr>
<td>0467 015</td>
<td>1.5</td>
<td>K</td>
<td>32</td>
<td>0.040</td>
<td>0.0766</td>
</tr>
<tr>
<td>0467 175</td>
<td>1.75</td>
<td>L</td>
<td>32</td>
<td>0.028</td>
<td>0.0903</td>
</tr>
<tr>
<td>0467 002</td>
<td>2</td>
<td>N</td>
<td>32</td>
<td>0.024</td>
<td>0.1103</td>
</tr>
<tr>
<td>0467 025</td>
<td>2.5</td>
<td>O</td>
<td>32</td>
<td>0.020</td>
<td>0.1440</td>
</tr>
<tr>
<td>0467 003</td>
<td>3</td>
<td>P</td>
<td>32</td>
<td>0.016</td>
<td>0.2403</td>
</tr>
<tr>
<td>0467 035</td>
<td>3.5</td>
<td>R</td>
<td>32</td>
<td>0.013</td>
<td>0.4306</td>
</tr>
<tr>
<td>0467 004</td>
<td>4</td>
<td>S</td>
<td>32</td>
<td>0.011</td>
<td>0.5760</td>
</tr>
<tr>
<td>0467 005</td>
<td>5</td>
<td>T</td>
<td>32</td>
<td>0.0085</td>
<td>0.9000</td>
</tr>
</tbody>
</table>

Ratio of Calculated Pulse $I^2t$ / Fuse Melting $I^2t$

$= 0.0245 \text{ A}^2\text{s} / 0.2403 \text{ A}^2\text{s} = \sim 10.2\%$

>100,000 pulses at 10.2% melting $I^2t$
Surge Protection Selection
- Metal Oxide Varistor
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)

• Key feature is the durability to repeatedly handle high peak pulse current, high-energy surge transients
Surge protection component
Functional regions of MOV (based on V-I curve)

- Leakage Region
- Normal Varistor Operation
- Upturn Region

**Voltage (V)**

- 1000
- 500
- 200
- 100
- 50
- 20
- 10

**Current (A)**

- $10^{-8}$
- $10^{-6}$
- $10^{-4}$
- $10^{-2}$
- $10^{0}$
- $10^{2}$
- $10^{4}$

**SLOPE:**

- $SLOPE = \frac{1}{a}$

**Equation:**

- $I = kV^a$

**Example:**

- $R = 10 \, \Omega$
- $R = 100 \, \Omega$

(TYPICAL V130LA2OA)
Surge Protection Selection

- Metal Oxide Varistor
- Example of selecting a MOV
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)

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>BRANDING</th>
<th>PART NUMBER</th>
<th>BRANDING</th>
<th>MODEL SIZE DISC DIA. (mm)</th>
<th>STANDARD MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>V130LA1P</td>
<td>P1301</td>
<td>V130LA1</td>
<td>1301</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>V130LA2P</td>
<td>P1302</td>
<td>V130LA2</td>
<td>1302</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>V130LA5P</td>
<td>P1305</td>
<td>V130LA5</td>
<td>1305</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>V130LA10AP</td>
<td>P130L10</td>
<td>V130LA10A</td>
<td>130L10</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>V130LA20AP</td>
<td>P130L20A</td>
<td>V130LA20A</td>
<td>130L20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>V130LA20BP</td>
<td>P130L20B</td>
<td>V130LA20B</td>
<td>130L20B</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>V140LA2P</td>
<td>P1402</td>
<td>V140LA2</td>
<td>1402</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>V140LA5P</td>
<td>P1405</td>
<td>V140LA5</td>
<td>1405</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>V140LA10AP</td>
<td>P140L10A</td>
<td>V140LA10A</td>
<td>140L10</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>V140LA20AP</td>
<td>P140L20A</td>
<td>V140LA20A</td>
<td>140L20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>V150LA1P</td>
<td>P1501</td>
<td>V150LA1</td>
<td>1501</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>V150LA2P</td>
<td>P1502</td>
<td>V150LA2</td>
<td>1502</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>V150LA5P</td>
<td>P1505</td>
<td>V150LA5</td>
<td>1505</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>V150LA10AP</td>
<td>P150L10A</td>
<td>V150LA10A</td>
<td>150L10</td>
<td>14</td>
<td></td>
</tr>
</tbody>
</table>

### 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)

<table>
<thead>
<tr>
<th>RoHS</th>
<th>LEAD-FREE AND ROHS COMPLIANT MODELS</th>
<th>PART NUMBER</th>
<th>STANDARD MODELS</th>
<th>MODEL SIZE DISC DIAMETER (mm)</th>
<th>SPECIFICATIONS (25°C)</th>
<th>DUTY CYCLE SURGE RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>V130LA5CP</td>
<td>V130LA5C</td>
<td>10</td>
<td>V₉ MIN (V)</td>
<td>V₉ MAX (V)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V130LA10CP</td>
<td>V130LA10C</td>
<td>14</td>
<td>184</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V130LA20CP</td>
<td>V130LA20C</td>
<td>20</td>
<td>184</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V130LA20CPX325</td>
<td>V130LA20C325</td>
<td>20</td>
<td>184</td>
<td>228</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V140LA5CP</td>
<td>V140LA5C</td>
<td>10</td>
<td>198</td>
<td>242</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V140LA10CP</td>
<td>V140LA10C</td>
<td>14</td>
<td>198</td>
<td>242</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V140LA20CP</td>
<td>V140LA20C</td>
<td>20</td>
<td>198</td>
<td>242</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V140LA20CPX340</td>
<td>V140LA20C340</td>
<td>20</td>
<td>198</td>
<td>230</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V150LA5CP</td>
<td>V150LA5C</td>
<td>10</td>
<td>212</td>
<td>268</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V150LA10CP</td>
<td>V150LA10C</td>
<td>14</td>
<td>212</td>
<td>268</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V150LA20CP</td>
<td>V150LA20C</td>
<td>20</td>
<td>212</td>
<td>268</td>
</tr>
<tr>
<td></td>
<td></td>
<td>V150LA20CPX360</td>
<td>V150LA20C360</td>
<td>20</td>
<td>212</td>
<td>243</td>
</tr>
</tbody>
</table>

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
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
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.

Compare requirements to V150LA10C(P)

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

Free to register now !!!
https://littelfuse.transim.com/login.aspx
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
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

Electrical
70,000 sq. ft.

Saskatoon, Canada

Piedras Negras, Mexico

Automotive
375,000 sq. ft.

Kaunas, Lithuania

Wuxi, China
Suzhou, China
Dongguan, China

Lipa City, Philippines

Automotive
70,000 sq. ft.

Electronics
600,000 sq. ft.

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
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  Overvoltage Protection  Power Monitoring and Protective Switching  Power Distribution and Control

Power Cross  ESD Protection  Ground-Fault Protection  Power Distribution Centers

Overloads & Short Circuits  Lightning Protection  Equipment Protection  Mining Control Consoles

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