Semiconductor Protection Devices
General and Specific
Len Stencel, Applications Manager
Two General Types of Semiconductor Protection Devices

• Shunting (shorting)
  • Limits Voltage (Crowbar or Clamp)
  • Parallel Connection
  • High resistance when voltage is below trigger point
  • Low (dynamic) resistance when triggered

• Limiting (ECL)
  • Limits or Blocks Current
  • Series Connection
  • Low resistance below trigger point
  • High resistance when triggered
General Characteristics of the Device Types

![Graph showing different characteristics of device types including blocking, current limiting, voltage limiting, and foldback characteristic.]
Blocking Devices

General Characteristics

- Linear Resistance Region
  - Very linear response when not triggered
  - Behaves like a resistor

- Transition Region
  - In general, the device should not be continuously operated in this region
    - Power dissipation is the primary concern

- Full Blocking State
  - Low quiescent current
  - Provides voltage isolation up to rated voltage

Bidirectional Device
**Blocking Devices**

*General Characteristics*

- **Series Resistance**
  - Lower for higher trigger current level devices with same voltage rating
  - Higher for higher voltage rating devices with same trigger current

- **Trigger Current**
  - Ranges from 50 mA to more than 500 mA
  - Devices can be paralleled for higher current capability (and lower resistance)

- **Max Voltage**
  - Ranges from 20V to 850V
Blocking Devices

*What’s Available? Configurations*

- Single Unidirectional
- Single Bidirectional
- Programmable Single Bidirectional
- Dual Unidirectional
- Dual Bidirectional
- Dual Bidirectional w/Voltage Control
Blocking Devices

What’s Available?

<table>
<thead>
<tr>
<th>Category</th>
<th>Max Voltage (V)</th>
<th>Trigger Current (mA)</th>
<th>Series Resistance (Ω)</th>
<th>Response time (ns)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Voltage</td>
<td>20 - 40</td>
<td>150-240*</td>
<td>3.6 - 6.5</td>
<td>60 - 200</td>
<td>SOT23, DFN</td>
</tr>
<tr>
<td>High Voltage</td>
<td>250 - 850</td>
<td>50 – 500*</td>
<td>2.6 - 22</td>
<td>1000</td>
<td>DFN</td>
</tr>
<tr>
<td>Application Specific</td>
<td>250 - 850</td>
<td>50 – 500*</td>
<td>50, 80</td>
<td>1000</td>
<td>DFN</td>
</tr>
</tbody>
</table>

* Several fixed values are available within this range. A programmable device is also available for the high voltage devices.

Notes:

1. Unidirectional and Bidirectional devices are available
2. Response time is from the trigger point to the full blocking state. The device limits current during this transition.
Blocking Devices

Applications

- Voice Lines
  - SLIC Protection
- Low and High Speed data communication Lines
  - Ethernet
  - XDSL
  - RS-485
    - 4-20ma Current loop
- Protection modules and dongles
- Process control equipment
- Test equipment
Application Example: **RS-485 Advanced Circuit Protection**

**Ultimate Protection Using a Blocking Device**

<table>
<thead>
<tr>
<th>Test Performed</th>
<th>Standard</th>
<th>Level</th>
<th>Notes</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surge</td>
<td>IEC 61000-4-5</td>
<td>1, X</td>
<td>Level X=5 kV; 1.2/50 μs, 8/20 μs</td>
<td>Pass</td>
</tr>
<tr>
<td>Power Cross</td>
<td>N/A</td>
<td>N/A</td>
<td>125 Vrms, continuous protection</td>
<td>Pass</td>
</tr>
<tr>
<td>ESD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Air Discharge</td>
<td>IEC 61000-4-2</td>
<td>1,2,4,X</td>
<td>Level X= 16 kV</td>
<td>Pass</td>
</tr>
<tr>
<td>- Contact Discharge</td>
<td>IEC 61000-4-2</td>
<td>1,2,3,4</td>
<td>Up to 8 kV</td>
<td>Pass</td>
</tr>
<tr>
<td>EFT (Modified, Direct Connect)</td>
<td>IEC 61000-4-4</td>
<td>4</td>
<td>2 kV, 100kHz</td>
<td>Pass</td>
</tr>
</tbody>
</table>
RS-485 Advanced Circuit Protection

5 KV Positive Surge per IEC61000-4-5

Note: This design is very robust and can handle the extremely high surge current without using an external 40 Ohm resistor in series with each line of the differential pair for the surge test, as allowed by the IEC specification.

