SIDACtor®

Data Book

by

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Teccor Electronics SIDACtor product is covered by these and other U.S. Patents:
4,685,120 - 4,827,497 - 4,905,119 - 5,479,031 - 5,516,705

All SIDACtors are recognized under “UL497B Protectors for Data Communications and Fire Alarm circuits”, UL File # E133083. All TeleLink fuses are recognized under UL file #E191008 and are also listed for CSA marking by certificate number LR 702828.

ISO 9001
TECCOR ELECTRONICS

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1 *Introduction*

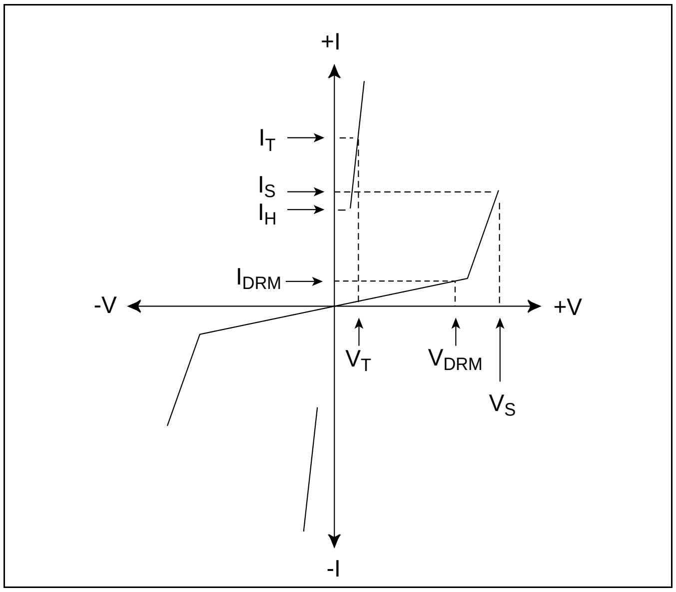
Product Description

SIDACtors are solid state crowbar devices designed to protect telecom equipment during hazardous transient conditions. Capitalizing on the latest in thyristor advancements, Teccor designs their SIDACtors with a patented ion implant technology. This technology ensures effective protection within nanoseconds, 500A surge current ratings, and simple solutions for regulatory requirements such as Bellcore 1089, FCC Part 68, ITU-T K. 20, ITU-T K. 21and UL1459 & 1950.

Operation

In the standby mode, SIDACtors exhibit a high off-state impedance eliminating excessive leakage currents and appearing transparent to the circuits they protect. Upon application of a voltage exceeding the switching voltage (V_S), SIDACtors will crowbar and simulate a short circuit condition until the current flowing through the device is either interrupted or drops below the SIDACtor's holding current (I_H). Once this occurs, SIDACtors will reset and return to their high off-state impedance.

V-I Characteristics



Advantages

The advantages of using a SIDACtor over other surge suppression devices is that the SIDACtor offers absolute surge protection regardless of the surge current available and the rate of applied voltage (dV/dt). Unlike other devices, the SIDACtor:

- Can not be damaged by voltage
- Eliminates hysteresis and heat dissipation typically found with a clamping device
- Eliminates voltage overshoot caused by fast rising transients
- Is non-degenerative
- Will not fatigue
- Has negligible capacitance making it ideal for high speed transmission equipment

Applications

When protecting telecommunication circuits, the SIDACtor is connected across Tip and Ring for metallic protection and across Tip, Ring, and ground for longitudinal protection. SIDACtors are typically placed behind some type of current limiting device such as a slow blow fuse. Common applications are:

- Central office line cards
- T-1/E-1, ISDN, and xDSL transmission equipment
- Customer Premises Equipment (CPE) such as phones, modems, and caller ID adjunct boxes
- PBX's, KSU's and other switches
- Primary protection including main distribution frames, 5-pin modules, building entrance equipment and station protection modules
- Data lines and security systems
- CATV line amplifiers and power inserters
- Sprinkler systems

For more information regarding specific applications, design requirements, or surge suppression, please contact Teccor Electronics directly at (972) 580-7777 or through our local area representative. Access Teccor's web site at http://www.teccor.com or e-mail us at: sidactor@teccor.com

Quality and Reliability

It is the policy of Teccor to ship quality product. We accomplish this through Total Quality Management based on the fundamentals of Customer Focus, Continuous Improvement and People Involvement.

In support of this commitment, the following principles apply:

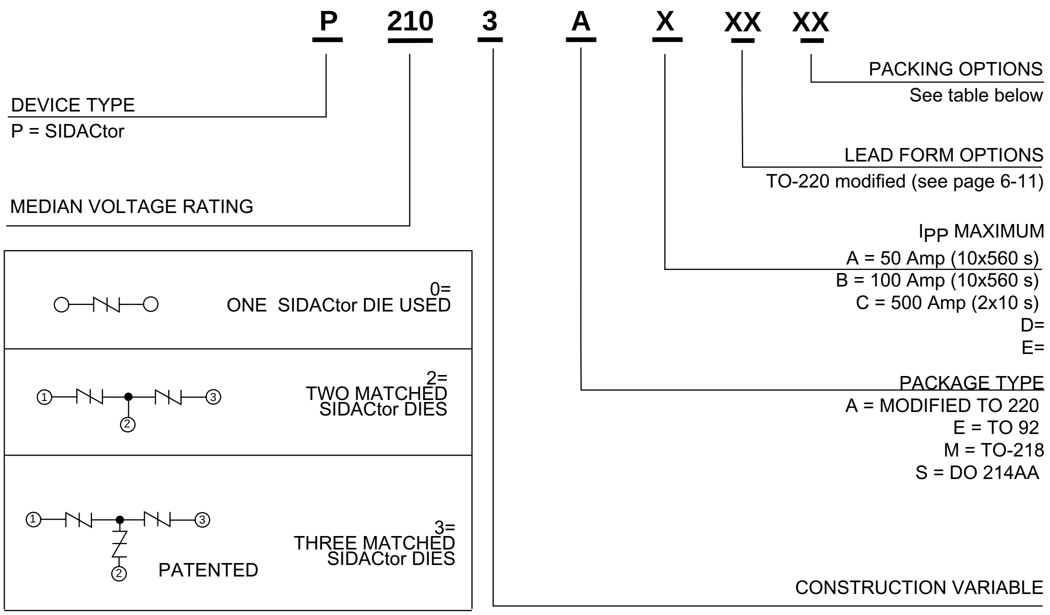
- Employees shall be respected, involved, informed and qualified for their job with appropriate education, training and experience.
- Customer expectations shall be met or exceeded by consistently shipping the agreed specifications, quality levels, quantities, schedules and test and reliability parameters.
- Suppliers shall be selected by considering quality, service delivery and cost of ownership.
- Design of products and processes will be driven by customer needs, reliability and manufacturability.

It is the responsibility of Management to incorporate these principles into policies and systems.

It is the responsibility of those in a Leadership role to coach their people and to reinforce these principles.

It is the responsibility of each individual employee to follow the spirit of this statement to ensure that we meet the primary policy . . . to ship quality product.

Part Number Description



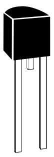
NOTE: Part number description does not apply to SLIC protectors.

Package Type	Description	Packing Quantity	Added Suffix	Page Number	Industry Standard
EA EB EC TO-92	Bulk Pack	2000		6.5	N/A
	Tape and Reel Pack	2000	RP1, RP2	6-9	EIA RS-468-B
TO 218	Bulk Pack	500		6-7	N/A
AA AB AC TO-220	Bulk Pack	500		6-6	N/A
	Tape and Reel Pack	700	RP	6-10	EIA RS-468-B
	Tape and Reel Pack for Type 61 leadform	700	RP		EIA RS-468-B
SA SB SC DO-214AA	Embossed Carrier Reel Pack	2500	RP	6-8	EIA-481-1
	Bulk Pack	5000			N/A

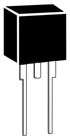
NOTE: Standard lead spacing for TO-92 Reel Pack is .200”.

Package Index

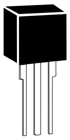
Package	Page	Package	Page
DO-214	2-3	Balanced Three Chip TO-220	2-12
TO-92	2-6	SLIC	2-14
TO-220, Type 61	2-8	SLIC - Battrax	2-16
Two Chip TO-220	2-10	CATV Series	2-18



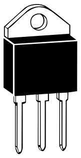
TO-92



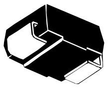
TO-220
Type 61



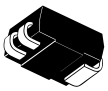
TO-220



TO-218M



DO-214AA



DO-214AA 3 LEAD

Electrical Parameters Defined

C_O - Off-state Capacitance
Typical capacitance measured in off-state.

dI/dt - Rate of Rise of Current
Maximum rated value of the acceptable rate of rise in current over time.

dV/dt - Rate of Rise of Voltage
Rate of applied voltage over time.

I_S - Switching Current
Maximum current required to switch to on-state.

I_{DRM} - Leakage Current
Maximum peak off-state current measured at V_{DRM}.

I_H - Holding Current
Minimum current required to maintain on-state.

I_{PP} - Peak Pulse Current
Maximum rated peak impulse current.

I_T - On-state Current
Maximum rated continuous on-state current.

I_{TSM} - Peak One Cycle Surge Current
Maximum rated one cycle AC current.

V_S - Switching Voltage
Maximum voltage prior to switching to on-state.

V_{DRM} - Peak off-state Voltage
Maximum voltage that can be applied while maintaining off-state.

V_F - On-state Forward Voltage
Maximum forward voltage measured at rated on-state current.

V_T - On-state Voltage
Maximum voltage measured at rated on-state current.

NOTE:

- On-state is defined as the low impedance condition reached during full conduction. It is also referred to as the crowbar condition and simulates a short circuit.
- Off-state is defined as the high impedance condition prior to beginning conduction. It is also referred to as the blocking condition and simulates an open circuit.

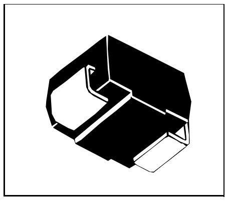
Notes

2 Data Sheets

Presented in this chapter are electrical parameters for the SIDACtor, Teccor's line of solid state over voltage protection devices.

Complete specifications for the following product families are presented on the following pages:

DO-214 SIDACtor



The DO-214 SIDACtor is a solid state protection device designed for telecommunications applications such as modems, line cards, fax machines, etc.

The SIDACtor is used to help equipment meet various regulatory requirements including: GR 1089, ITU K.20 & K.21, IEC 950, UL 1459 & 1950 and FCC Part 68.

Part Number*	**V_{DRM} Volts**	**V_S Volts**	**V_T Volts**	**I_{DRM} µAmps**	**I_S mAmps**	**I_T Amps**	**I_H mAmps**	**C_O pF**
P0080S_	6	25	5	5	800	1	50	100
P0300S_	25	40	5	5	800	1	50	110
P0640S_	58	77	5	5	800	1	150	50
P0720S_	65	88	5	5	800	1	150	50
P0900S_	75	98	5	5	800	1	150	50
P1100S_	90	130	5	5	800	1	150	40
P1300S_	120	160	5	5	800	1	150	40
P1500S_	140	180	5	5	800	1	150	40
P1800S_	160	220	5	5	800	1	150	30
P2300S_	190	260	5	5	800	1	150	30
P2600S_	220	300	5	5	800	1	150	30
P3100S_	275	350	5	5	800	1	150	30
P3500S_	320	400	5	5	800	1	150	30

* For individual "SA", "SB" and "SC" surge ratings, see table below.

Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- Listed SIDACtors are bi-directional. All electrical parameters & surge ratings apply to forward and reverse polarities.
- V_{DRM} is measured at I_{DRM}.
- V_S is measured at 100V/µs.
- Special voltage (V_S & V_{DRM}) and holding current (I_H) requirements are available upon request.
- Off-state capacitance is measured at 1MHz with a 2 volt bias and is a typical value for "SA" and "SB" product. "SC" capacitance is approximately 2x the listed value. The off-state capacitance of the P0080SB is equal to our "SC" device.

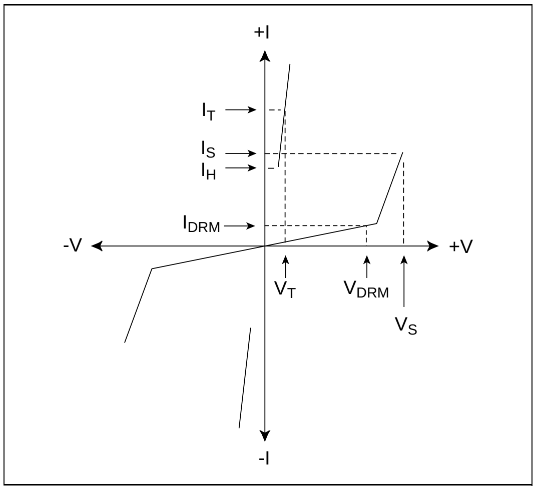
Surge Ratings

Series	**I_{PP} 2x10µs Amps**	**I_{PP} 8x20µs Amps**	**I_{PP} 10x160µs Amps**	**I_{PP} 10x560µs Amps**	**I_{PP} 10x1000µs Amps**	**I_{TSM} 60Hz Amps**	**dI/dt Amps/µs**
A		150	100	50	50	20	500
B		250	150	100		30	500
C	500	400	200		100	60	500

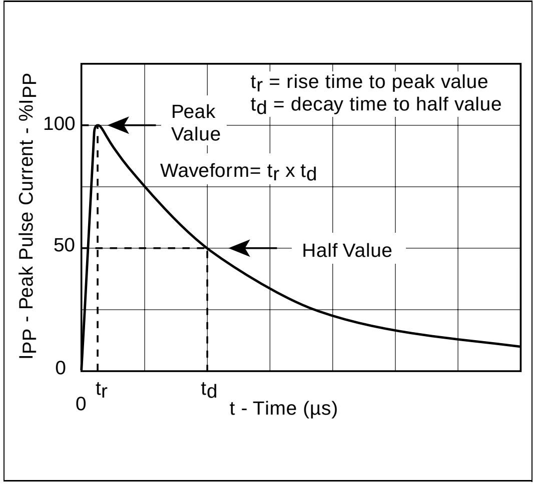
Thermal Considerations

Package	Symbol	Parameter	Value	Unit
DO-214	T_j	Junction Temperature Range	-40 to +150	°C
	T_s	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	+75	°C
	$R_{\theta jc}$	Thermal Resistance: junction to case	+28	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	+90	°C/W

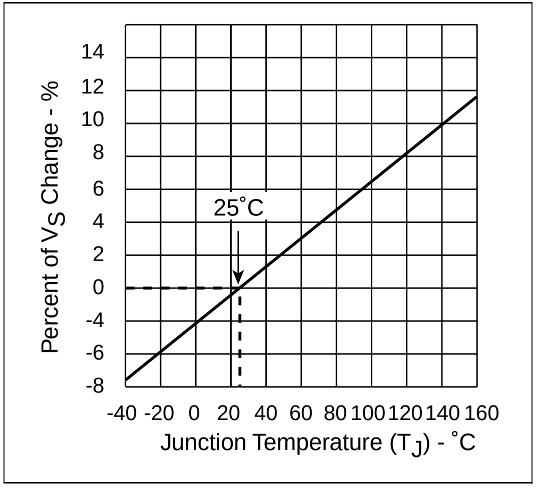
V-I Characteristics



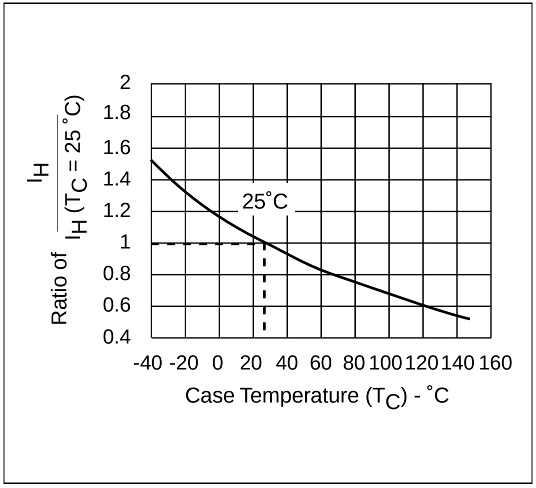
$t_r x t_d$ Pulse Wave-form



Normalized V_S Change vs. Junction Temperature



Normalized DC Holding Current vs. Case Temperature



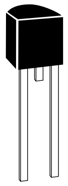
DO-214 SIDACtor

Package Symbolization

Standardized Part Number	Symbolized Part Number	Standardized Part Number	Symbolized Part Number
P0080SA	P_8A	P1800SA	P18A
P0080SB	P_8B	P1800SB	P18B
P0080SC	P_8C	P1800SC	P18C
P0300SA	P03A	P2000SA	P20A
P0300SB	P03B	P2000SB	P20B
P0300SC	P03C	P2000SC	P20C
P0640SA	P06A	P2300SA	P23A
P0640SB	P06B	P2300SB	P23B
P0640SC	P06C	P2300SC	P23C
P0641SA	P61A	P2600SA	P26A
P0641SC	P61C	P2600SB	P26B
P0720SA	P07A	P2600SC	P26C
P0720SB	P07B	P3100SA	P31A
P0720SC	P07C	P3100SB	P31B
P0721SA	P71A	P3100SC	P31C
P0721SC	P71C	P3500SA	P35A
P0900SA	P09A	P3500SB	P35B
P0900SB	P09B	P3500SC	P35C
P0900SC	P09C	B1100CA	B10A
P1100SA	P11A	B1100CC	B10C
P1100SB	P11B	B1160CA	B60A
P1100SC	P11C	B1160CC	B60C
P1200SA	P12A	B1200CA	B20A
P1200SB	P12B	B1200CC	B20C
P1200SC	P12C	B2100CA	B21A
P1300SA	P13A	B2100CC	B21C
P1300SB	P13B	B2160CA	B26A
P1300SC	P13C	B2160CC	B26C
P1500SA	P15A	B2200CA	B22A
P1500SB	P15B	B2200CC	B22C
P1500SC	P15C		

Note: On the DO-214 package, date code is located below the Symbolized Part Number. TO-92 and TO-220 devices have full part numbers and a date code printed on the part.

TO-92 SIDACtor



The TO-92 SIDACtor is a solid state protection device designed for telecommunications applications such as modems, line cards, fax machines, etc.

The SIDACtor is used to help equipment meet various regulatory requirements including: GR 1089, ITU K.20 & K.21, IEC 950, UL 1459 & 1950 and FCC Part 68.

Electrical Parameters

Part Number*	V_{DRM} Volts	V_S Volts	V_T Volts	I_{DRM} µAmps	I_S mAmps	I_T Amps	I_H mAmps	C_O pF
P0080E_	6	25	5	5	800	1	50	100
P0300E_	25	40	5	5	800	1	50	110
P0640E_	58	77	5	5	800	1	150	50
P0720E_	65	88	5	5	800	1	150	50
P0900E_	75	98	5	5	800	1	150	50
P1100E_	90	130	5	5	800	1	150	40
P1300E_	120	160	5	5	800	1	150	40
P1500E_	140	180	5	5	800	1	150	40
P1800E_	160	220	5	5	800	1	150	30
P2300E_	190	260	5	5	800	1	150	30
P2600E_	220	300	5	5	800	1	150	30
P3100E_	275	350	5	5	800	1	150	30
P3500E_	320	400	5	5	800	1	150	30

* For individual “EA”, “EB” and “EC” surge ratings, see table below. (P0080EB is not available.)

Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- Listed SIDACtors are bi-directional. All electrical parameters & surge ratings apply to forward and reverse polarities.
- V_{DRM} is measured at I_{DRM}.
- V_S is measured at 100V/µs.
- Special voltage (V_S & V_{DRM}) and holding current (I_H) requirements are available upon request.
- Off-state capacitance is measured at 1MHz with a 2 volt bias and is a typical value for “EA” and “EB” product. “EC” capacitance is approximately 2x the listed value.

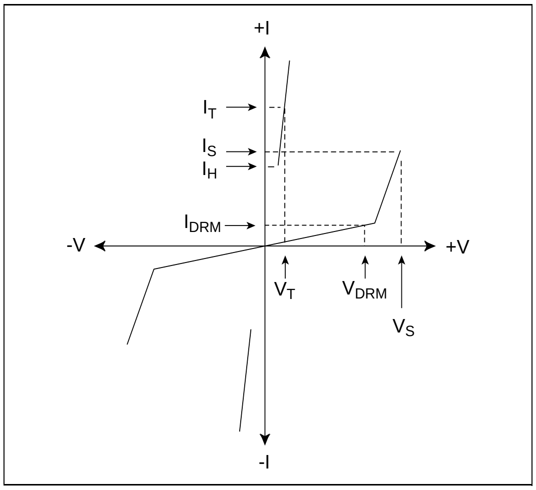
Surge Ratings

Series	I_{PP} 2x10µs Amps	I_{PP} 8x20µs Amps	I_{PP} 10x160µs Amps	I_{PP} 10x560µs Amps	I_{PP} 10x1000µs Amps	I_{TSM} 60Hz Amps	dI/dt Amps/µs
A		150	100	50	50	20	500
B		250	150	100		30	500
C	500	400	200		100	60	500

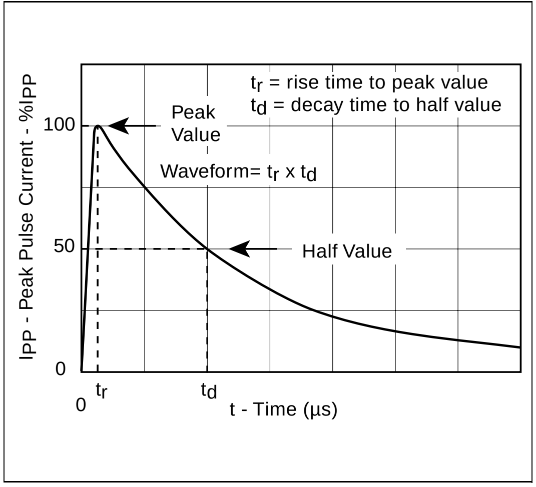
Thermal Considerations

Package	Symbol	Parameter	Value	Unit
TO-92	T_j	Junction Temperature Range	-40 to +150	°C
	T_s	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	+110	°C
	$R_{\theta jc}$	Thermal Resistance: junction to case	+28	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	+90	°C/W

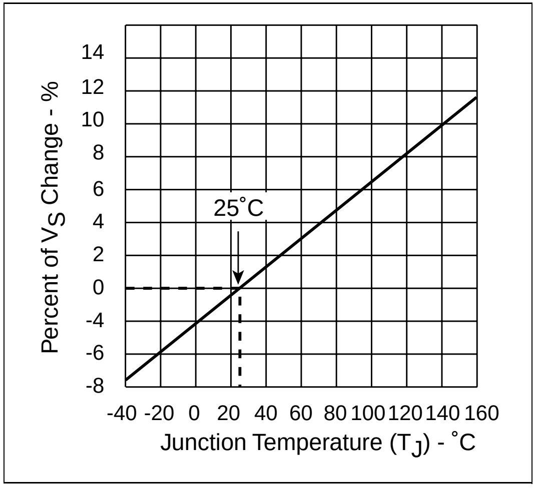
V-I Characteristics



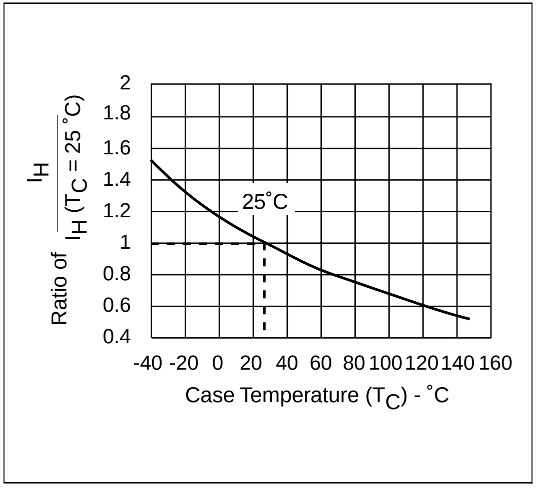
$t_r x t_d$ Pulse Wave-form



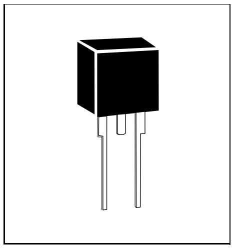
Normalized V_S Change vs. Junction Temperature



Normalized DC Holding Current vs. Case Temperature



TO-220 Type 61 SIDACtor



The modified TO-220 Type 61 SIDACtor is a solid state protection device designed for telecommunications applications that do not reference earth ground.

The SIDACtor is used to help equipment meet various regulatory requirements including: GR 1089, ITU K.20 & K.21, IEC 950, UL 1459 & 1950 and FCC Part 68.

Electrical Parameters

Part Number	V_{DRM} Volts	V_S Volts	V_T Volts	I_{DRM} µAmps	I_S mAmps	I_T Amps	I_H mAmps	C_O pF
P2000AA61	180	220	5	5	800	1	150	30
P2200AA61	200	240	5	5	800	1	150	30
P2400AA61	220	260	5	5	800	1	150	30
P2500AA61	240	290	5	5	800	1	150	30
P3000AA61	270	330	5	5	800	1	150	30
P3300AA61	300	360	5	5	800	1	150	30

Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- Listed SIDACtors are bi-directional. All electrical parameters & surge ratings apply to forward and reverse polarities.
- V_{DRM} is measured at I_{DRM}.
- V_S is measured at 100V/µs.
- Special voltage (V_S & V_{DRM}) and holding current (I_H) requirements are available upon request.
- Off-state capacitance is measured at 1MHz with a 2 volt bias and is a typical value.

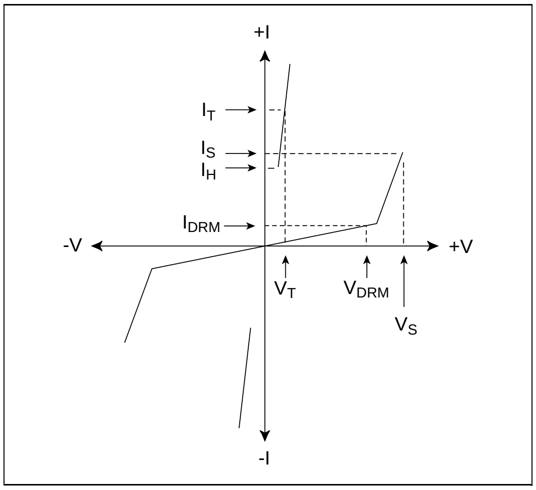
Surge Ratings

Series	I_{PP} 0.2x310µs Amps	I_{PP} 2x10µs Amps	I_{PP} 8x20µs Amps	I_{PP} 10x160µs Amps	I_{PP} 10x560µs Amps	I_{PP} 5x320µs Amps	I_{PP} 10x1000µs Amps	I_{TSM} 60Hz Amps	dI/dt Amps/µs
A	20	200	150	100	50	75	50	20	500

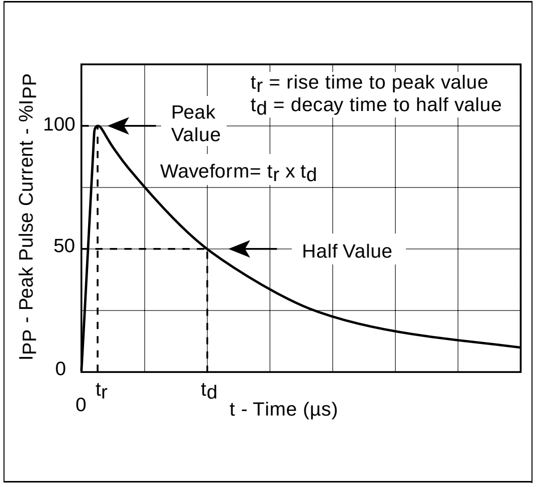
Thermal Considerations

Package	Symbol	Parameter	Value	Unit
Modified TO-220	T_j	Junction Temperature Range	-40 to +150	°C
	T_s	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	+115	°C
	$R_{\theta jc}$	Thermal Resistance: junction to case	+12	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	+50	°C/W

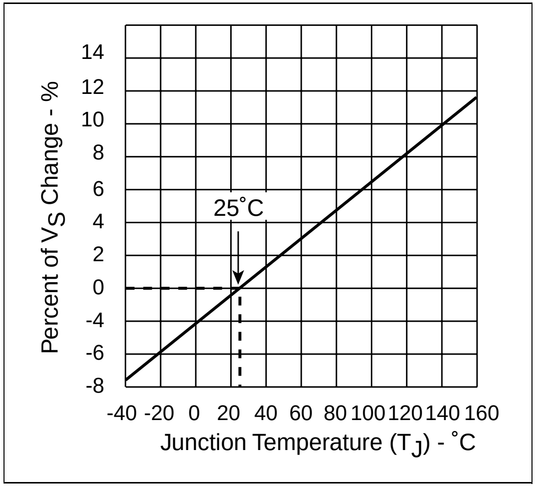
V-I Characteristics



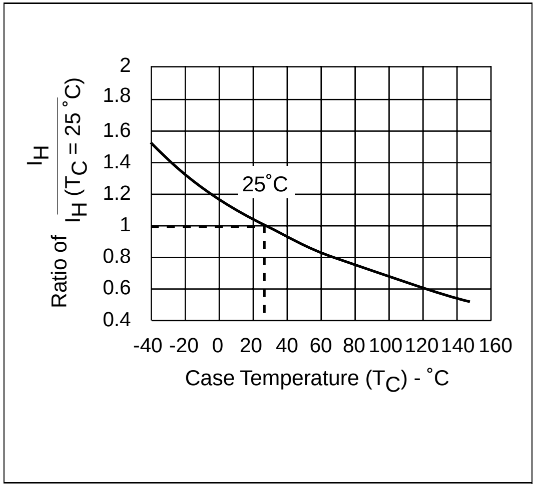
$t_r x t_d$ Pulse Wave-form



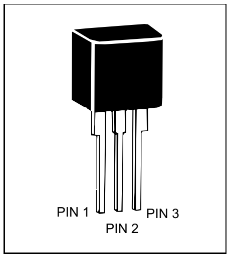
Normalized V_S Change vs. Junction Temperature



Normalized DC Holding Current vs. Case Temperature



Two Chip TO-220 SIDACtor



The two chip modified TO-220 SIDACtor is a solid state protection device designed for telecommunications applications that reference Tip and Ring to earth ground but do not require balanced protection.

The SIDACtor is used to help meet various regulatory requirements including: GR 1089, ITU K.20 & K.21, IEC 950, UL 1459 & 1950 and FCC Part 68.

Electrical Parameters

Part Number*	V_{DRM} Volts pins 1-2, 3-2	V_S Volts	V_{DRM} Volts pins 1-3	V_S Volts	V_T Volts	I_{DRM} µAmps	I_S mAmps	I_T Amps	I_H mAmps	C_O pF
P0602A_	25	40	50	80	5	5	800	1	50	110
P1402A_	58	77	116	154	5	5	800	1	150	50
P1602A_	65	95	130	190	5	5	800	1	150	50
P2202A_	90	130	180	260	5	5	800	1	150	40
P2702A_	120	160	240	320	5	5	800	1	150	40
P3002A_	140	180	280	360	5	5	800	1	150	40
P3602A_	160	220	320	440	5	5	800	1	150	40
P4202A_	190	250	380	500	5	5	800	1	150	30
P4802A_	220	300	440	600	5	5	800	1	150	30
P6002A_	275	350	550	700	5	5	800	1	150	30

* For individual “AA”, “AB” and “AC” surge ratings, see table below.

Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- Listed SIDACtors are bi-directional. All electrical parameters & surge ratings apply to forward and reverse polarities.
- V_{DRM} is measured at I_{DRM}.
- V_S is measured at 100V/µs.
- Special voltage (V_S & V_{DRM}) and holding current (I_H) requirements are available upon request.
- Off-state capacitance is measured between PINS 1-2 and 3-2 at 1MHz with a 2 volt bias and is a typical value for “AA” and “AB” product. “AC” capacitance is approximately 2x the listed value.

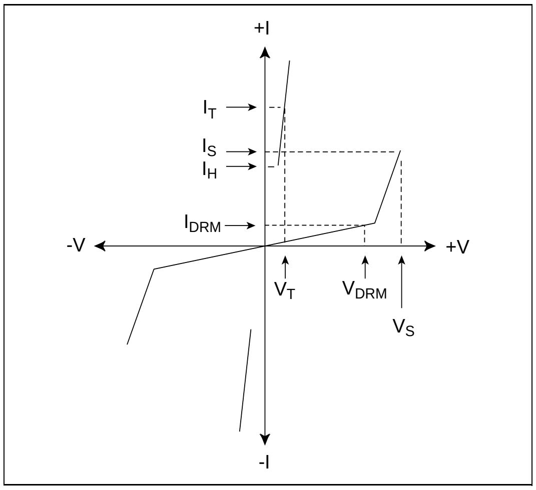
Surge Ratings

Series	I_{PP} 2x10µs Amps	I_{PP} 8x20µs Amps	I_{PP} 10x160µs Amps	I_{PP} 10x560µs Amps	I_{PP} 10x1000µs Amps	I_{TSM} 60Hz Amps	dI/dt Amps/µs
A		150	100	50	50	20	500
B		250	150	100		30	500
C	500	400	200		100	60	500

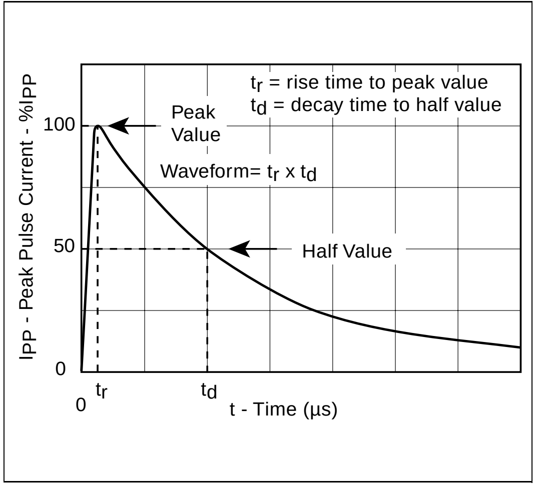
Thermal Considerations

Package	Symbol	Parameter	Value	Unit
Modified TO-220	T_j	Junction Temperature Range	-40 to +150	°C
	T_s	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	+115	°C
	$R_{\theta jc}$	Thermal Resistance: junction to case	+12	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	+50	°C/W

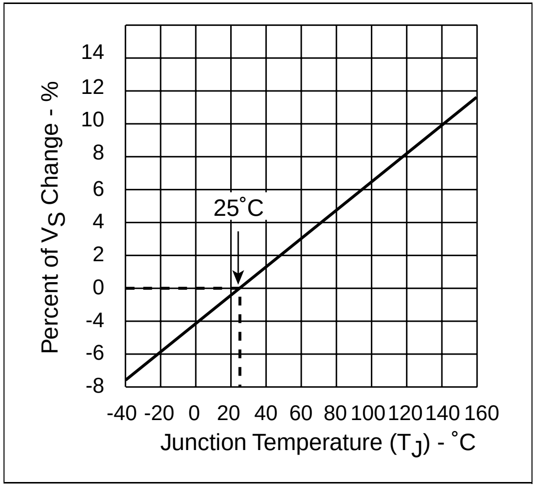
V-I Characteristics



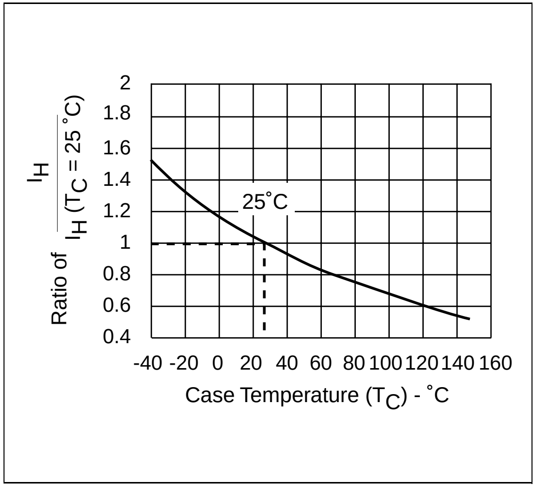
$t_r x t_d$ Pulse Wave-form



Normalized V_S Change vs. Junction Temperature



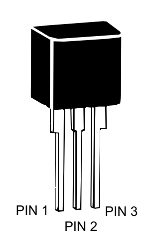
Normalized DC Holding Current vs. Case Temperature



Balanced Three Chip TO-220 SIDACtor

The three chip modified TO-220 SIDACtor is a balanced solid state protection device designed for telecommunications systems that reference Tip and Ring to earth ground. Applications include any piece of transmission equipment that requires balanced protection.

The SIDACtor is used to help equipment meet various regulatory requirements including: GR 1089, ITU K.20 & K.21, IEC 950, UL 1459 & 1950 and FCC Part 68.



Electrical Parameters

Part Number*	V_{DRM} Volts pins 1-2, 3-2	V_S Volts pins 1-2, 3-2	V_{DRM} Volts pins 1-3	V_S Volts pins 1-3	V_T Volts	I_{DRM} µAmps	I_S mAmps	I_T Amps	I_H mAmps	C_O pF
P1553A_	130	180	130	180	10	5	800	1	150	40
P1803A_	150	210	150	210	10	5	800	1	150	40
P2103A_	170	250	170	250	10	5	800	1	150	40
P2353A_	200	270	200	270	10	5	800	1	150	40
P2703A_	230	300	230	300	10	5	800	1	150	30
P3203A_	270	350	270	350	10	5	800	1	150	30
P3403A_	300	400	300	400	10	5	800	1	150	30
P5103A_	420	600	420	600	10	5	800	1	150	30

* For individual “AA”, “AB” and “AC” surge ratings, see table below.

Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- Listed SIDACtors are bi-directional. All electrical parameters & surge ratings apply to forward and reverse polarities.
- V_{DRM} is measured at I_{DRM}.
- V_S is measured at 100V/µs.
- Special voltage (V_S & V_{DRM}) and holding current (I_H) requirements are available upon request.
- Off-state capacitance is measured between (Pin 1-2 and 3-2) at 1MHz with a 2 volt bias and is a typical value for “AA” and “AB” product. “AC” capacitance is approximately 2x the listed value.
- Designed to meet balance requirements of GTS 8700 and GR 974.

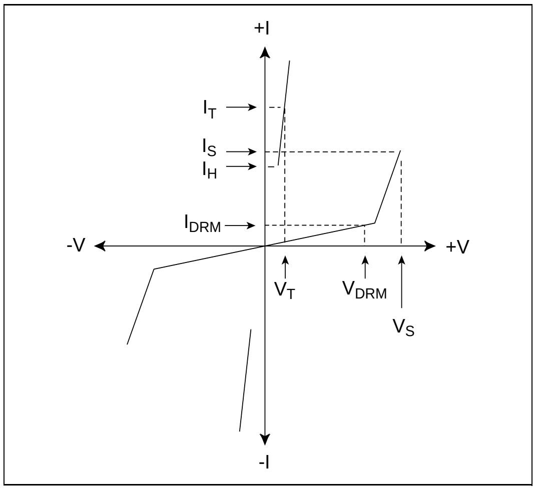
Surge Ratings

Series	I_{PP} 2x10µs Amps	I_{PP} 8x20µs Amps	I_{PP} 10x160µs Amps	I_{PP} 10x560µs Amps	I_{PP} 10x1000µs Amps	I_{TSM} 60Hz Amps	dI/dt Amps/µs
A		150	100	50	50	20	500
B		250	150	100		30	500
C	500	400	200		100	60	500

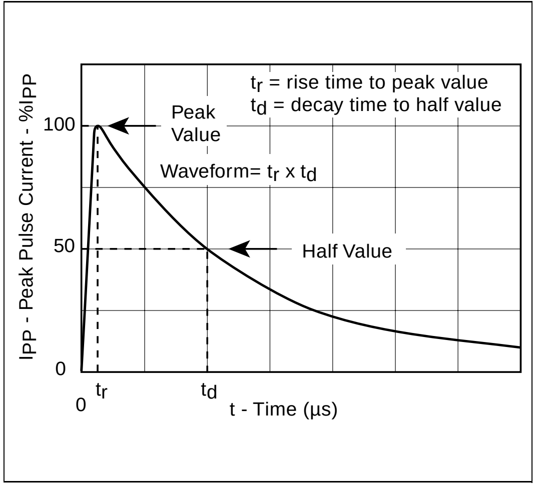
Thermal Considerations

Package	Symbol	Parameter	Value	Unit
Modified TO-220	T_j	Junction Temperature Range	-40 to +150	°C
	T_s	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	+115	°C
	$R_{\theta jc}$	Thermal Resistance: junction to case	+12	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	+50	°C/W

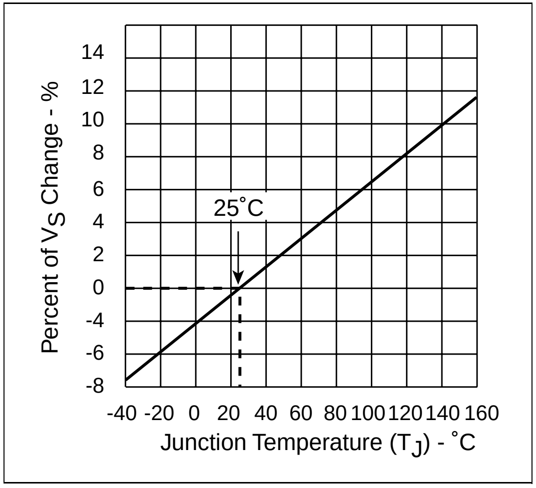
V-I Characteristics



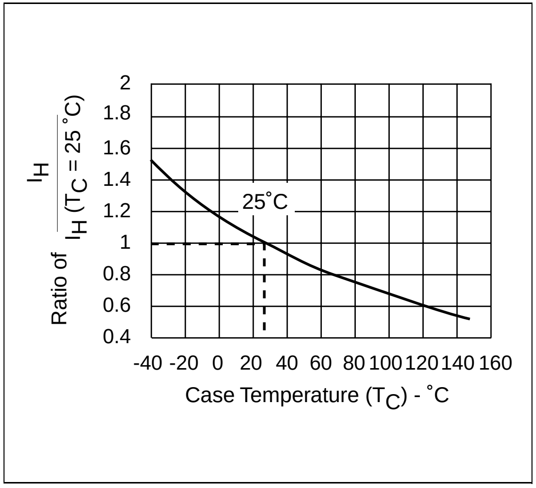
$t_r x t_d$ Pulse Wave-form



Normalized V_S Change vs. Junction Temperature



Normalized DC Holding Current vs. Case Temperature

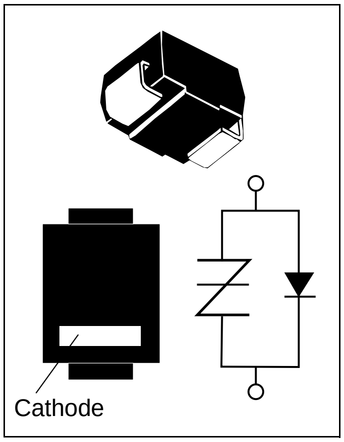


Subscriber Line Interface Circuit (SLIC) Protection (DO-214)

The P0641S_ and the P0721S_ are unidirectional solid state protection devices constructed with a SIDACtor and integrated diode.