The peak current into the transceiver is held to ~500 mA and is reduced to the very low quiescent level (<1 mA) of the Blocking Device in about 3 µs.
The current into the protected device is limited to short duration current pulses with a peak value of ~300 mA as it transitions between normal operation and the blocking state.
The current into the protected device is limited to just over 1 A, a fraction of the 29 A peak current from the ESD event.
Bourns RS-485 Advanced Circuit Protection

16 kV Air Discharge ESD Protection

The current into the protected device is limited to just over 1 A, a fraction of the 30 A peak current from the ESD event.
Application Example: RS-485

Signal Quality

- **250 Kbps**

- **10 Mbps**

- **2 Mbps**

- **20 Mbps**

**Example:**

CH1 = Txin  
CH2 = A,  
CH3 = B  
M = A - B,  
Ch4 = RXout

Test: Two boards connected together with 1 foot of twisted pair and 120 ohm termination at each end.
RS-485 Advanced Circuit Protection

Test Results Summary

• The blocking device used in conjunction with the TVS diode and the MOV provides a high level of protection:
  • 5 kV Surge Protection (IEC 61000-4-5)
  • 125 Vrms Power Cross Protection
  • 8 kV contact and 15 kV Air Discharge ESD Protection (IEC 61000-4-2)
  • Level 4 (2kV) Electrical Fast Transient (EFT) Protection (IEC 61000-4-4)

• Signal quality was excellent up to a 2 Mbps data rate and acceptable out to 10 Mbps
  • Performance at 20 Mbps could be improved by replacing the MOV with a GDT to reduce the capacitive load on the line
Shunting Devices

*General Characteristics: Crowbar*

- **Inactive State**
  - Looks like a high impedance load
    - Primarily a capacitive load

- **Breakdown Region**
  - Voltage clamping action before switching to the low voltage state

- **Fully Active (Low Voltage) State**
  - When the breakover current level is reached the device will switch to the low voltage state
  - A minimum current (hold current) is required to remain in this state
Shunting Devices

*General Characteristics: Crowbar*

- **Capacitance**
  - Decreases as breakover voltage is increased
  - Increases as surge current capability is increased

- **Maximum Peak Pulse Current Rating**
  - Up to ~200 A for the 10/1000 μs waveform

- **Breakover Voltage Range**
  - 15 V to 600 V
Shunting Devices

What’s Available

- Single Unidirectional
- Dual Unidirectional
- Single Bidirectional
- Dual Bidirectional
- Triple Element
- Triple Element
- Gated Unidirectional
- Dual Gate Unidirectional
- Dual Complementary Gate
- Dual Gated w/Anti Parallel Diodes
- Quad Gated w/Anti Parallel Diodes

Note: This is not an exhaustive survey.
## Shunting Devices

### What’s Available

<table>
<thead>
<tr>
<th>Category</th>
<th>Type</th>
<th>$I_{PPM}(A)$ 10/1000 $\mu s$</th>
<th>$V_{DRM}$ (V)</th>
<th>Capacitance (pF)</th>
<th>$I_H$ (mA)</th>
<th>Package(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Current, Fixed Voltage</td>
<td>Unidirectional, Bidirectional, Single/Dual</td>
<td>18 - 80</td>
<td>8 - 550</td>
<td>3.3 - 150</td>
<td>10 - 150</td>
<td>SOT23-5, SMA, SMB, SOIC (8), DO-15, QFN, TO220</td>
</tr>
<tr>
<td>High Current, Fixed Voltage</td>
<td>Unidirectional, Bidirectional, Single/Dual</td>
<td>100 - 200</td>
<td>58 - 550</td>
<td>35 - 300</td>
<td>50 - 225</td>
<td>SMB, TO-92, QFN, TO-220</td>
</tr>
<tr>
<td>Programmable*</td>
<td>Single, Dual, Quad</td>
<td>20 -150</td>
<td>90 - 250</td>
<td>32 - 100</td>
<td>20 - 180</td>
<td>SOIC (8), MS-013</td>
</tr>
<tr>
<td>Triple element</td>
<td>Delta, &quot;Y&quot; config.</td>
<td>30 - 45</td>
<td>8 - 270</td>
<td>17 - 50</td>
<td>30 - 150</td>
<td>SOIC (8)</td>
</tr>
</tbody>
</table>