Used to protect SLIC IC's from being damaged during transient voltage activity, the P0641S_ and P0721S_ help line cards meet various regulatory requirements including: GR 1089, ITU K.20 & K.21, IEC 950, UL 1459 & 1950 and FCC Part 68.

For specific design criteria see page 3-21.



Electrical Parameters

Part Number*	V_{DRM} Volts	V_S Volts	V_T Volts	V_F Volts	I_{DRM} µAmps	I_S mAmps	I_T Amps	I_H mAmps	C_O pF
P0641S_	58	77	5	5	5	800	1	120	70
P0721S_	65	88	5	5	5	800	1	120	70
P1101S_	90	130	5	5	5	800	1	120	60

* For individual "SA" and "SC" surge ratings, see table below.

Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- V_{DRM} is measured at I_{DRM}.
- V_S and V_F are measured at 100V/µs.
- Special voltage (V_S & V_{DRM}) and holding current (I_H) requirements are available upon request.
- Off-state capacitance is measured at 1MHz with a 2 volt bias and is a typical value for "SA" product. "SC" capacitance is approximately 2x the listed value.

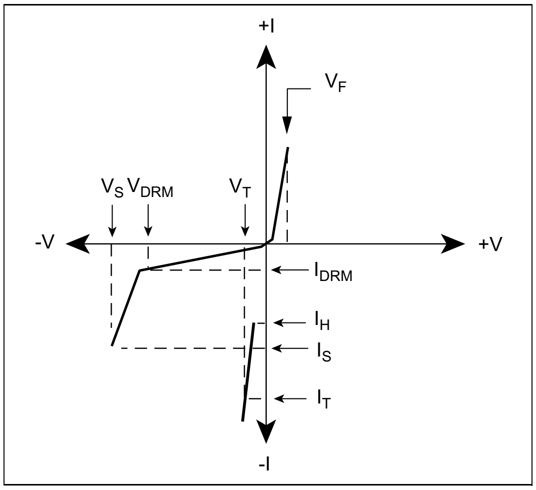
Surge Ratings (Preliminary Data)

Series	I_{PP} 2x10µs Amps	I_{PP} 8x20µs Amps	I_{PP} 10x160µs Amps	I_{PP} 10x560µs Amps	I_{PP} 10x1000µs Amps	I_{TSM} 60Hz Amps	dI/dt Amps/µs
A		150	100	50	50	20	500
C	500	400	200		100	60	500

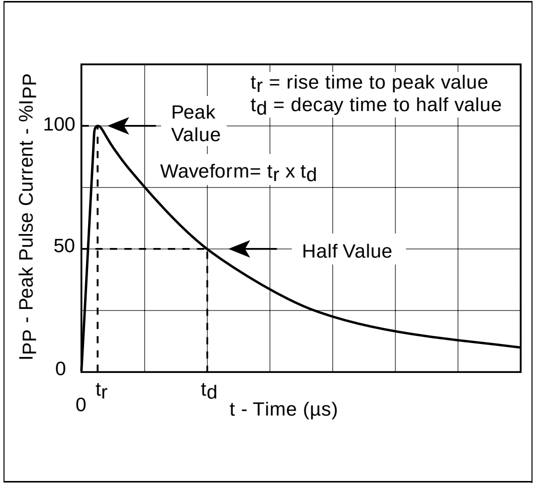
Thermal Considerations

Package	Symbol	Parameter	Value	Unit
DO-214	T_j	Junction Temperature Range	-40 to +150	°C
	T_s	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	+75	°C
	$R_{\theta jc}$	Thermal Resistance: junction to case	+28	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	+90	°C/W

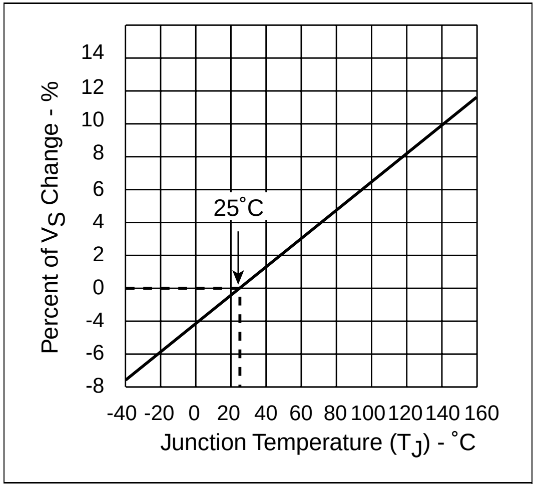
V-I Characteristics



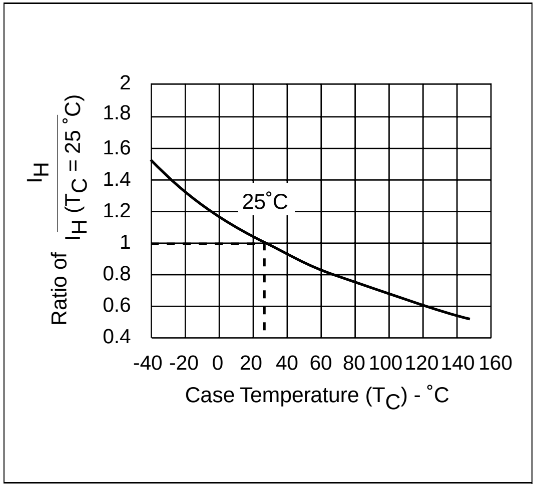
t_rxt_d Pulse Wave-form



Normalized V_S Change vs. Junction Temperature



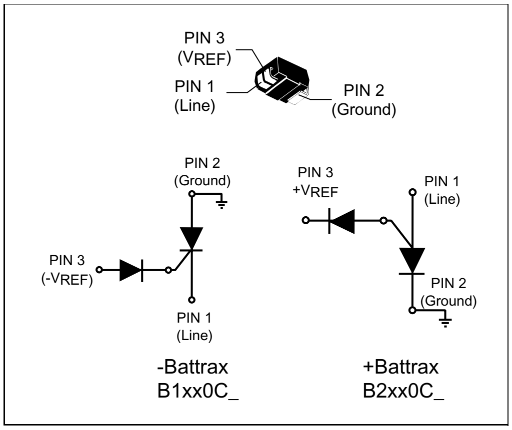
Normalized DC Holding Current vs. Case Temperature



Subscriber Line Interface Circuit (SLIC) Protection Battrax (Modified DO-214)

The Battrax is a solid state protection device that can be referenced to either a positive or negative voltage source using the B1xx0C_ for a $-V_{REF}$ and the B2xx0C_ for a $+V_{REF}$. Designed using a high holding current SCR and an integrated diode, the B1xx0C_ Battrax begins to conduct at $|-V_{REF}|+|-1.2V|$ while the B2xx0C_ Battrax begins to conduct at $|+V_{REF}|+|1.2V|$.

For specific diagrams using the Battrax, please see pages 3-21 and 3-22.



Electrical Parameters (Preliminary Data for Positive Tracking Devices)

Part Number*	V_{DRM} Volts	V_S Volts	V_T Volts	V_F Volts	I_{DRM} µAmps	I_{GT} mAmps	I_T Amps	I_H mAmps	C_O pF
B1100C_	$\vert -V_{REF}\vert + \vert -1.2V\vert$	$\vert -V_{REF}\vert + \vert -10V\vert$	5	5	5	100	1	100	50
B1160C_	$\vert -V_{REF}\vert + \vert -1.2V\vert$	$\vert -V_{REF}\vert + \vert -10V\vert$	5	5	5	100	1	160	50
B1200C_	$\vert -V_{REF}\vert + \vert -1.2V\vert$	$\vert -V_{REF}\vert + \vert -10V\vert$	5	5	5	100	1	200	50
B2050C_	$\vert +V_{REF}\vert + \vert -1.2V\vert$	$+V_{REF} + 10V$	5	5	5	50	1	50	50

* For individual “CA” and “CC” surge ratings, see table below.

Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- I_{PP} ratings assume a $V_{REF} = \pm 48V$.
- V_{DRM} is measured at I_{DRM}.
- V_S is measured at 100V/µs.
- Off-state capacitance is measured at 1MHz with a 2 volt bias and is a typical value. “CC” product is approximately 2x the listed value.
- +Battrax information is preliminary data.
- V_{REF} maximum value for the B1100, B1160, and/or B1200 is 200V.
- V_{REF} maximum value for the B2050 is 100V.

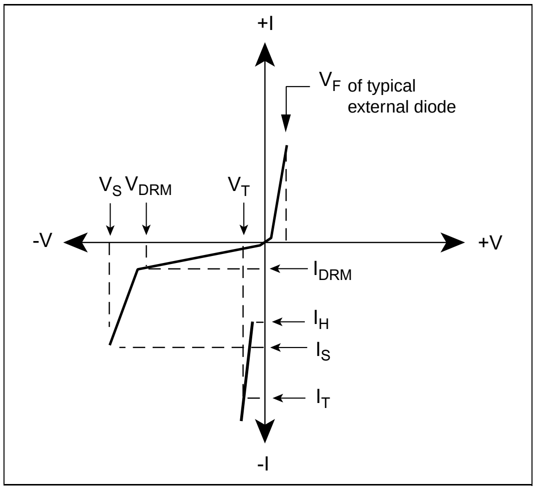
Surge Ratings (Preliminary Data for Positive Tracking Devices)

Series	I_{PP} 2x10µs Amps	I_{PP} 8x20µs Amps	I_{PP} 10x160µs Amps	I_{PP} 10x560µs Amps	I_{PP} 10x1000µs Amps	I_{TSM} 60Hz Amps	dI/dt Amps/µs
A		150	100	50	50	40	500
C	500	400	200		100	60	500

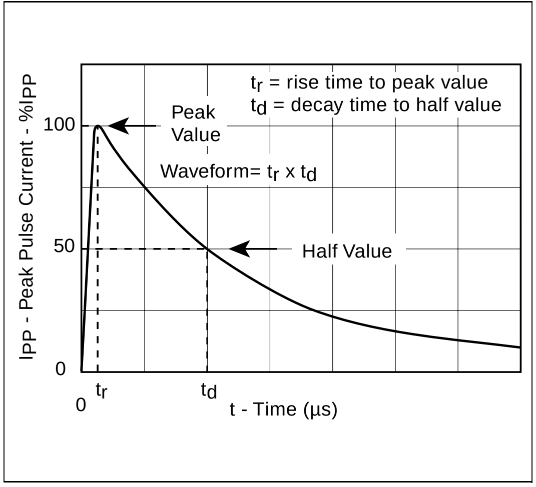
Thermal Considerations

Package	Symbol	Parameter	Value	Unit
Battrax	T_j	Junction Temperature Range	-40 to +150	°C
	T_s	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	+75	°C
	$R_{\theta jc}$	Thermal Resistance: junction to case	+26	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	+85	°C/W

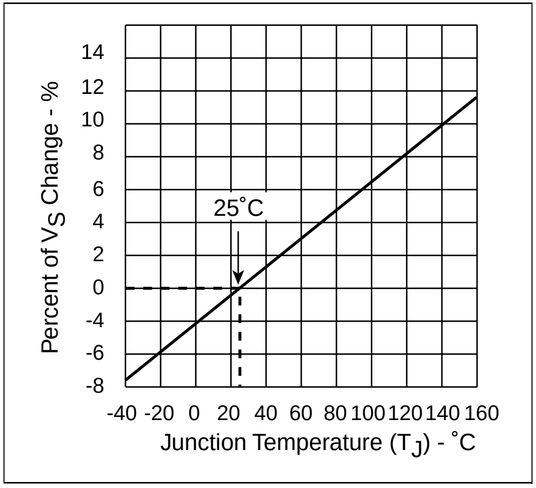
V-I Characteristics



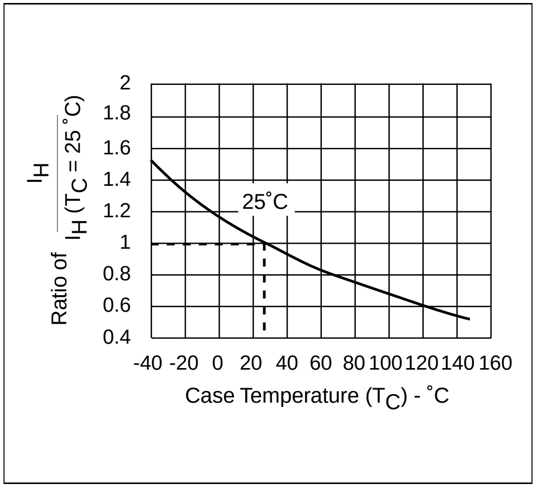
$t_r x t_d$ Pulse Wave-form



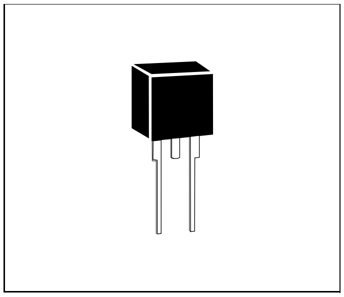
Normalized V_S Change vs. Junction Temperature



Normalized DC Holding Current vs. Case Temperature



CATV Series SIDACtor



The P1400AD SIDACtor is a 1000A rated solid state protection device offered in a TO-220 package and is designed to meet the severe surge requirements found in a CATV environment.

Used in Hybrid Fiber Coax (HFC) applications, the P1400AD replaces the gas tube that is traditionally used for station protection due to the P1400AD's tight voltage tolerances.

Electrical Parameters

Part Number	**V_{DRM} Volts**	**V_S Volts**	**V_T Volts**	**I_{DRM} µAmps**	**I_S mAmps**	**I_T Amps**	**I_H mAmps**	**C_O pF**
P1400AD	120	160	5	5	800	1	50	200

Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- Listed SIDACtors are bi-directional. All electrical parameters & surge ratings apply to forward and reverse polarities.
- V_{DRM} is measured at I_{DRM}.
- V_S is measured at 100V/µs.
- Special voltage (V_S & V_{DRM}) and holding current (I_H) requirements are available upon request.
- Off-state capacitance is measured at 1MHz with a 2 volt bias and is a typical value.

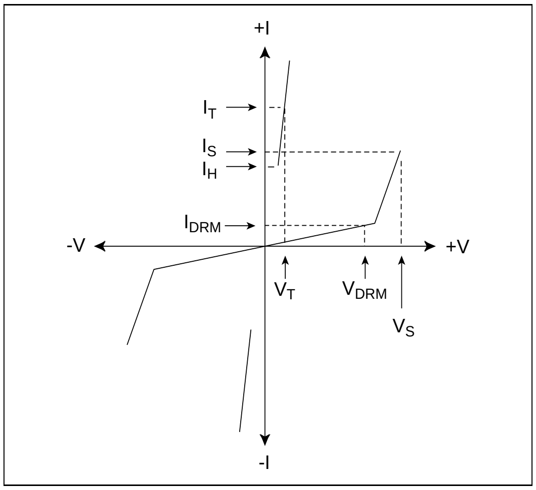
Surge Ratings

Series	**I_{PP} 8x20µs Amps**	**I_{PP} 10x1000µs Amps**	**I_{TSM} 60Hz Amps**	**dI/dt Amps/µs**
P1400AD	1000	250	120	500

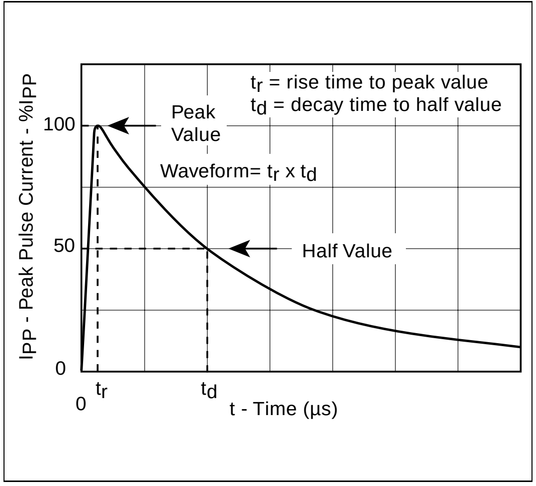
Thermal Considerations

Package	Symbol	Parameter	Value	Unit
P1400AD	T_j	Junction Temperature Range	-40 to +150	°C
	T_s	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	80	°C
	$R_{\theta jc}$	Thermal Resistance: junction to case	2.8	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	60	°C/W

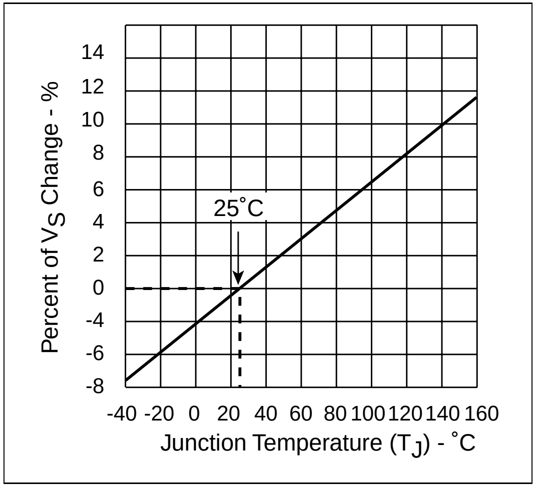
V-I Characteristics



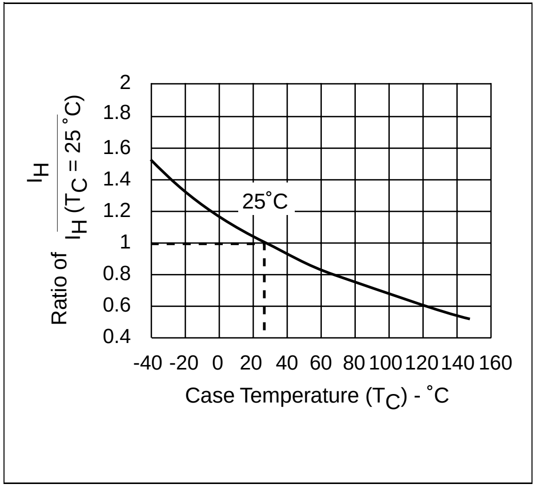
$t_r x t_d$ Pulse Wave-form



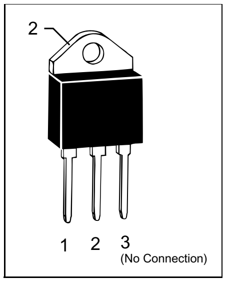
Normalized V_S Change vs. Junction Temperature



Normalized DC Holding Current vs. Case Temperature



CATV Series SIDACtor



The P1900ME is a 3000A rated solid state protection device offered in a non-isolated TO-218 package and is designed to meet the severe surge requirements found in a CATV environment.

Used on CATV line amplifiers and power inserters, the P1900ME replaces traditional gas tubes due to the P1900ME's tight voltage tolerances.

Electrical Parameters

Part Number	V_{DRM} Volts	V_S Volts	V_T Volts	I_{DRM} µAmps	I_S mAmps	I_T Amps*	I_H mAmps	C_O pF
P1900ME	140	220	5	5	800	2	50	750
P2300ME	180	260	5	5	800	2	50	750

* I_T is a free air rating; heat sink I_T rating is 25A.