* With and without antiparallel diode, single and dual polarity are available

**Note:** This is not an exhaustive survey.
Shunting Devices

Applications

- Primary and Secondary Protection
- SLIC Protection
- Signal, Data and Control Lines
  - Ethernet
  - ISDN
  - RS-232
  - XDSL
  - RS-485
  - 4-20ma Current loop
- Process control equipment
- Test equipment
Application Example

Programmable Thyristor for SLIC Protection

GR1089 Intrabuilding Lightning Protection

<table>
<thead>
<tr>
<th>Test connection</th>
<th>Waveshape</th>
<th>Open-Circuit Voltage (V)</th>
<th>Short-Circuit Current (A)</th>
<th>Generator Resistance (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse</td>
<td>2/10 μs</td>
<td>800</td>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>2/10 μs</td>
<td>1500</td>
<td>100</td>
<td>15</td>
</tr>
</tbody>
</table>

- No series resistor is shown.
- If a series resistor is required the peak current into the protector will be lowered.
- For example, if an 8 Ohm series resistor were used, the current for the Transverse and Longitudinal tests would be reduced to 50 A and 65 A (2 x 65), respectively

V\text{BATH} = - 60 \text{ V}
SLIC Protection
800V, 100A 2/10 μs, Transverse Surge

Positive Voltage
Negative Voltage
Current
Gate Voltage

No Load

Diagram and graph showing electrical components and waveforms.
SLIC Protection
1500V, 2/10 μs, Longitudinal Surge

No Load

VG = - 60 V

R Voltage
T Voltage

T and R Voltages

T Current

Gate Voltage
Programmable Thyristor

Test Results Summary

- The Intrabuilding lightning test per GR1089 was performed with no series resistance
  - **Transverse (2/10 μs, 800 V, 100A)**
    - Positive Direction - Clamp voltage was 11.9V for 109 A of surge current
    - Negative Direction – Clamp voltage was -70.4 V for -109 A of current
      (Note that the gate voltage dropped 3.2 V)
  - **Longitudinal (2/10 μs, 1500 V, 100A)**
    - Positive Direction - Clamp voltage was 12.8 to 13.2 V for 111 A of surge current
    - Negative Direction – Clamp voltage was -72.8 to 74.0 V for -112 A of current
      (Note that the gate voltage dropped 6.2 V)
Voltage Limiting Devices (TVS Diodes)

*General Characteristics*

- **Inactive Region**
  - 0 V to working (standoff) voltage in each direction for a bidirectional device
  - Primarily a capacitive load

- **Active Region**
  - Clamping/Breakdown
    - Voltage continues to increase as current increases
  - Some devices have significant foldback
    - e.g. punch-through diodes
Voltage Limiting Devices (TVS Diodes)

General Characteristics (Unidirectional Devices)

- Capacitance decreases as the standoff voltage capability of the diode is increased
- Capacitances increases as the peak power capability of the diode is increased
- Leakage current increases as the standoff voltage is reduced (especially levels ≤ 3.3 V)
Voltage Limiting Devices (TVS Diodes)

*What’s Available? Sample of Available Configurations*

- **Unidirectional**
- **Bidirectional**
- **Unidirectional w/Steering Diodes**
- **Bidirectional w/Steering Diodes**
- **Dual Bidirectional**
- **Quad Unidirectional**
- **Quad Unidirectional w/Steering diodes**

**Note:** Devices are available to protect 1, 2, 4, 5, 6, 8 or more lines
## Voltage Limiting Devices (TVS Diodes)

### What’s Available?

#### Discrete TVS Diodes

<table>
<thead>
<tr>
<th>Category</th>
<th>Type</th>
<th>P&lt;sub&gt;PPM&lt;/sub&gt; Range (W)*</th>
<th>V&lt;sub&gt;R&lt;/sub&gt; Range (V)</th>
<th>Capacitance (pF)</th>
<th>Packages</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Power</td>
<td>Unidirectional, Bidirectional</td>
<td>≤ 500</td>
<td>2.5 - 36</td>
<td>1 - 500</td>
<td>0402, 0603, 0805, SOD-323, SOD-523, SOT-23</td>
<td>Steering diodes are used to achieve low capacitance</td>
</tr>
<tr>
<td>Medium Power</td>
<td>Unidirectional, Bidirectional</td>
<td>600 - 3,000</td>
<td>5 - 170, 400</td>
<td>20 - 10,000</td>
<td>SMA, SMB, SMC,</td>
<td>Bidirectional devices have lower capacitance than unidirectional devices</td>
</tr>
<tr>
<td>High Power</td>
<td>Unidirectional, Bidirectional</td>
<td>5,000-30,000</td>
<td>28 - 300</td>
<td>80 - 30,000</td>
<td>SMC, Axial lead</td>
<td>Bidirectional devices have lower capacitance than unidirectional devices</td>
</tr>
<tr>
<td>Very High Power</td>
<td>Unidirectional, Bidirectional</td>
<td>&gt; 30,000</td>
<td>15 - 470</td>
<td>2,000 - 12000</td>
<td>Axial Lead, Surface Mount</td>
<td>1,3,6,10 and 15 kA devices</td>
</tr>
</tbody>
</table>

#### TVS Diode Arrays

<table>
<thead>
<tr>
<th>Category</th>
<th>Capacitance Range(pF)</th>
<th># of Lines</th>
<th>I&lt;sub&gt;PPM&lt;/sub&gt; Range (A)*</th>
<th>V&lt;sub&gt;R&lt;/sub&gt; Range (V)</th>
<th>Packages</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultra Low Capacitance (&lt; 3 pF)</td>
<td>0.25 - 3</td>
<td>2, 4, 6, 7</td>
<td>1-25</td>
<td>2.8 - 5</td>
<td>SOT-143A, SC70-6, DFN-10, SOT23-6, SOT563, DFN-6, DFN-10, SC-89, SC-75</td>
<td>Steering diodes are used to achieve low capacitance</td>
</tr>
<tr>
<td>Low Capacitance</td>
<td>3.5 - 10</td>
<td>2, 4, 6, 8</td>
<td>2 - 40</td>
<td>2.8 - 12</td>
<td>SOT-143A, SO-8, SOT353, SLP2020P6, DFN-10, SLP3020N10</td>
<td>Steering diodes are used to achieve low capacitance</td>
</tr>
<tr>
<td>High Capacitance</td>
<td>12 - 500</td>
<td>2, 4, 5, 6, 7, 8</td>
<td>7-100</td>
<td>3 - 36</td>
<td>SOT-23, SO-8, SO-16, SOT-563</td>
<td>Steering diodes are used to achieve low capacitance,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Unidirectional devices without steering diodes have higher capacitance</td>
</tr>
</tbody>
</table>

Note: This is not an exhaustive survey.
Voltage Limiting Devices (TVS Diodes)

Applications

- Primary and Secondary Protection
- Signal, Data and Control Lines
  - Ethernet
  - USB
  - HDMI
  - XDSL
  - Thunderbolt
- Power Port Protection
  - AC and DC power lines
- Process control equipment
- Test equipment
TVS Diode Application Example