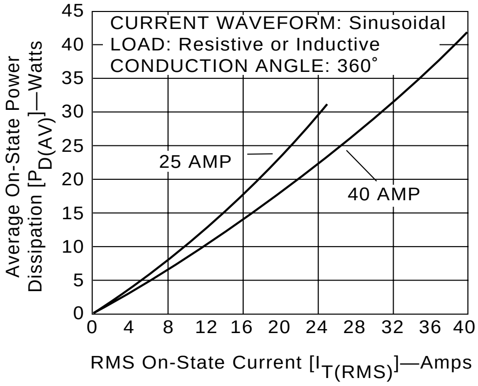
Notes:

- All measurements are made at an ambient temperature of 25°C. I_{PP} applies to -40°C through +85°C temperature range.
- I_{PP} is a repetitive surge rating and is guaranteed for the life of the product.
- Listed SIDACtors are bi-directional. All electrical parameters & surge ratings apply to forward and reverse polarities.
- V_{DRM} is measured at I_{DRM}.
- V_S is measured at 100V/µs.
- Special voltage (V_S & V_{DRM}) and holding current (I_H) requirements are available upon request.
- Off-state capacitance is measured at 1MHz with a 2 volt bias and is a typical value.

Surge Ratings

Series	I_{PP} 8x20µs	I_{TSM} 60Hz	dI/dt Amps/µs
P1900ME	3000	400	500
P2300ME	3000	400	500

Power Dissipation (Typical) vs On-State Current (25 and 40 Amp Devices)

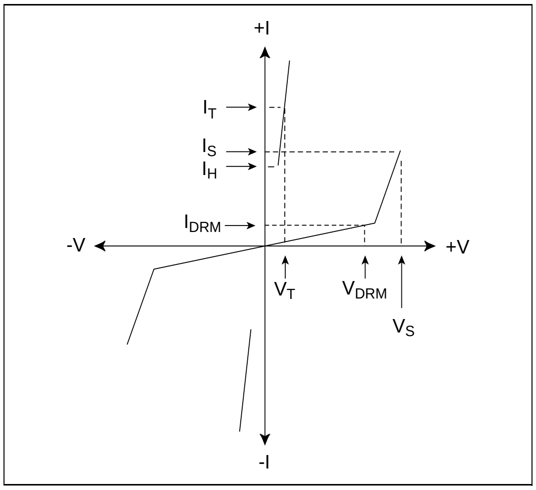


Thermal Considerations

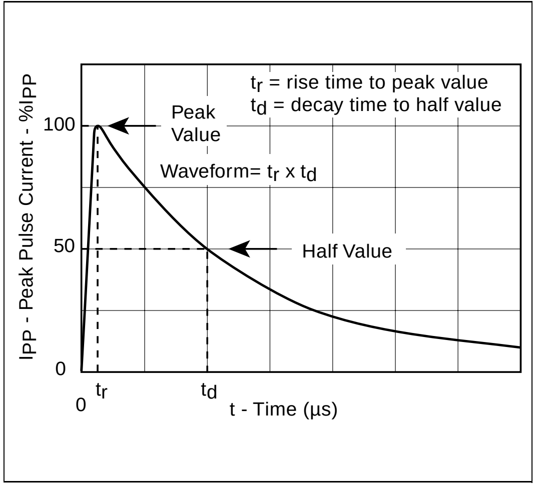
Package	Symbol	Parameter	Value	Unit
P1900ME	T_j	Junction Temperature Range	-40 to +150	°C
	T_S	Storage Temperature Range	-65 to +150	°C
	T_c	Maximum Case Temperature	+80	°C
	$R_{\theta jc}$*****	Thermal Resistance: junction to case	+2.8	°C/W
	$R_{\theta ja}$	Thermal Resistance: junction to ambient	+60	°C/W

* $R_{\theta jc}$ rating assumes heat sinking is employed.

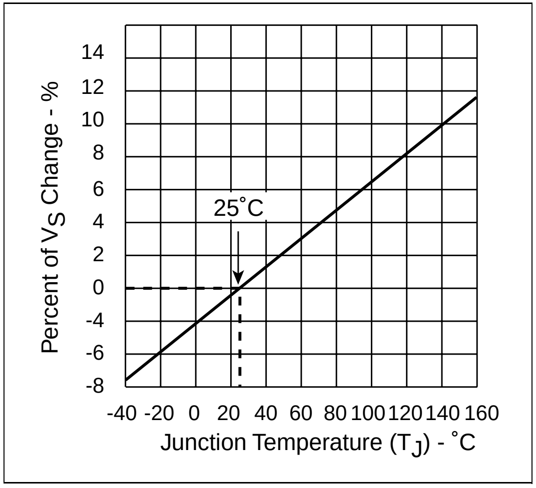
V-I Characteristics



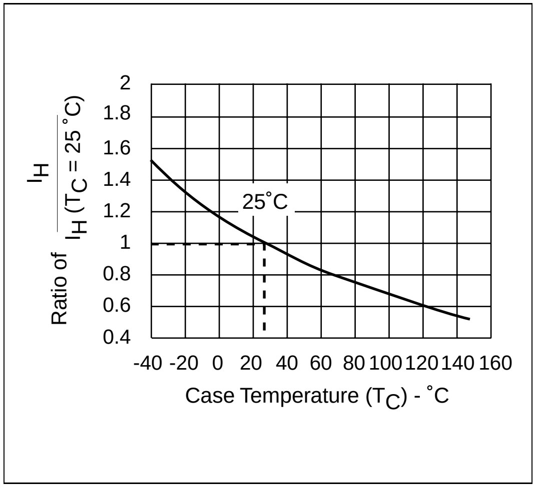
$t_r x t_d$ Pulse Wave-form



Normalized V_S Change vs. Junction Temperature



Normalized DC Holding Current vs. Case Temperature



3 Reference Designs

This section is intended to offer specific examples of how the SIDACtor can be used by manufacturers to ensure their equipment provides long term operability and uninterrupted service during transient electrical activity. For additional line interface protection circuits, refer to Regulatory Compliant Solutions beginning on page 4-37.

NOTES:

The circuits referenced in this section represent typical interfaces used in telecommunications equipment. The SIDACtor is not the sole component that is required to pass applicable regulatory requirements such as UL 1950, UL 1459, GR 1089 or FCC Part 68 requirements nor are these requirements specifically directed at the SIDACtor.

The SIDACtor as a component is recognized under UL497B

Customer Premises Equipment (CPE)

Overview

CPE is defined as any telephone terminal equipment which resides at the customers site and is connected to the public switched telephone network (PSTN). Telephones, modems, caller ID adjunct boxes, PBX's and answering machines are all considered CPE.

Protection Requirements

CPE should be protected against over-voltages that can exceed 800V and surge currents up to 100A. In Figures 3-1 through 3-5, the SIDACtor was chosen because the associated peak pulse current (I_{PP}) is great enough to withstand the lightning immunity test of FCC Part 68 without the additional use of series line impedance. Likewise, the fuse in Figures 3-1 through 3-5 was chosen because the amps^{2}time (I^2t) rating is large enough to withstand the lightning immunity tests of FCC Part 68, but small enough to pass UL power cross conditions.

Applicable Regulatory Requirements

- FCC Part 68
- UL 1459
- UL 1950

All CPE that is intended for connection to the PSTN must be registered in compliance with FCC Part 68. Also, because the National Electric Code mandates that "equipment intended for connection to the telephone network be listed for that purpose", consideration should be given to certifying equipment with an approved safety lab such as Underwriters Laboratories.

CPE Reference Circuits

Figures 3-1 through 3-5 are examples of interface circuits which meet all applicable regulatory requirements for CPE. The P3100SB and P3100EB are used in these circuits because the peak off-state voltage (V_{DRM}) is greater than the potential of a Type B ringer superimposed on a POTS (plain old telephone service) battery.

$$150V_{RMS}\sqrt{2} + 56.6Vpk = 268.8Vpk$$

It should be noted that the circuits shown in Figures 3-1 through 3-5 provide an operational solution for FCC Part 68, however FCC Part 68 allows CPE designs to pass non-operationally as well.

For a non-operational solution, the I_{PP} rating of the SIDACtor and the I^2t rating of the fuse should be coordinated such that both will withstand the Type B surge, but during the Type A surge, the fuse will open (Table 5-1, Fuse Selection Criteria).

Note: For alternative line interface protection circuits, please refer to Regulatory Requirements and Regulatory Compliant Solutions.

Figure 3-1 Basic CPE Interface

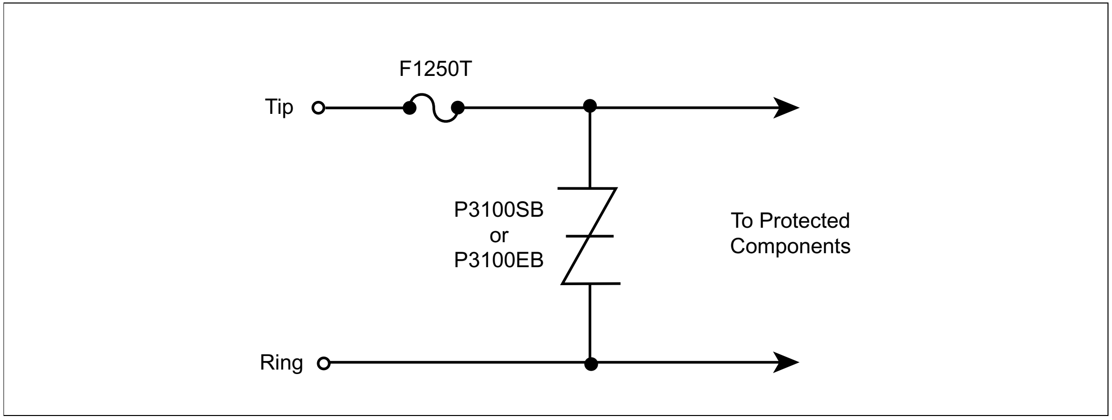


Figure 3-2 Transformer Coupled Tip and Ring Interface

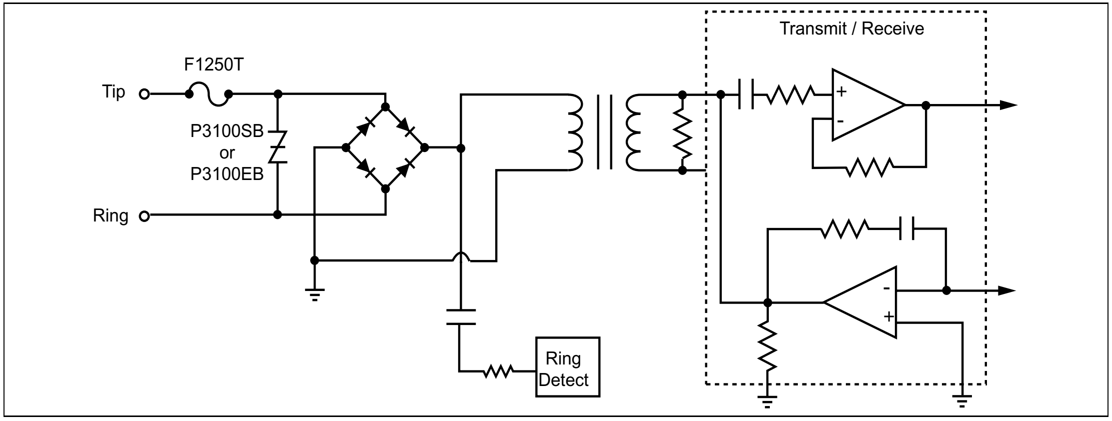


Figure 3-3 Modem Interface

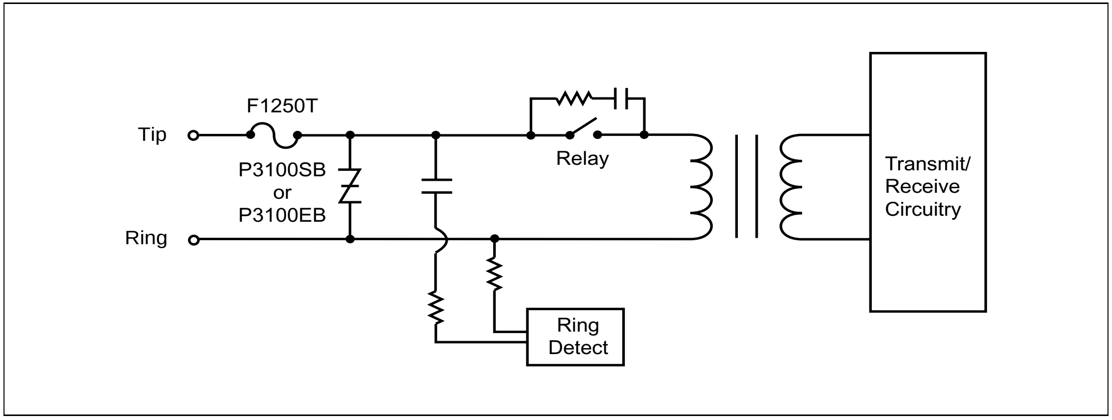


Figure 3-4 CPE Transistor Network Interface - Option 1

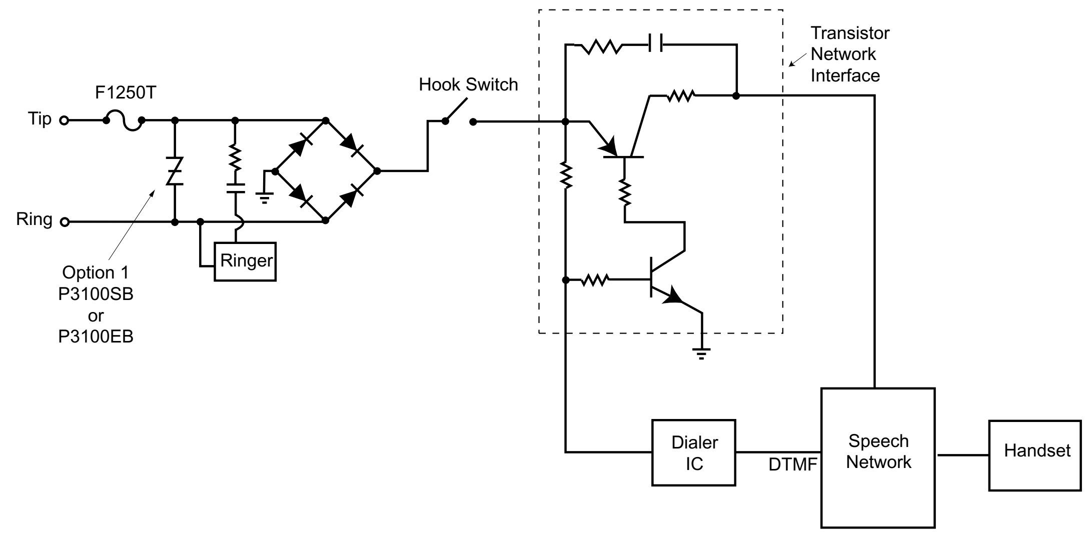


Figure 3-5 CPE Transistor Network Interface - Option 2

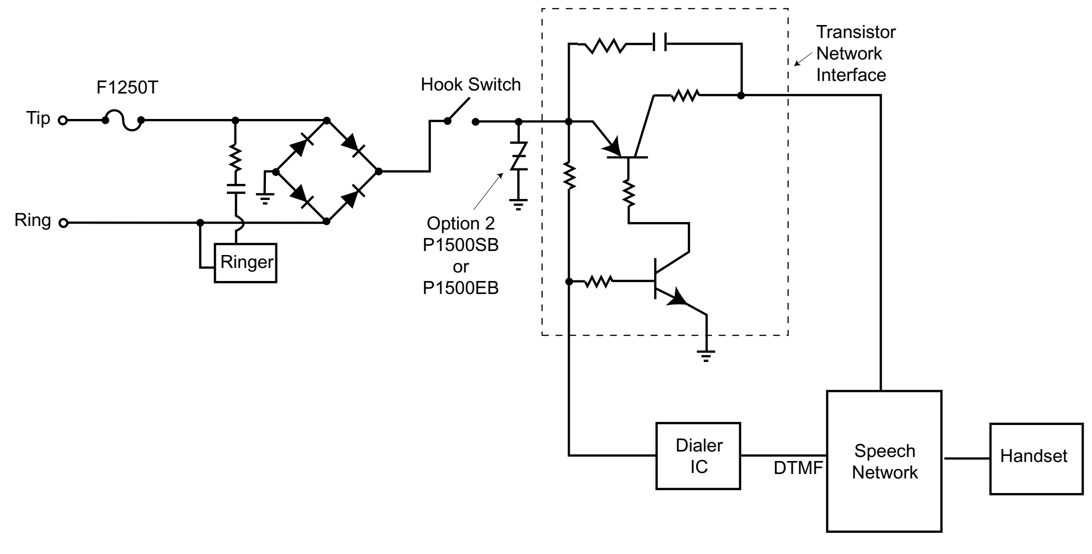
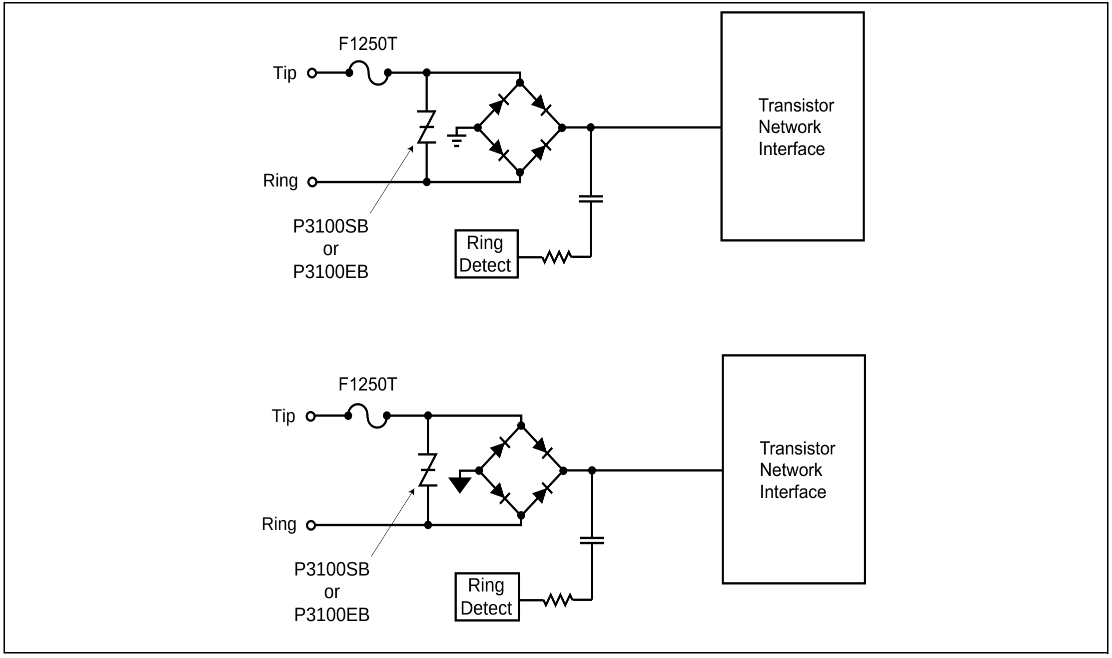


Figure 3-6 Two line CPE Interface



Digital Transmission Equipment

Overview

Digital transmission equipment encompasses a broad range of transmission protocols such as T1/E1, xDSL, and ISDN. Digital transmission equipment is located at the central office, customer premises, and remote locations.

Protection Requirements

Digital transmission equipment should be protected against over-voltages that can exceed 2500V and surge currents up to 500A. In Figures 3-7 through 3-17, the SIDACtor was chosen because the associated peak pulse current (I_{PP}) is great enough to withstand the lightning immunity tests of GR 1089 without the additional use of series line impedance. Likewise, the fuse in Figures 3-7 through 3-17 was chosen because the amps^{2}time (I^2t) rating is large enough to withstand the lightning immunity tests of GR 1089, but small enough to pass GR 1089 current limiting protector test and power cross conditions.

Applicable Regulatory Requirements

- FCC Part 68
- GR 1089-CORE
- ITU-T K.20
- UL 1459
- UL 1950

Most transmission equipment sold in the US must adhere to GR 1089. For Europe and other regions, ITU-T K.20 is typically the recognized standard.

ADSL/CDSL Circuit Protection

Asymmetric Digital Subscriber Lines (ADSL) and Consumer Digital Subscriber Lines (CDSL) employ an asymmetic digital line technology (Figure 3-7). This technology employs a transmission rate up to 6.144 Mbps from the Central Office Terminal (COT) to the Remote Terminal (RT) and a 640 kbps transmission rate from the RT to the COT at distances up to 12,000 feet. Currently ANSI T1.413 specifies a maximum ring voltage of $103V_{RMS}$ and a boosted battery of $60V_{DC}$, however this is subject to change.