*Ethernet: GR1089 Port Type 4 Lightning Protection*

**Bidirectional TVS Diode Protection Circuit**

**Ethernet Transformers (1.2/50 μs, 8/20 μs Combination Wave)**

- With Secondary Shorted
  - Secondary Current is reduced by about a factor of 4
  - Duration of Surge current is reduced
A Gigabit router was used as the load. The on board transformer was replaced with shorts and the evaluation board was connected to the router with a 3 inch long CAT5 cable. Part of the casing was removed from the cable so that a current probe could be attached to the line under test. For this test, one line (1/2 of a signal pair) is tested at a time with the other seven lines grounded.
Application Example: Ethernet
TVS Diode Circuit, 1.2/50 µs, 8/20 µs Combination Wave Test

CH1 = PHY – VOLTAGE
CH2 = PHY + VOLTAGE
CH3 = Total Surge CURRENT
CH4 = PHY INPUT CURRENT

Peak Voltage: 12.4 V
Peak Current: 4 A
Energy: ~ 50 µJ
Application Example: Ethernet

TVS Diode Circuit Test Results Summary

- GR1089, Port type 4
  - Metallic (1.2/50 μs, 8/20 μs, 800 V, 100A)
    - Voltage across the PHY differential input is limited to 12.4 V
    - Current into the PHY is limited to just over 4 A
    - Energy PHY is subjected to is limited to ~50 μJ
Current Limiting Devices

• Linear Resistance Region
  • Very linear response when not triggered
  • Behaves like a high quality resistor

• Current Limiting State
  • Limits to a predetermined level
  • Provides voltage isolation up to rated voltage
Current Limiting Devices

*General Characteristics*

- Devices exhibit 30-40% of foldback from the peak current
- The current level increases as the voltage across the device is increased
- Series resistance decreases as the trigger current value of the device is increased
# Current Limiting Devices

## What’s Available?

<table>
<thead>
<tr>
<th>Type</th>
<th>Package Style</th>
<th>Trigger Current (mA)</th>
<th>Series Resistance</th>
<th>Channel to Channel Resistance Match</th>
<th>Max Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dual Channel</td>
<td>DFN 2.5 x 4 mm</td>
<td>Min. 250, Nom. 375, Max 500</td>
<td>2.3 Ω</td>
<td>± 0.05 Ω</td>
<td>40</td>
</tr>
<tr>
<td>Dual Channel</td>
<td>DFN 3.5 x 4 mm</td>
<td>Min. 500, Nom. 750, Max 1000</td>
<td>1.4 Ω</td>
<td>± 0.03 Ω</td>
<td>40</td>
</tr>
<tr>
<td>Dual Channel</td>
<td>DFN 4.5 x 4 mm</td>
<td>Min. 750, Nom. 1125, Max 1500</td>
<td>1.0 Ω</td>
<td>± 0.02 Ω</td>
<td>40</td>
</tr>
</tbody>
</table>

**Notes:**
1. All devices are Bidirectional
Current Limiting Devices

*Applications*

- Low and High Speed data communication Lines
  - Ethernet
  - xDSL
  - RS-485
  - 4-20ma Current loop, HART Modem
- Protection modules and dongles
- Process control equipment
- Test equipment
Application Example: Ethernet

Current Limiter with TVS Diode

- SM51589L Ethernet Transformer
- CDSOD323-T05C TVS Diode
- TCS-DL004-250-WH Transient Current Suppressor

Current Limiter Current vs. Voltage

Test Circuit

- Signal Generator
- Power Amp
- 5 Ω
- 1/3 TCS-DL004-250-WH

Device Voltage

- (10 V, 300 mA)
- (30 V, 350 mA)
A Gigabit router was used as the load. The on board transformer was replaced with shorts and the evaluation board was connected to the router with a 3 inch long CAT5 cable. Part of the casing was removed from the cable so that a current probe could be attached to the line under test. For this test, one line (1/2 of a signal pair) is tested at a time with the other seven lines grounded.
Application Example: Ethernet Current Limiter with TVS Diode

**1.2/50, 8/20 µs CW Surge Test (800 V/100 A), Metallic**

*TVS Peak Voltage: ~15 V*

*PHY sees:*
- Peak Voltage: 5.2 V
- Peak Current: 571 mA
- Energy: ~ 3 µJ
Application Example: Ethernet
Current Limiter with TVS Diode