Protection Circuitry

In Figure 3-8, longitudinal protection was not used at either the ATU-C interface or the ATU-R interface due to the absence of earth ground connections. In both instances, metallic protection is accomplished using the P3500SC SIDACtor and F1250T TeleLink. For ATU's not isolated from earth ground, please reference the HDSL protection topology.

Component Selection

The P3500SC SIDACtor and F1250T TeleLink were chosen to protect the ATU's because both components meet GR 1089 surge immunity requirements without the use of additional series resistance. Furthermore, although the P3100 series SIDACtor may be used to meet current ANSI specifications, Teccor recommends the P3500 series to ensure compliance with a $150V_{RMS}$ ringing signal superimposed on a $105V_{DC}$ boosted battery.

Figure 3-7 ADSL Overview

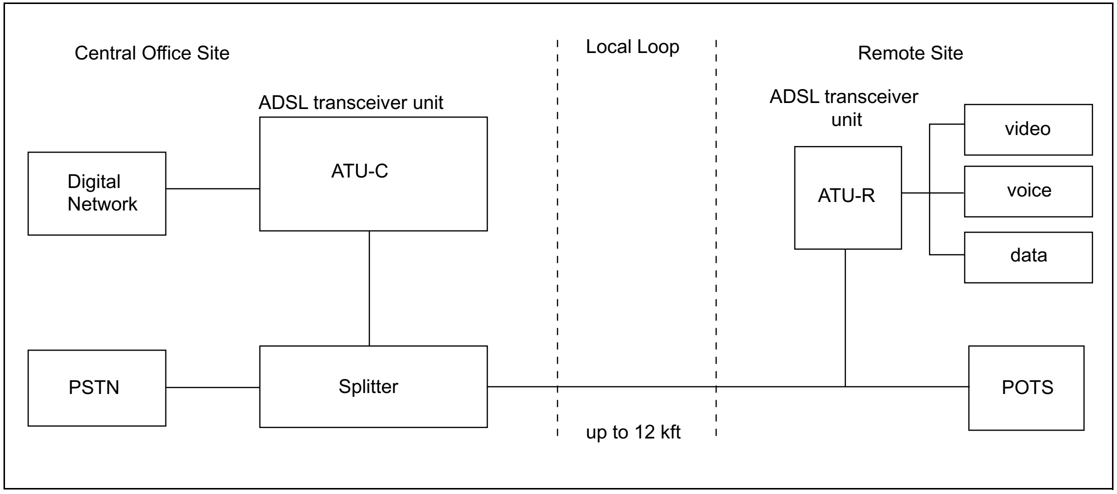
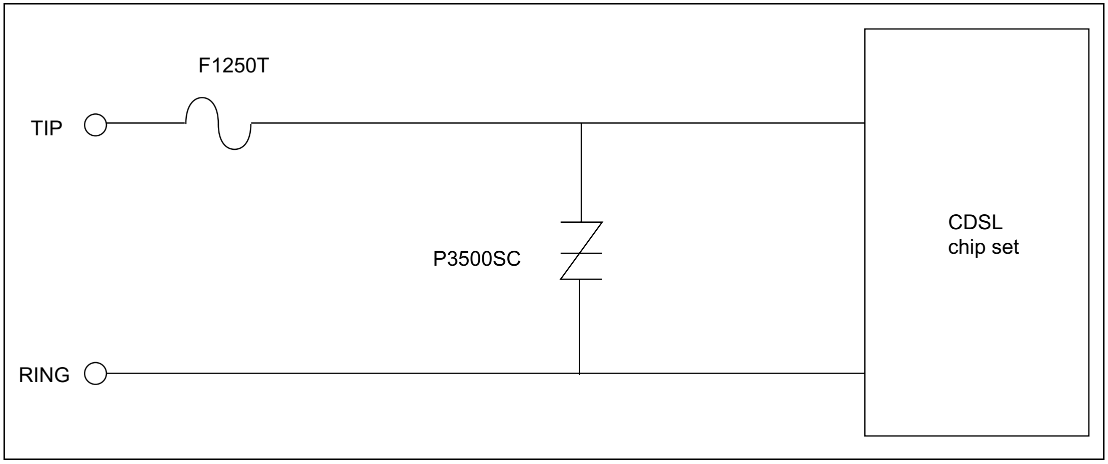


Figure 3-8 CDSL Protection



HDSL Circuit Protection

High Bit Digital Subscriber Lines (HDSL) employ a digital line technology that utilizes a 1.544 Mbps (T-1 equivalent) transmission rate for distances up to 12,000 feet, eliminating the need for repeaters. The signaling levels are a maximum of +/- 2.5V while loop powering is typically under 190V.

Protection Circuitry

Longitudinal protection is required at both of the HTU-C and HTU-R interfaces because of the ground connection used with loop powering. In Figure 3-10, this is accomplished using two P2300SC SIDACtor's for over voltage protection and two F1250T TeleLink fuses (one on TIP, one on RING) for over current protection. For the transceiver side of the coupling transformer, additional over voltage protection is shown using the P0080SA SIDACtor.

Component Selection

The P2300SC SIDACtor and the F1250 TeleLink were chosen because both components meet GR 1089 surge immunity requirements without the use of additional series resistance. The P2300SC voltage rating was selected to ensure loop powering up to 180V. For loop powering greater than 180V, the P2600SC should be considered. The P0080SA SIDACtor was chosen to eliminate any sneak voltages that may appear below the voltage rating of the P2300SC.

Figure 3-9 HDSL Overview

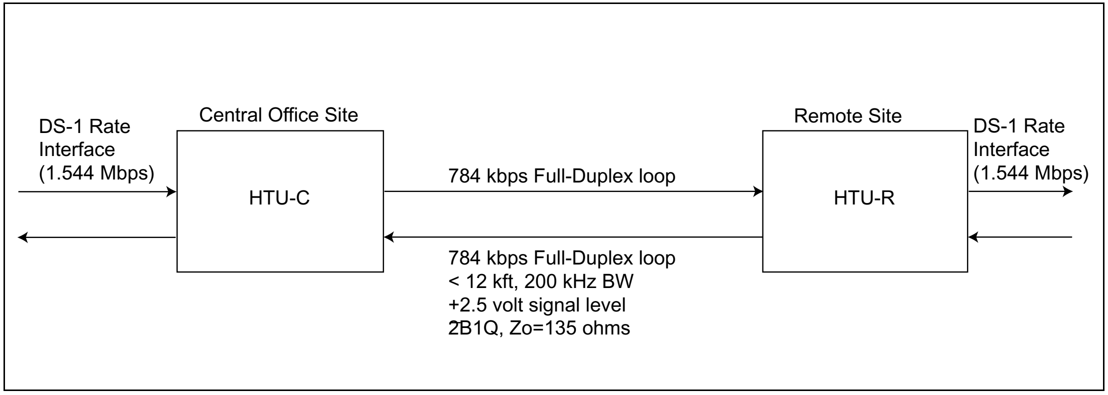
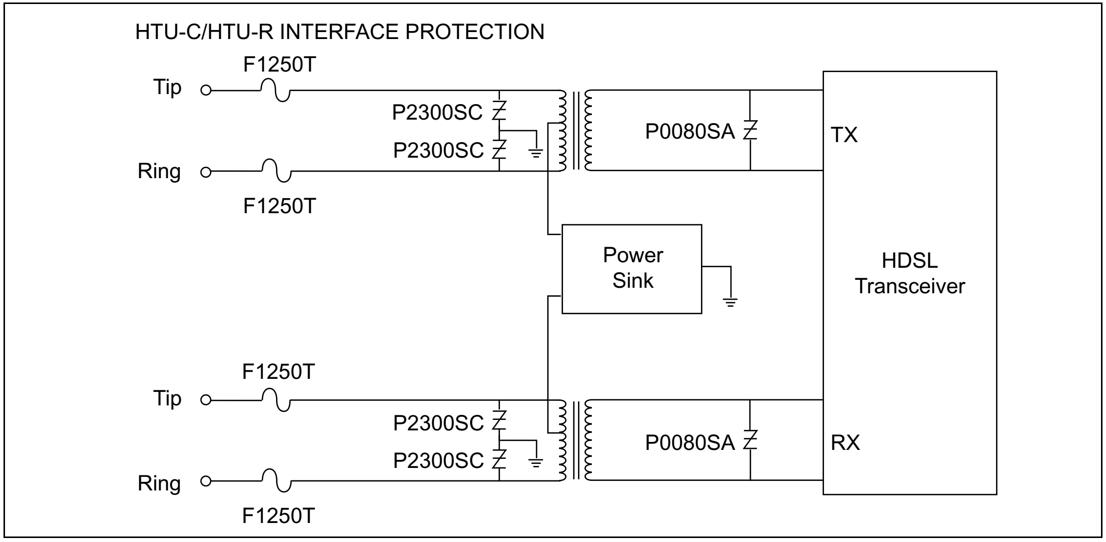


Figure 3-10 HDSL Protection



ISDN Circuit Protection

Integrated Services Digital Network (ISDN) circuits require protection at the NT1 U-interface and at the Terminating Equipment (TE) and/or Terminating Adapter (TA) S/T interface. Signal levels at the U interface are typically +/-2.5V, but with sealing currents and Maintenance Loop Test (MLT) procedures, voltages approaching $150V_{RMS}$ can occur.

Protection Circuitry

In Figure 3-12, longitudinal protection was not used at either the U or the TA/TE interface due to the absence of an earth to ground connection. At the U interface, metallic protection is accomplished using the P2600SC SIDACtor and F1250T TeleLink while the TA/TE interface uses the P0640SC SIDACtor and F1250T TeleLink. For interfaces not isolated from earth ground, please reference the HDSL protection topology.

Component Selection

The “SC” SIDACtors and F1250T TeleLink were chosen because these components meet GR 1089 surge immunity requirements without the use of additional series resistance. The P2600SC voltage rating was selected to ensure coordination with MLT voltages that can approach $150V_{RMS}$. The voltage rating of the P0640SC was selected to ensure coordination with varying signal voltages.

Figure 3-11 ISDN Overview

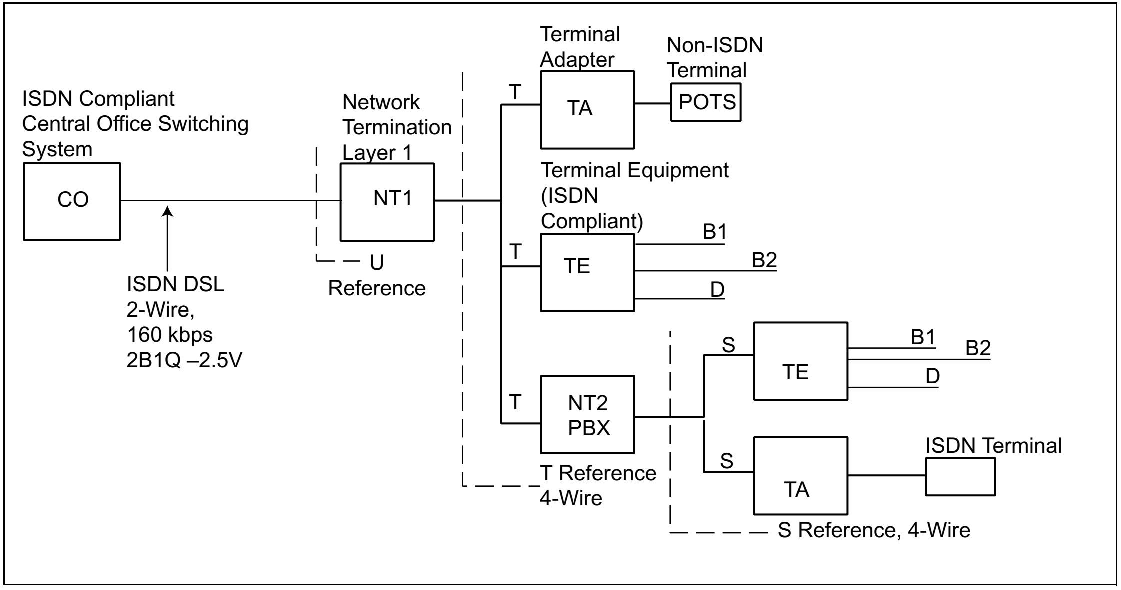
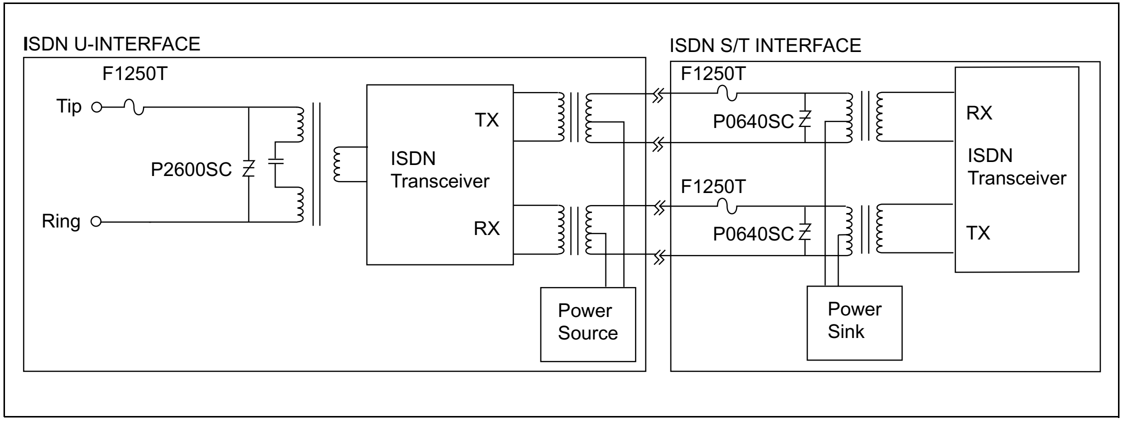


Figure 3-12 ISDN Protection



Pair Gain Circuit Protection

A digital pair gain system differs from an ISDN circuit in that ring detection, ring trip, ring forward, and off hook detection are carried within the 64 kbps bit stream for each channel rather than using a separate D channel. The pair gain system also uses loop powering from 10V up to 145V with a typical maximum current of 75mA.

Protection Circuitry

In Figure 3-14, longitudinal protection is required at the Central Office Terminal (COT) interface because of the ground connection used with loop powering. This is accomplished using two P1800SC SIDACtor's for over voltage protection and two F1250T TeleLink fuses (one on TIP, one on RING) for over current protection. For the U-interface side of the coupling transformer, additional over voltage protection is shown using the P0080SA SIDACtor.

For the Customer Premises (CP) and the Remote Terminal (RT) interfaces where an earth ground connection is not utilized, only metallic protection is required. Figure 3-15 shows metallic protection being satisfied using a single P3100SC across TIP and RING and a single F1250T on either Tip or Ring.

Component Selection

The "SC" SIDACtor and F1250T TeleLink were chosen because both components meet GR 1089 surge immunity requirements without the use of additional series resistance. The voltage rating of the P1800SC was selected to ensure coordination with loop powering up to 150V. The voltage rating of the P3100SC was selected to ensure coordination with POTS ringing and battery voltages.

Figure 3-13 Pair Gain Overview

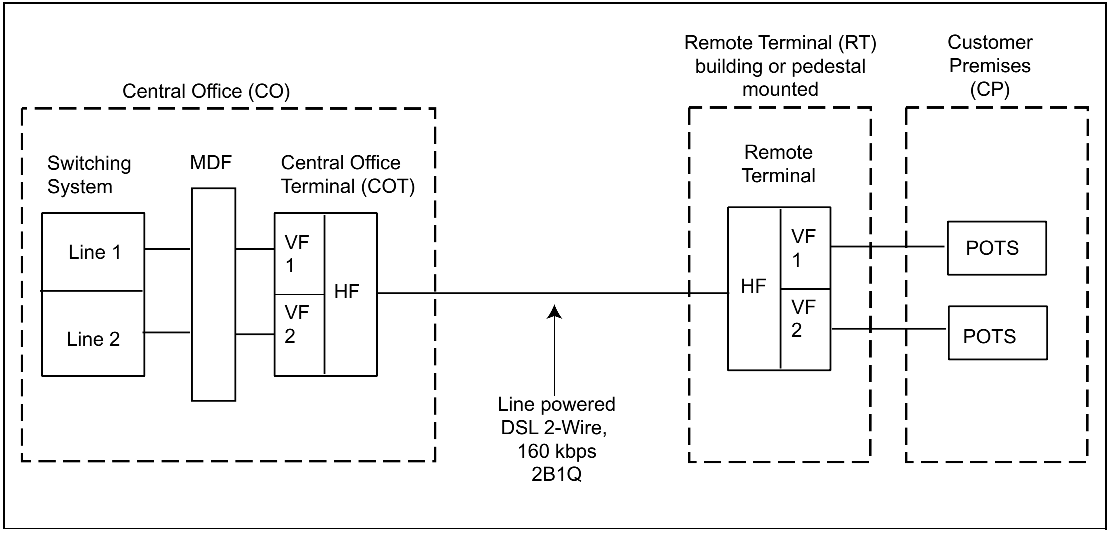


Figure 3-14 Pair Gain COT Protection

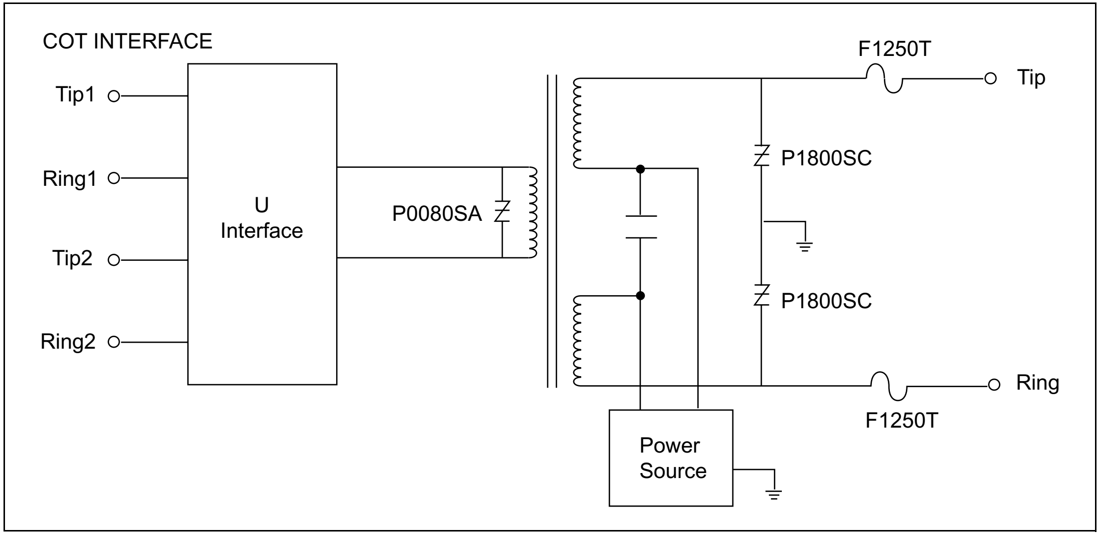
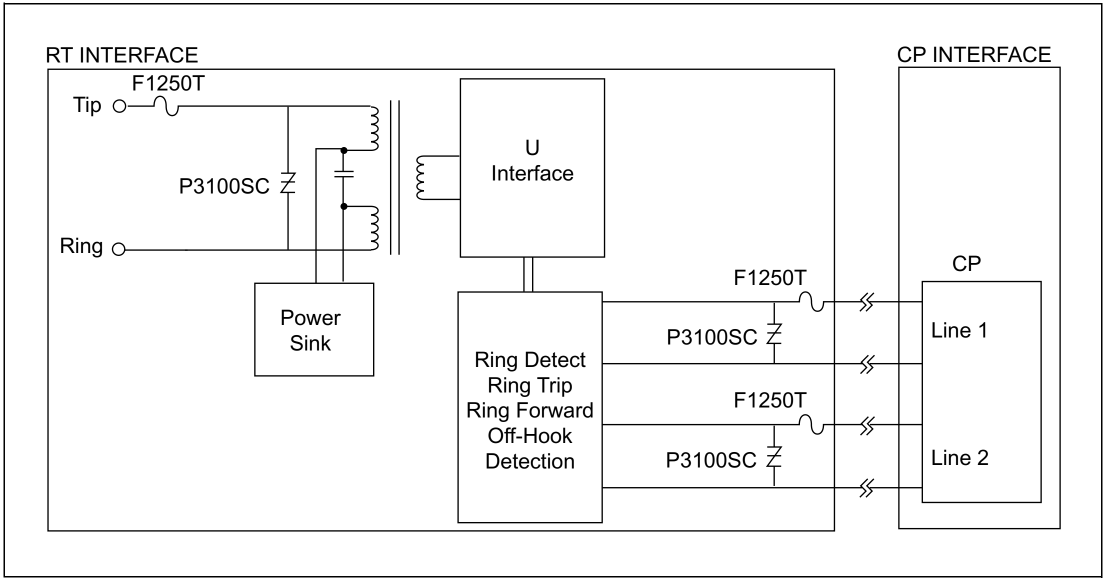


Figure 3-15 Pair Gain RT Protection



T-1/E-1 Circuit Protection

T-1/E-1 networks offer data rates up to 1.544 Mbps (2.058 for E-1) on a four wire system. Signal levels on the TX pair are typically between 2.4V and 3.6V while the RX pair could go as high as 12V. Loop powering is typically +/-130V at 60mA, although some systems can go as high as 150V.