GbE Signal Amplitude and Template Tests per IEEE802.3

<table>
<thead>
<tr>
<th>Line Pair</th>
<th>Point</th>
<th>TVS diode Only (mV)</th>
<th>% Peak voltage difference Between Points A and B</th>
<th>TCS-DL004-250-WH and TVS diode (mV)</th>
<th>% Peak voltage difference Between Points A and B</th>
<th>Loss due to TCS™ (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>768.7</td>
<td>0.73%</td>
<td>754.1</td>
<td>0.49%</td>
<td>-0.17</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>763.1</td>
<td></td>
<td>750.4</td>
<td></td>
<td>-0.15</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>760.7</td>
<td>0.50%</td>
<td>746.5</td>
<td>0.44%</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>756.9</td>
<td></td>
<td>743.2</td>
<td></td>
<td>-0.16</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>772.4</td>
<td>0.06%</td>
<td>759.9</td>
<td>0.13%</td>
<td>-0.14</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>771.9</td>
<td></td>
<td>760.9</td>
<td></td>
<td>-0.12</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>768.7</td>
<td>0.88%</td>
<td>754.5</td>
<td>0.76%</td>
<td>-0.16</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>762.0</td>
<td></td>
<td>748.8</td>
<td></td>
<td>-0.15</td>
</tr>
</tbody>
</table>

Notes:
1. The required amplitude range for the signal at points A and B is 670 mV to 820 mV.
2. The % peak voltage difference between points A and B must be < 1 %

The loss due to the addition of the Current limiting device results in < 0.2 dB of attenuation. This is equivalent to less than 1 m of CAT5 cable.
Application Example: Ethernet

Current Limiter with TVS Diode

GbE Signal Amplitude and Template Tests per IEEE802.3

Point A Template Test

Point F Template Test
Application Example: Ethernet Current Limiter with Steering Diodes

- SM51589L Ethernet Transformer
- BAV99S Clamp Diodes to Supply and Ground
- TCS-DL004-250-WH Transient Current Suppressor

PHY sees:
- Peak Voltage: 5.4 V
- Peak Current: 595 mA
- Energy: ~ 3 µJ

Diode Clamp Voltage: ~34 V
**Application Example: Ethernet**

**Summary:** Protecting a PHY Using a Current Limiter

<table>
<thead>
<tr>
<th>Test</th>
<th>Protection Circuit</th>
<th>Diode Clamp Differential Voltage (V)</th>
<th>PHY Differential Input Voltage(V)</th>
<th>PHY Input Current</th>
<th>Estimate of Energy Absorbed by PHY (µ J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential Surge Test per GR-1089-CORE-ISSUE 6 (800V/100A)</td>
<td>TVS Diode Only</td>
<td>12.4</td>
<td>12.4 (same)</td>
<td>4A peak</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>TVS Diode with Current Limiter</td>
<td>~15</td>
<td>5.2</td>
<td>&lt;300mA*</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Steering diodes with Current Limiter</td>
<td>34</td>
<td>5.4</td>
<td>&lt;300mA*</td>
<td>3</td>
</tr>
</tbody>
</table>

* After initial peak

- The current limiter reduces the current seen by the PHY signal inputs
  - After the initial peak, current is reduced by over 90%.

- The current limiter also isolates the PHY inputs from the voltage across the TVS diode or steering diodes
  - Peak PHY input voltage is determined by its ESD protection and the current through the TCS-DL device. In this case the voltage level is reduced by over 50%.

- The energy the PHY had to absorb was reduced by more than 90% compared to using a TVS diode alone

- All designs pass IEEE802.3 signal amplitude and template tests
# General Summary

## Semiconductor Protection Technology

<table>
<thead>
<tr>
<th>Type</th>
<th>Subtype</th>
<th>Technology</th>
<th>Limiting Speed</th>
<th>Precision</th>
<th>Impulse Capability</th>
<th>Parallel Capacitance</th>
<th>Series Resistance</th>
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<td>Thyristor</td>
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<td>Clamp</td>
<td>TVS Diodes</td>
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Thank you!