Protection Circuitry

In Figure 3-17, longitudinal protection is required at the Central Office Terminal (COT) interface because of the ground connection used with loop powering. This is accomplished using two P1800SC SIDACtor's for over voltage protection and two F1250T TeleLink fuses (one on TIP, one on RING) for over current protection. For the transceiver side of the coupling transformer, additional over voltage protection is shown using the P0300SA SIDACtor. For the regenerator where an earth ground connection is not utilized, only metallic protection is required. Metallic protection is satisfied using a single P0640SC SIDACtor across TIP and RING and a single F1250T TeleLink on either Tip or Ring.

Component Selection

The "SC" SIDACtor and F1250T TeleLink were chosen because these components meet GR 1089 surge immunity requirements without the use of additional series resistance. The voltage rating of the P1800SC was selected to ensure loop powering up to 150V. The voltage rating of the P0640SC was selected to ensure coordination with varying voltage signals.

Figure 3-16 T-1/E-1 Overview

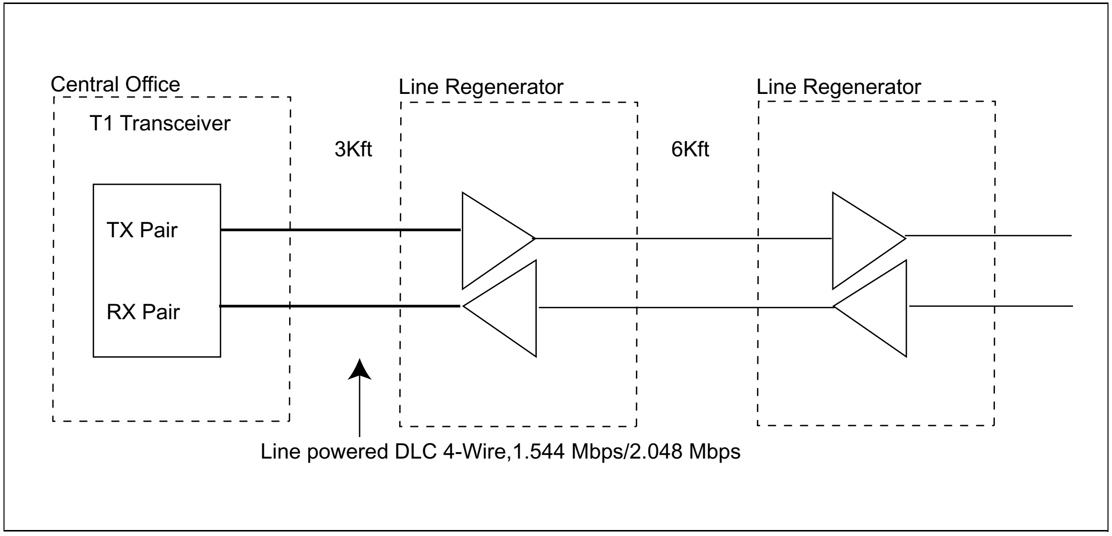
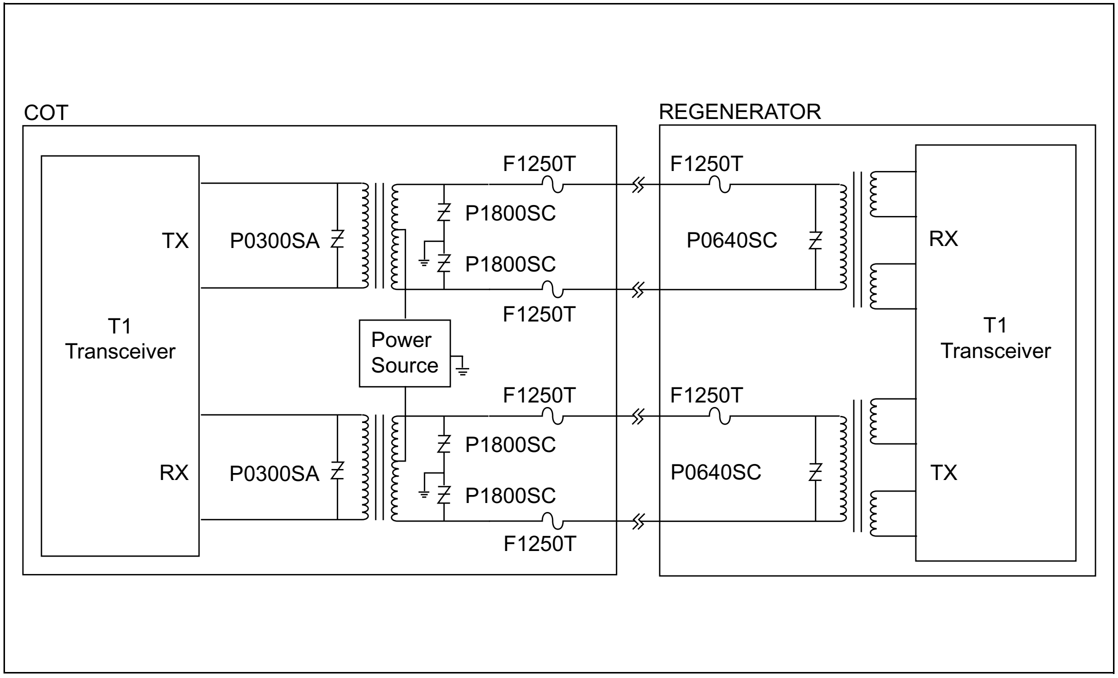


Figure 3-17 T-1/E-1 Protection



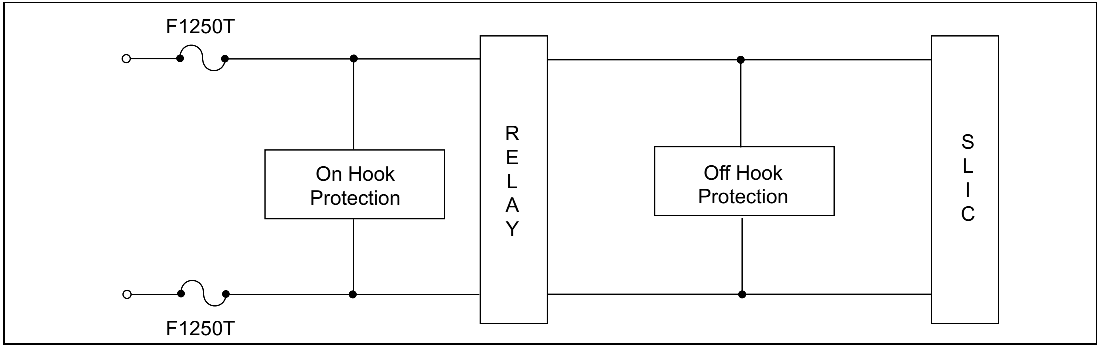
Analog Line Cards

Because line cards are highly susceptible to transient voltages, network hazards such as lightning and power cross conditions pose a serious threat to equipment deployed at the central office and in remote switching locations. To minimize this threat, adequate levels of protection must be designed to ensure reliable operation and regulatory compliance.

Protection Requirements

When designing over voltage protection for analog line cards, it is often necessary to provide both on-hook (relay) and off-hook (SLIC) protection. Figure 3-18 shows this being accomplished in two stages.

Figure 3-18 SLIC Overview



Applicable Regulatory Requirements

- GR 1089-CORE
- UL 1459
- ITU-T K.20
- UL 1950
- FCC Part 68

On-Hook (Relay) Protection

On-hook protection is accomplished by choosing a SIDACtor that meets the following criteria to ensure proper coordination between the ring voltage and the maximum voltage rating of the relay to be protected.

$V_{DRM} > V_{BATT} + V_{RING}$

$V_S \leq V_{\text{Relay Breakdown}}$

This criterion is typically accomplished using two P2600S_ (where _ denotes the surge current rating) SIDACtors connected from TIP to GND and RING to GND. However those who choose to use relays such as Lucent's LCAS (Line Card Access Switch) should consider the P1200S_ from TIP to GND and the P2000S_ from RING to GND.

Off-Hook (SLIC) Protection

Off-hook protection is accomplished by choosing a SIDACtor that meets the following criteria to ensure proper coordination between the supply voltage (V_{REF}) and the maximum voltage rating of the SLIC to be protected.

$V_{DRM} > V_{REF}$

$V_S \leq V_{\text{SLIC Breakdown}}$

This criterion can be accomplished a variety of different ways. For applications that use an external ring generator and a fixed battery voltage, two P0641S_ (or P0721S_ depending on the value of V_{REF}) SIDACtors are used; one TIP to GND, one RING to GND. For applications that use a ring generating SLIC such as AMD's Am79R79, the P11xx0C_ can be used.

I_{PP} Selection

To ensure the proper surge current rating of the SIDACtor is selected, the I_{PP} of the SIDACtor must be greater than or equal to the maximum available surge current ($I_{PK(available)}$) of the applicable regulatory requirements. The maximum available surge current is calculated by dividing the peak surge voltage supplied by the voltage generator (V_{PK}) by the total circuit resistance (R_{TOTAL}). The total circuit resistance is determined by adding the source resistance (R_S) of the surge generator to the series resistance that is in front of the SIDACtor on both TIP and RING (R_{TIP} and R_{RING}).

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

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

For metallic surges:

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

For longitudinal surges:

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

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

Reference Designs

Reference Diagrams

Figure 3-19 uses Teccor's "C" rated SIDACtors and the F1250T TeleLink fuse to meet the surge immunity requirements of Bellcore 1089. On-hook protection is accomplished using Teccor's P1200SC and P200SC which were specifically designed to protect Lucent Microelectronics Line Card Access Switch (LCAS). Off-hook protection is accomplished using two P0641SC's. Note the absence of any additional series resistance. This is because the "C" series SIDACtor and F1250T TeleLink were designed to withstand GR 1089 without the aid of additional components such as line feed resistors and PTC's.

Figure 3-20 uses the P2600SA and P0721SA for over voltage protection and the F0500T for over current protection in addition to 20Ω of series resistance on both TIP and RING. The series resistance is required to limit the transient surge currents to within the surge current rating of the "A" series SIDACtors and the F0500T TeleLink fuse.

Figure 3-21 uses Teccor's Battrax to protect AMD's Am79R79 from over-voltages and the F1250T to protect against sustained power cross conditions. The Battrax was designed specifically to protect SLIC's that can not withstand potential differences greater than V_{REF} ±10V.

Figure 3-22 shows how to protect a SLIC by utilizing 20Ω series resistors on both TIP and RING in addition to Teccor's Battrax (B1100CC) and a diode bridge (General Semiconductor p/n EDF1BS). However, the overshoot caused by the diode bridge must be considered. The series resistance (a minimum of 20Ω on TIP and 20Ω on RING) limits the 100A simultaneous surge current from TIP to GND and RING to GND (200A total) to within the surge current rating of the SIDACtor and Battrax. The diode bridge shunts all positive voltages to GND and the B1100CC shunts all negative voltages greater than $|-V_{REF} - 1.2V|$ to GND.

Some applications may require the use of 50Ω line feed resistors. In this instance, **Figure 3-23** shows how to replace multiple SLIC protectors using one B1160CC and two EDF1BS diode bridges. The overshoot caused by the diode bridge must be considered. The only caution in such an approach with regards to the Battrax is that it is imperative that the sum of the loop currents does not exceed the Battrax's holding current. In **Figure 3-23**, the loop current would have to be limited to 80mA. For applications that would require 4 twisted pair to be protected with one Battrax, the B1200CC should be used and the loop current would have to be limited to 50mA.

Figure 3-19 SLIC Protection

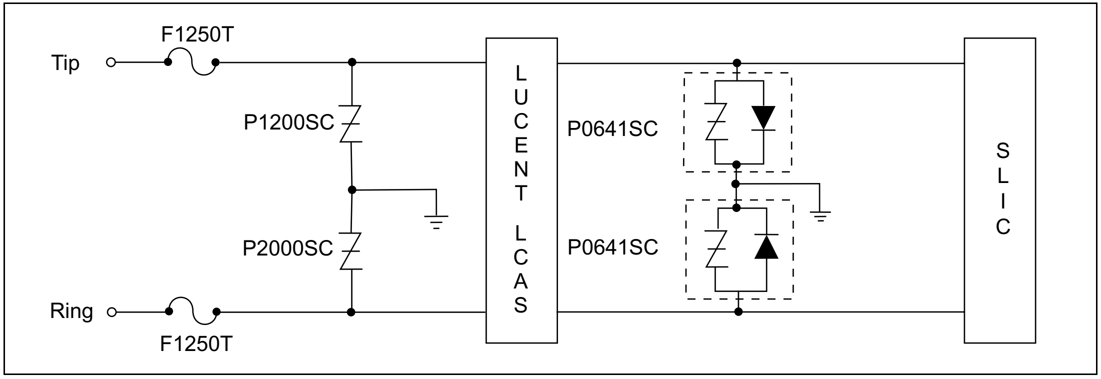


Figure 3-20 SLIC Protection

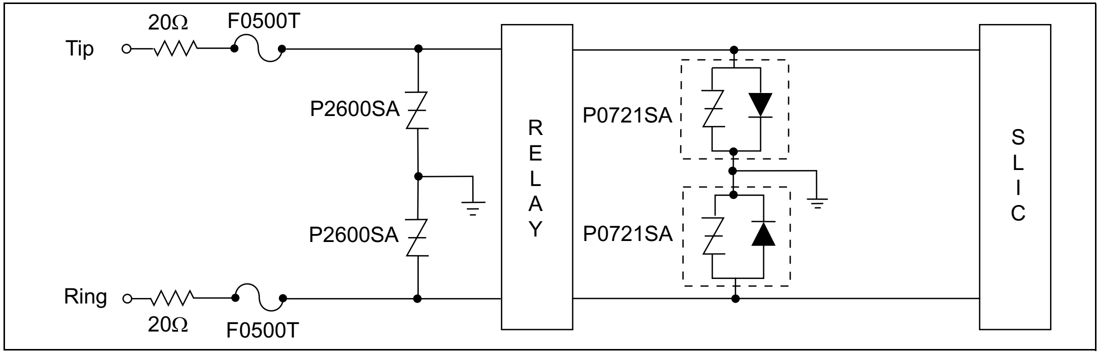


Figure 3-21 SLIC Protection

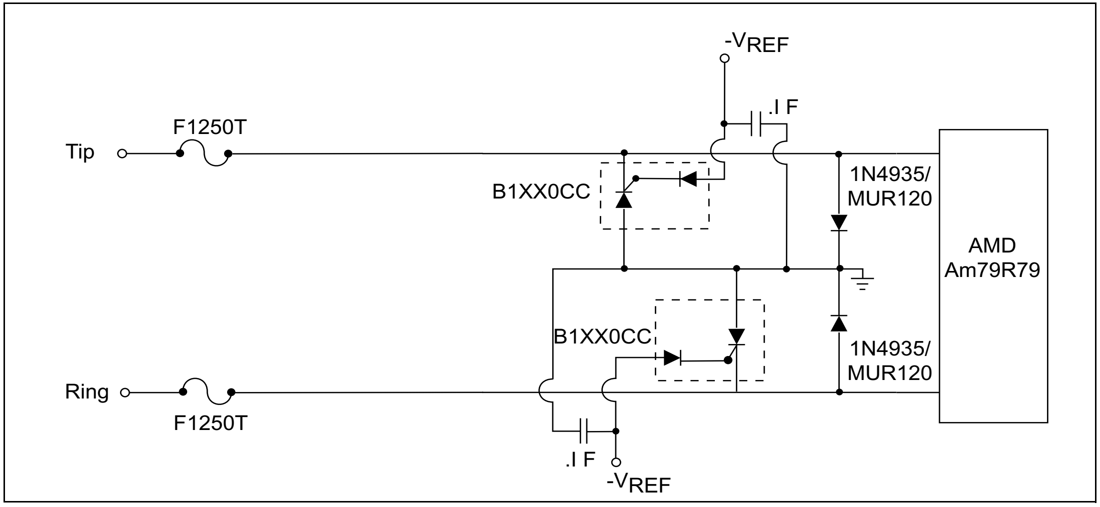


Figure 3-22 SLIC Protection

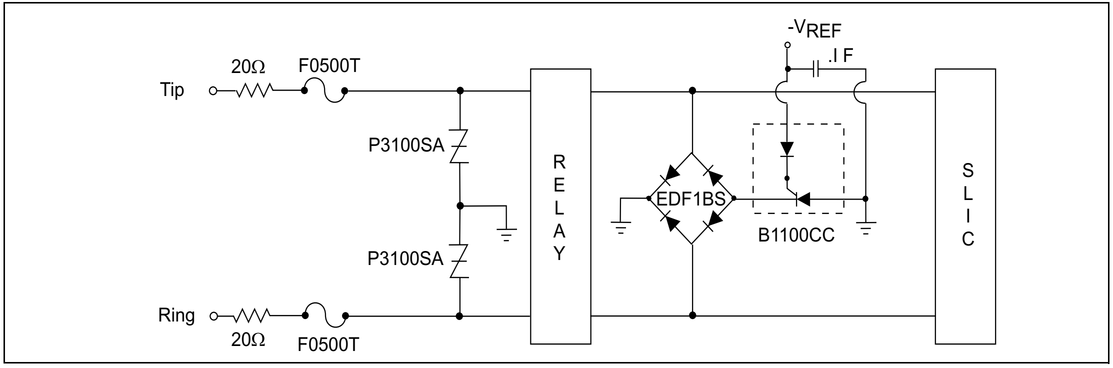
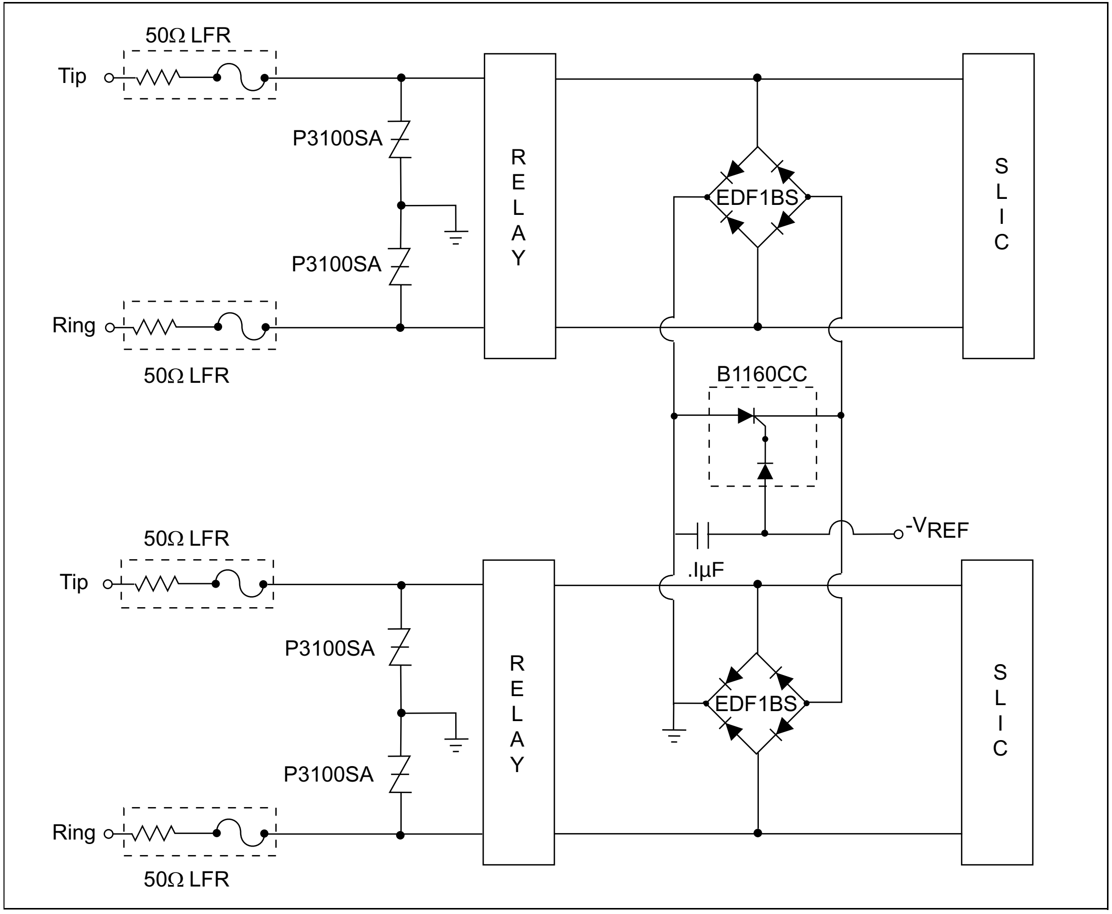


Figure 3-23 SLIC Protection



PBX Systems

Branch Exchange Switches

PBX's, KSU's, and PABX's contain line cards that support various transmission protocols such as ISDN, T1/E1, HDSL, and ADSL (Figure 3-24). PBXs also have features such as a POTS (plain old telephone service) pull through which allows stations to have outside line access in the event of power failure. All incoming lines to the PBX are subject to environmental hazards such as lightning and power cross.

Protection Requirements

Branch exchange switches should be protected against over-voltages that can exceed 800V and surge currents of up to 100A.

Applicable Regulatory Requirements

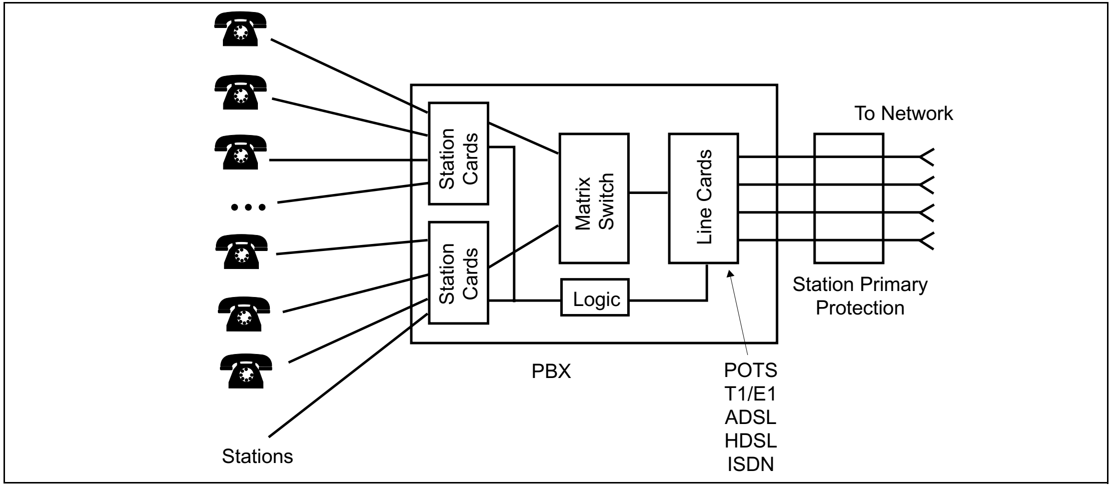
- FCC Part 68
- UL 1459
- UL 1950

Branch Exchange Reference Circuit

The following sections contain interface circuits used for protection of PBX line cards.

- For POTS protection see pages 3-3 through 3-6.
- For ADSL/CDSL protection see page 3-8
- For HDSL protection see page 3-10.
- For ISDN protection see page 3-12.
- For T1/E1 protection see page 3-16.
- For Station Protection see pages 3-19 through 3-23.

Figure 3-24 PBX Overview



CATV Equipment

As cable providers enter the local exchange market, protection of CATV equipment becomes even more critical in order to ensure reliable operation of equipment and uninterrupted service.

Protection Requirements

CATV line equipment should be able to withstand over-voltages that exceed 6000V and surge currents of up to 3000A. CATV station protectors should be able to withstand over-voltages that exceed 5000V and surge currents of up to 1000A. The SIDACtors chosen in Figures 3-25 through 3-28 meet these requirements.

Applicable Regulatory Requirements

- UL 497C
- SCTE IPS-SP-204
- SCTE Practices
- NEC Article 830

Power Inserter and Line Amplifier Reference Circuit

Figures 3-25 & 3-26 show how the P1900ME SIDACtor is used to protect line amplifiers and power supplies versus using Teccor's patented circuit that requires two SCRs and one SIDACtor (Figure 3-27). The P1900ME is used because the peak off-state voltage (V_{DRM}) is well above the peak voltage of the CATV power supply ($90V_{RMS}\sqrt{2}$) and the peak pulse current rating (I_{PP}) is 3000A.

Figure 3-25 CATV Amplifier Diagram

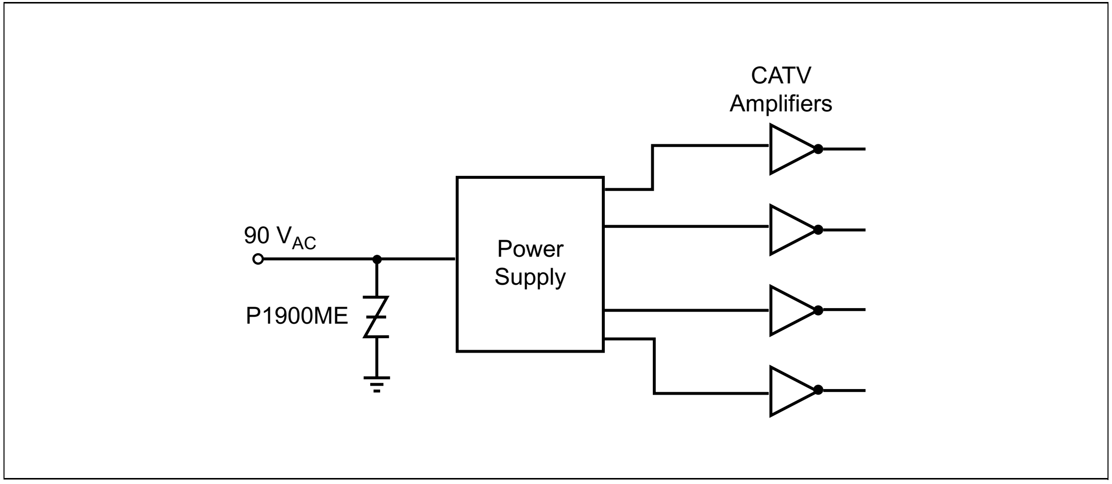


Figure 3-26 CATV Amplifier Protection (incorporated into a power inserter module)

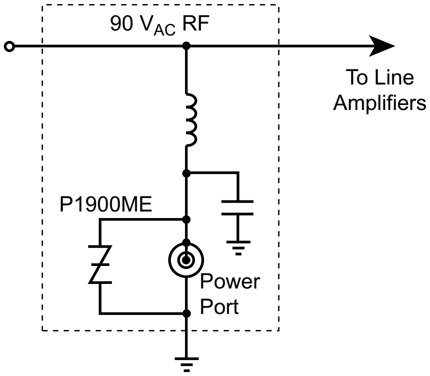
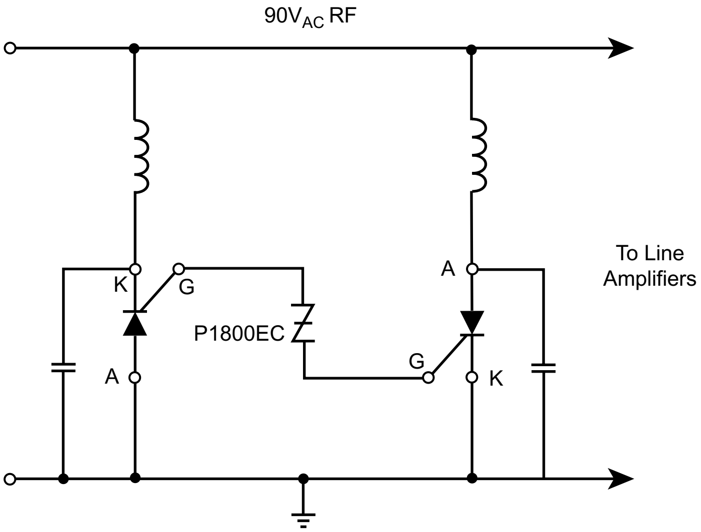


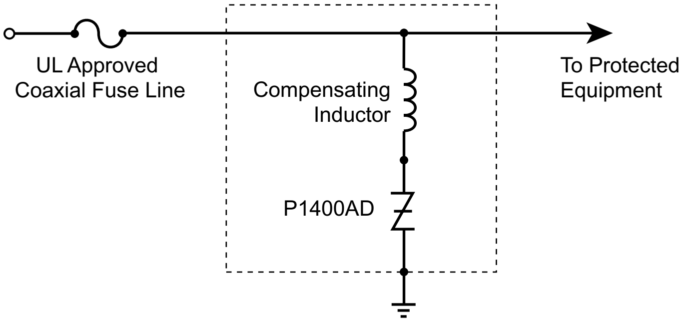
Figure 3-27 CATV Amplifier Protection



Station Protection Reference Circuit

Figure 3-28 shows a P1400MD SIDACtor used in a CATV station protection application. Note that a compensation inductor may be required to meet insertion and reflection loss requirements for CATV networks. If so, the inductor should be designed to saturate quickly and withstand surges of up to 200V and 1000A. An inductor with a core permeability of approximately 900 and wound with 24 gauge wire to an inductance of 20 to 30 µH is an example of a suitable starting point, but the actual value is design dependent and must be verified through laboratory testing.

Figure 3-28 CATV Station Protection



Primary Protection

Overview

Primary telecommunications protectors are required to be deployed at points where exposed twisted pairs enter an office building or residence. This requirement is mandated in North America by the National Electric Code (NEC) and is done so to protect end users from the hazards associated with lightning and power cross conditions.

Provided by the local exchange carrier, primary protection can be segregated into three distinct categories:

1. Station protection - typically associated with a single twisted pair.
2. Building entrance protection - typically associated with multiple (25 or more) twisted pair.
3. Central office protection - typically associated with numerous twisted pair feeding into a switch.

Station protectors provide primary protection for a single dwelling residence or office. The station protector is located at the network interface unit (NIU) which acts as the point of demarcation, separating the operating companies lines from the customer's.

Building entrance protection is accomplished by installing a multi-line distribution panel that has integrated over-voltage protection. These panels are normally located where multiple twisted pairs enter a building.

Central and remote office protection is accomplished using a 5-pin protection module which is plugged into a main distribution frame (MDF). Like station and building entrance protection, the MDF is located where exposed cables enter the switching office.

Protection Requirements

Station protectors should be able to withstand over-voltages that exceed 5000V and surge currents up to 250A. Building entrance and 5-pin module protectors should be able to withstand over-voltages that exceed 2500V and surge currents of up to 100A. The SIDACtors shown in Figures 3-29 & 3-30 meet these requirements.

Applicable Regulatory requirements

- UL 497
- GR 974-CORE
- ITU K.28

Primary Protection Reference Circuit

Figures 3-29 & 3-30 show different configurations used in primary protection. It should be noted that the peak off-state voltage (V_{DRM}) of any device intended to be used in primary protection applications should be greater than the potential of a Type B ringer superimposed on a POTS (plain old telephone service) battery.

$$150V_{RMS}\sqrt{2} + 56.6Vpk = 268.8Vpk$$

Figure 3-29 Asymmetrical Primary Protection

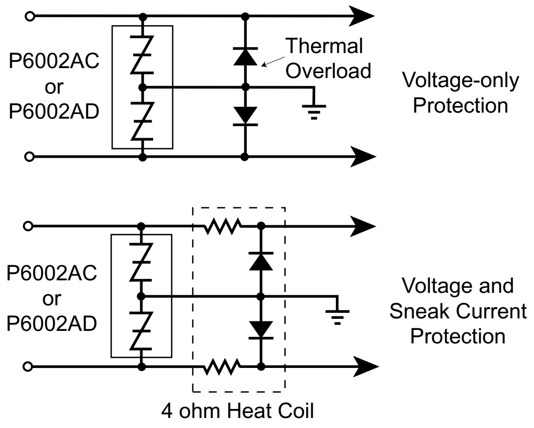
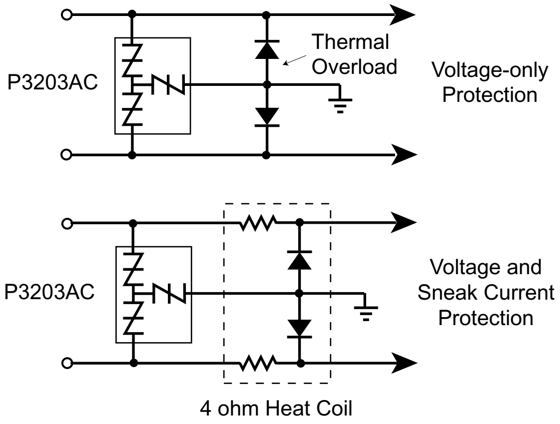


Figure 3-30 Symmetrical Primary Protection



Secondary Protection

Secondary Protectors

Secondary protectors are adjunct devices (they can be either stand alone units or integrated into strip protectors and UPS') used to enhance the protection level of customer premise equipment (CPE). Due to the inadequate level of protection being designed into CPE, secondary protectors are often required to help prevent premature failure of equipment that is exposed to environmental hazards (Figure 3-31).

Protection Requirements

Secondary protectors should be able to withstand over-voltages that can exceed 800V and surge currents of up to 100A. In Figure 3-32, the SIDACtor was chosen because the associated peak pulse current (I_{PP}) is great enough to withstand the lightning immunity tests of FCC Part 68 without the additional use of series line impedance. Likewise, the fuse in Figure 3-32 was chosen because the amps^{2}time (I^2t) rating is large enough to withstand the lightning immunity tests of FCC Part 68, but small enough to pass UL power cross conditions.

Applicable Regulatory Requirements

- UL 497A

Secondary Protection Reference Circuit

Figure 3-32 is an example of an interface design for a secondary protector. The P3203AB SIDACtor is used because the peak off-state voltage (V_{DRM}) is greater than the potential of a Type B ringer signal superimposed on the POTS (plain old telephone service) battery.

$$150V_{RMS}\sqrt{2} + 56.6Vpk = 268.8Vpk$$

Coordination between the station protector and the secondary protector occurs due to the line impedance between the two devices (Figure 3-31). The line impedance helps ensure that the primary protector will begin to conduct while the secondary protector limits any of the let through voltage to within the V_S rating of the SIDACtor.

Figure 3-31 CPE Secondary Protection

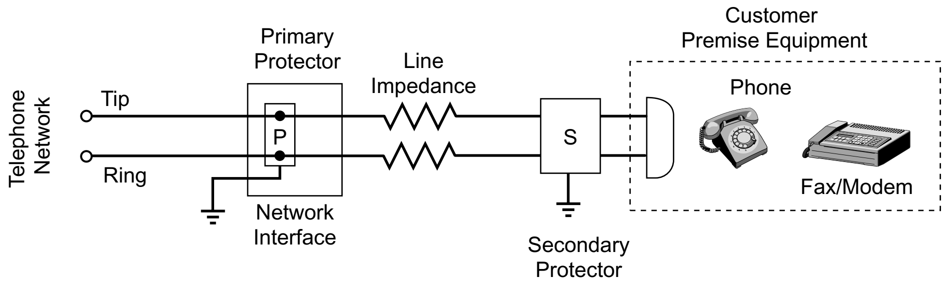
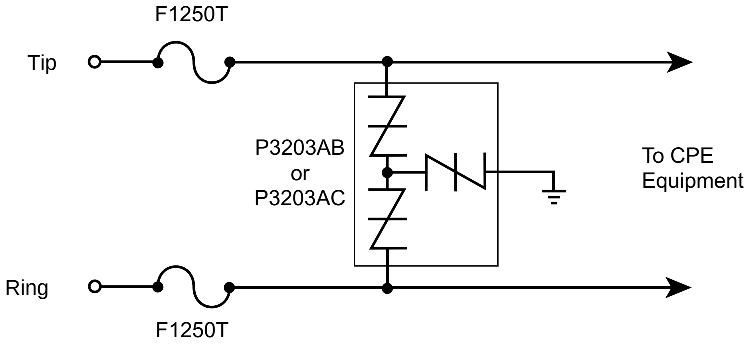


Figure 3-32 CPE Protection



Triac Protection

Thyristors

Damage can occur to a thyristor if the thyristor's repetitive peak off-state voltage is exceeded. A thyristor's repetitive peak off-state voltage may be exceeded due to dirty AC power mains, inductive spikes, motor latch up, etc.

Thyristor Reference Circuit

Figures 3-33 & 3-34 show two different methods of protecting a triac. In Figure 3-33, a SIDACtor is connected from MT2 to the gate of the triac. When the voltage applied to the triac exceeds the SIDACtor's V_{DRM}, the SIDACtor turns on, producing a gate current which turns the triac on.

The circuit in Figure 3-34 places a SIDACtor across MT2 and MT1 of the triac. In this instance the SIDACtor protects the triac by turning on and shunting the transient before it exceeds the V_{DRM} rating of the triac.

Regardless of the method chosen, when using a SIDACtor to protect a thyristor, the following design considerations must be followed:

- V_{DRM} of the SIDACtor < V_{DRM} of Triac
- SIDACtor V_{DRM} > 120% $V_{PK(power\ supply)}$
- SIDACtor must be placed behind the load

Figure 3-33 TRIAC Protection

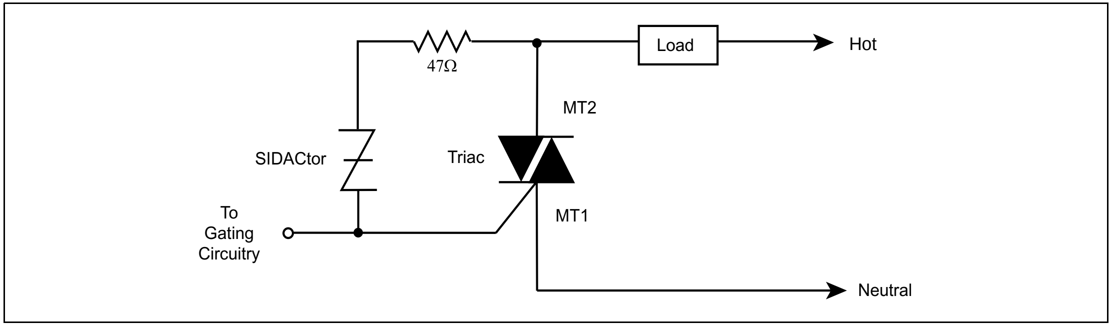
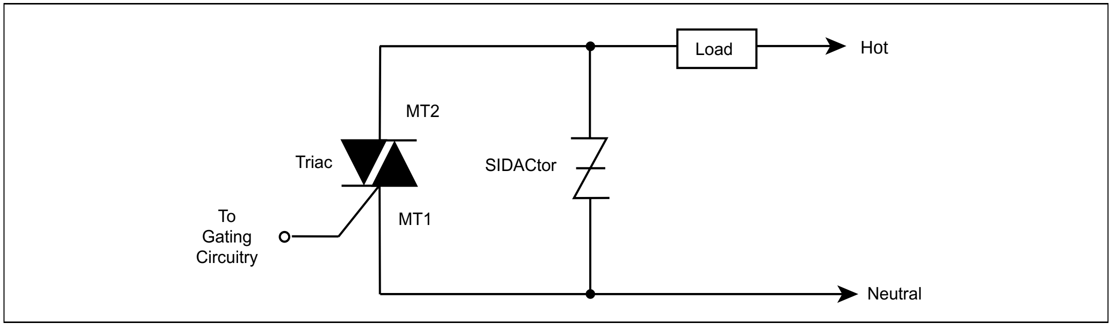


Figure 3-34 TRIAC Protection



Data Line Protectors

Data Line Protection

In many office and industrial locations, data lines (such as RS-232) and AC power lines run in close proximity to each other which often results in voltage spikes being induced onto the data line, causing damage to sensitive equipment.

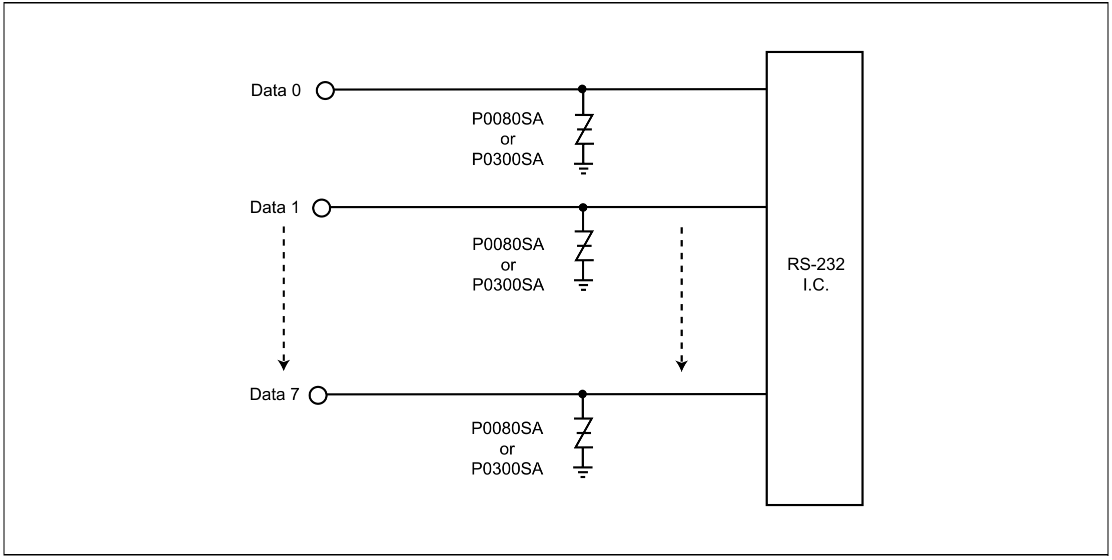
Protection Requirements

Data lines should be protected against over-voltages that can exceed 1500V and surge currents up to 50A.

Data Line Reference Circuit

Figure 3-35 shows how a SIDACtor is used to protect low voltage data line circuits.

Figure 3-35 Data Line Protection



Notes

4 Regulatory Requirements

Due to the enormous cost of interrupted service and failed network equipment, service providers have adopted various specifications to help regulate the reliability and performance of the telecommunications product that they purchase. In Europe and much of the Far East, the most common standards are: ITU-T K.20 and K.21; in North America, most operating companies base their requirements on GR 1089, FCC Part 68, and UL1459/UL1950.

Note: This section is not intended to cover the listed regulatory requirements in their entirety, nor does it guarantee that the most current information was used.

This section is merely a paraphrase of existing documents and should only be used as a reference. For exact specifications, the referenced document should be obtained from the appropriate source.

GR 1089-Core

Overview

In the United States, the telecommunication network is primarily operated by the Regional Bell Operating Companies (RBOC's) which follow the standards set by Bellcore or a derivative thereof. GR 1089-Core (often referred to as Bellcore 1089), “Electromagnetic Compatibility and Electrical Safety Generic Criteria for Network Telecommunications Equipment” covers the requirements for telecommunications equipment connected to the outside world through twisted pair, and addresses the criteria for protection from lightning and AC power cross disturbances.

Because twisted pair can be likened to metallic conductors exposed to lightning and AC power faults, GR 1089 has documented the standards they feel should be met by manufacturers of public switched telephone network (PSTN) equipment to ensure safe and reliable operation.

The criteria used to set these standards is based on transient conditions at exposed sites such as remote facilities, central offices, and customers’ premises where operating companies provide some type of primary voltage protection (typically found in the form of gas discharge tubes or carbon blocks) which is meant to limit transient voltages to $1000V_{PK}$ for surge conditions and $600V_{RMS}$ for power cross conditions.

In conjunction with primary voltage protectors, operating companies may also incorporate fuse links if there is the possibility of exposing the twisted pair to outside power lines. These fuse links are equivalent to 24 or 26 gauge copper wire and are coordinated with the current carrying capacity of the voltage protector.

The last element of protection that may be provided by the operating company are current limiters, which if provided, will be found on the line side of the network equipment after the primary voltage protection device. These current limiters typically come in the form of heat coils and have a continuous rating of 350mA.

Requirements

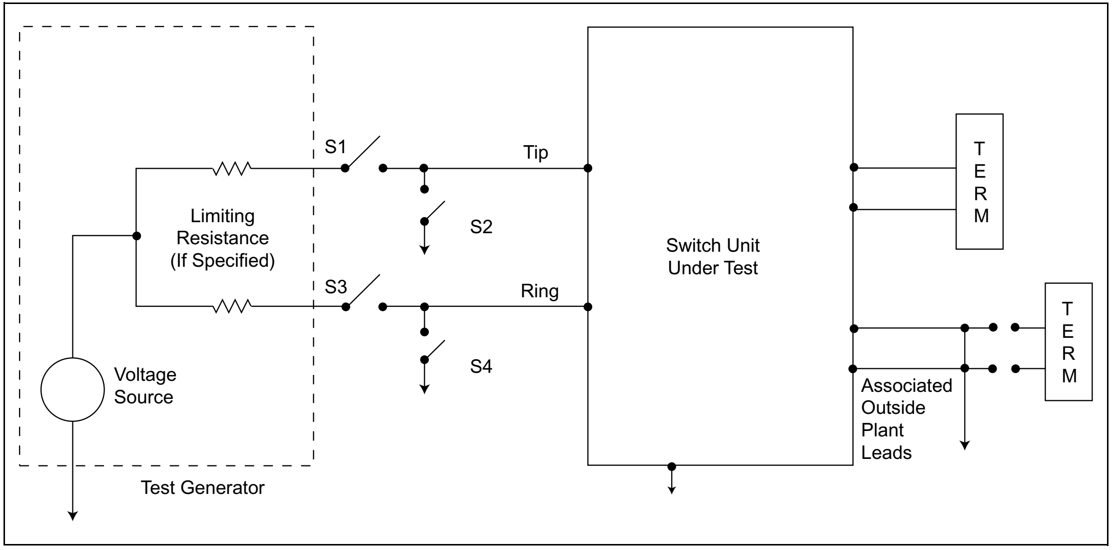
Equipment required to meet GR 1089 must be designed to pass both First and Second Level Lightning Surge and AC Power Fault Tests, a Current Limiter Test, and a Short Circuit Test. A minimum of three units will be tested for each of the operating states that the equipment under test (EUT) may be expected to function; idle, transmit, receive, on-hook, off-hook, talking, dialing, ringing, and testing. Test connections are shown in Table 4-1 and connection appearances are shown in Figure 4-1.

Table 4-1 Test Conditions

Test	Two-Wire Interface	Four-Wire Interface
A	1. Tip to Generator, Ring to ground. 2. Ring to Generator, Tip to ground. 3. Tip and Ring Surged Simultaneously	1. Each lead (T,R,T_1,R_1) tied to the Generator with the other three leads grounded. 2. Tip and Ring to Generator, simultaneously, T_1 and R_1 to ground. 3. T_1 and R_1 to Generator, simultaneously, Tip and Ring to ground.
B	Tip and Ring Surged Simultaneously.	T, R, T_1, R_1 to Generator simultaneously.

Notes:
1. When performing longitudinal tests, the test generator will have a dual output.
2. Connection appearances are shown in Figure 4-1.

Figure 4-1 Connection Appearances



Connections to Test Generator	S1	S2	S3	S4
Condition A-1 of Table 4-1	Closed	Open	Open	Closed
Condition A-2 of Table 4-1	Open	Closed	Closed	Open
Condition A-3 of Table 4-1	Closed	Open	Closed	Open

Note:
Other outside plant leads associated with the unit should be grounded during test and the test repeated with these leads terminated as in service. Leads that do not connected to outside plant should be terminated as is appropriate for the operating mode(s) of the unit.

Passing Criteria

Passing criteria for the First Level Lightning Surge Test and the First Level AC Power Fault Test is that the EUT will not be damaged and it will operate as intended after the stress is removed. Passing criteria for the Second Level Lightning Surge Test and Second Level AC Power Fault Test is that the EUT may be damaged, but it may not become a fire, fragmentation, or electrical safety hazard. Passing criteria for the Current Limiter Test is that the EUT may be damaged, but it may not exceed the acceptable time/current criteria (i.e., it can not cause the wiring simulator in Figure 4-2 to open) nor become a fire, fragmentation, or electrical safety hazard.

The indicator used in measuring fire, fragmentation, and electrical safety hazards is a bleached, untreated cotton cheesecloth which is wrapped around the EUT. Compliance with testing is determined by the absence of ignition, charring, and the ejection of molten material or fragments.

Lightning Fault Immunity Test

Metallic Voltage - is defined as the potential difference between Tip and Ring. Metallic voltages occur when there is an imperfect balance on the twisted pair. This imbalance typically arises due to unmatched components, but can also occur when longitudinal surges are converted to metallic surges due to asymmetrical operation of over-voltage protectors.

Longitudinal Voltage - is defined by Bellcore as half of the sum of the potential difference seen between the Tip conductor and earth ground and the Ring conductor and earth ground. During transient activity, damaging voltages are propagated over the phone lines raising the potential difference of each line with respect to earth ground. It is this potential difference that is often attributed to failed network equipment and is simulated in Tests 1, 2, 3, and 5 in Table 4-2.

Test 4 in Table 4-2 simulates transients that are coupled to the network equipment via ground conductors. These transients occur when nearby lightning strikes produce large surge currents which generate excessive voltage due to the resistive path of the protector and power grounds.

First Level Lightning Surge Test

To pass the First Level Lightning Surge Test, the EUT must be undamaged and continue to operate properly after the stress is removed. This is referred to as passing “operationally”. The conditions for the First Level criteria are shown in Table 4-2. The applicants have the option to submit their equipment to meet surges 1, 2, 4 and 5 or surges 3, 4, and 5.

Table 4-2 First Level Lightning Surge Test

Test (Note 1 & 2)	Surge Voltage (V_{PK})	Wave-form	Surge Current per Conductor (A)	Repetitions Each Polarity	Test Connections (Table 4-1, Fig. 4-1)
1	± 600	10x1000µs	100	25	A
2 (Note 3)	± 1000	10x360µs	100	25	A
3 (Note 3)	± 1000	10x1000µs	100	25	A
4	± 2500	2x10µs	500	10	B
5 (Note 4)	± 1000	10x360µs	25	5	B

Notes:

1. Primary protectors are removed for all tests.
2. For EUT containing secondary voltage limiting and current limiting protectors, tests are to be performed at the indicated voltage(s) and repeated at a reduced voltage and current just below the operating threshold of the secondary protectors.
3. Test 1 and 2 can be replaced with test 3 or vice-versa.
4. This test is to be performed on up to 12 Tip and Ring pairs simultaneously.

Second Level Lightning Surge Test

The Second Level Lightning Surge Test (Table 4-3) does not require the EUT to pass operationally, but GR 1089 does require that the EUT not become a fire, fragmentation, or electrical safety hazard. This is referred to as passing “non-operationally”.

Table 4-3 Second Level Lightning Surge Test

Test	Surge Voltage (V_{PK})	Wave-form	Surge Current (A)	Repetitions Each Polarity	Test Connections (Table 4-1, Fig. 4-1)
1	± 5000	2x10µs	500	1	B

Notes:

1. Primary protectors are removed
2. For EUT containing secondary voltage limiting and current limiting protectors, tests are to be performed at the indicated voltage(s) and repeated at a reduced voltage and current just below the operating threshold of the secondary protectors.

AC Power Fault Tests

Because power companies and operating companies often share telephone poles, trenches, and the like, network equipment is often subjected to the voltages seen on power lines. If direct contact between the telephone line and the primary power line occurs, the operating companies network equipment may see as much as $600V_{RMS}$ for 5 seconds, by which time the power companies power system should clear itself. If direct contact occurs with the secondary power line, voltages will be limited to $277V_{RMS}$, but these voltages may be seen indefinitely because the resultant current may be within the operating range of the power system and the power system will not reset itself.

Another risk involved with power lines is indirect contact. Because of the large magnetic fields created by the currents in the power lines, large voltages may be induced upon the phone lines via electro-magnetic coupling. In this instance voltages should be limited to $1000V_{PK}$ and $600V_{RMS}$ by the primary protectors, while the current will be limited by the current carrying capacity of the 24 gauge wire.

First Level AC Power Fault Criteria

Test conditions for the First Level AC Power Fault Test are shown in Table 4-4. The EUT is required to pass operationally.

Table 4-4 First Level AC Power Fault Test

Test	Applied Voltage, 60Hz (V_{RMS})	Short Circuit Current per Conductor (A)	Duration	Primary Protectors	Test Connections (Table 4-1, Fig. 4-1)
1 (Note 1)	50	.33	15 minutes	Removed	A
2 (Note 1)	100	.17	15 minutes	Removed	A
3 (Note 1)	200, 400, 600	1A at 600V	60 Applications, 1 Second Each	Removed	A
4	1000	1	60 Applications, 1 Second Each	In Place	B
5 (Note 2)	N/A	N/A	60 Applications, 5 Seconds Each	Removed	N/A
6	600	0.5	30s	Removed	A
7	600	2.2	2s	Removed	A
8	600	3	1s	Removed	A
9	1000	5	0.5	In Place	B

Notes:

1. For EUT containing secondary voltage limiting and current limiting protectors, tests are to be performed at the indicated voltage(s) and repeated at a reduced voltage and current just below the operating threshold of the secondary protectors.
2. Test 5 simulates a high impedance induction fault. For specific information, please contact Teccor Electronics.

Second Level AC Power Fault Criteria

Test conditions for the Second Level AC Power Fault Test are dependent on whether the EUT is intended for customer premises equipment or non-customer premises equipment. In both instances, although the EUT is not required to pass operationally, it may not become a fire, fragmentation, or electrical safety hazard.

Second Level AC Power Fault Criteria for Non-Customer Premises Equipment

For non-customer premises equipment, test conditions are shown in Table 4-5 (it should be noted that test conditions 1, 3, and 4 may be omitted if the EUT has previously met UL 1459) and test connections are shown in Figure 4-1.

Table 4-5 Second Level AC Power Fault Test for Non-Customer Premises Equipment

Test (Note 1, 2)	Applied Voltage, 60Hz (V_{RMS})	Short Circuit Current per Conductor (A)[5]	Duration	Test Connections (Table 4-1, Fig. 4-1)
1	120, 277	25	15 minutes	A
2	600	60	5 seconds	A
3	600	7	5 seconds	A
4 (Note 3)	100-600	2.2A at 600V	15 minutes	A
5 (Note 4)	N/A	N/A	15 minutes	N/A

Notes:

1. Primary protectors are removed for all tests.
2. For EUT containing secondary voltage limiting and current limiting protectors, tests are to be performed at the indicated voltage(s) and repeated at a reduced voltage and current just below the operating threshold of the secondary protectors.
3. This test is to be performed between the ranges of 100V-600V and is intended to produce the greatest heating affect.
4. Test 5 simulates a high impedance induction fault. Specific information regarding this test is available upon request.
5. These tests are repeated using a short-circuit value just below the operating threshold of the current limiting device or if the EUT uses a fuse as current limiting protection, the fuse may be bypassed and the short circuit current available adjusted to 135% of the fuse rating.

Second Level AC Power Fault for Customer Premises Equipment

For customer premises equipment, the EUT is tested to the conditions shown in Table 4-6 and connected to a circuit equivalent to Figure 4-2. During this test, the wiring simulator can not open. For equipment that uses premises type of wiring, the wiring simulator is a 1.6A Type MDQ fuse from Bussman. For equipment that is connected via cable, the wiring simulator is a piece of 26 gauge copper wire.

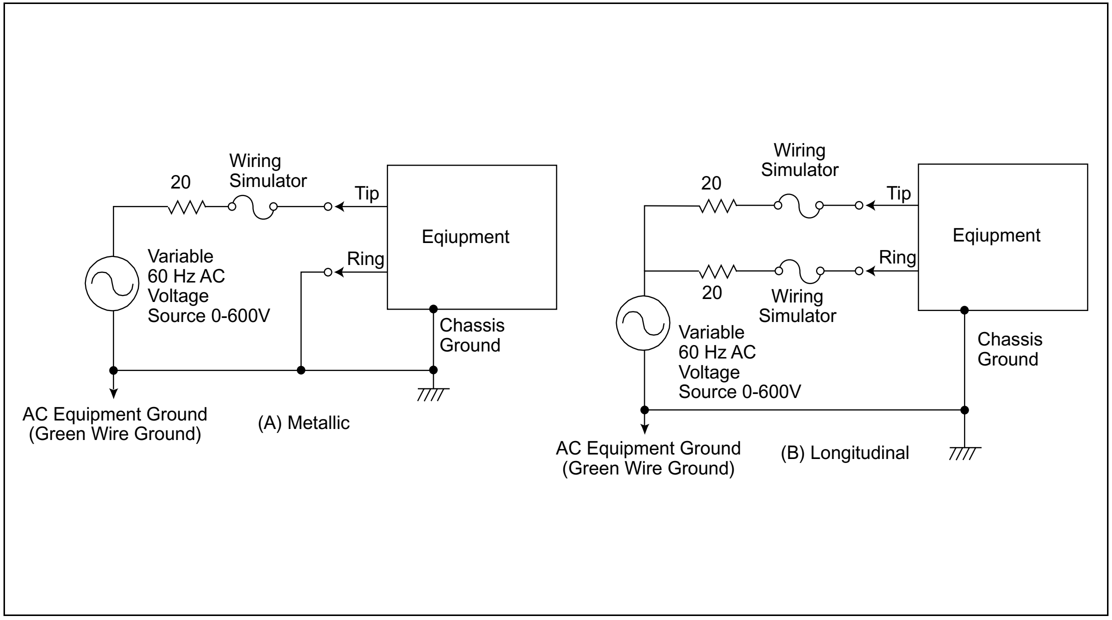
Table 4-6 Second Level AC Power Fault for Customer Premises Equipment

Test	Applied Voltage, 60Hz (V_{RMS})	Source Impedance Ω	Test Connections (Table 4-1, Fig. 4-2)
1	300	20	(Note 1)
2	600	20	A

Notes:

1. Applied between exposed surfaces and ground.
2. The 60Hz signal is applied with an initial amplitude of $30V_{RMS}$ and 30mA and increased by 20% every 15 minutes until:
    a. The voltage reaches the maximum specified.
    b. The current reaches 20A or the wiring simulator opens.
    c. The EUT fails open circuit.
3. If the EUT fails open circuit, the test will continue for an additional 15 minutes to ensure that another component of the EUT does not create a fire, fragmentation, or electrical safety hazard.

Figure 4-2 Second Level AC Power Fault and Current Limiter Connection



Current Limiting Protector Test

The purpose of the Current Limiting Protector Test (Table 4-7) is to determine if the EUT allows an excessive amount of current flow under power fault conditions. During this test, the EUT is connected to a circuit equivalent to Figure 4-2 with a 1.6A Type MDQ fuse from Bussman used as the wiring simulator. If the EUT draws enough current to open the fuse, then the acceptable time/current criteria has not been met and external current limiting protectors must be specified for use with that equipment in the manufacturers documentation.

Table 4-7 Current Limiting Protector Test

Test	Applied Voltage, 60Hz (V_{RMS})	Source Impedance Ω	Duration	Test Connections (Table 4-1, Fig. 4-2)
1	600	2	15 minutes	A

Short Circuit Test

In addition to the AC Power Fault and Current Limiter Tests, Bellcore compliant equipment must also pass a Short-Circuit Test. During this test, a short circuit condition is applied to the following Tip and Ring appearances for thirty minutes while the EUT is powered and under operating conditions:

- Tip-to-Ring, Tip-to-ground with Ring open-circuit.
- Ring-to-ground with Tip open-circuit.
- Tip and Ring-to-ground simultaneously for thirty minutes.

At no time will the short circuit exceed 1 ohm. For equipment with more than one twisted pair, the short circuit will be applied to all twisted pair simultaneously. To comply with the short circuit test, the EUT must function normally after the short-circuit condition has been applied and a fire hazard may not be present.

Intra-Building Lightning and AC Power Fault Test

Not all equipment is intended to be off premise equipment nor is all equipment intended to interface with the telephone outside plant. For such equipment, the EUT need only meet the Intra-Building Lightning Surge Test found in Table 4-8 and the Intra-Building AC Power Fault Test found in Table 4-9.

Table 4-8 Intra-Building Lightning Surge Test

Test	Surge Voltage (V_{PK})	Wave-form	Surge Current per Conductor (A)	Repetitions Each Polarity	Test Connections (Table 4-1, Fig. 4-1)
1	± 800	2x10µs	100	1	A
2	± 1500	2x10µs	100	1	B

Note:
The EUT shall not be damaged and shall continue to operate. Because the intensity of the Intra-Building Tests are much less than those found in Table 4-2 through Table 4-6, if the EUT only meets the criteria found in Table 4-8 and 4-9, documentation must be included indicating that the equipment is solely intended for intra-building (non-exposed wiring) connections.

Table 4-9 Second Level Intra-Building AC Power Fault Test

Test	Applied Voltage, 60Hz (V_{RMS})	Short Circuit Current per Line Conductor (A)	Duration	Primary Protectors	Test Connections (Table 4-1, Fig. 4-1)
1	120	25	15 minutes	Removed	A

Note:
For EUT containing secondary voltage limiting and current limiting protectors, tests are to be performed at the indicated voltage(s) and repeated at a reduced voltage and current just below the operating threshold of the secondary protectors. This second level test may be destructive but shall not become a fire, fragmentation or electrical fire hazard.

ITU-T K.20 and K.21

Overview

Although the ITU does not have the authority to legislate that organizations follow their recommendations, their standards are recognized in many places throughout Europe and the Far East.

ITU-T, the Telecommunication Standardization Sector of the International Telecommunication Union, has developed fundamental testing methods that have been established to cover various environmental conditions to help predict the survivability of network and customer based switching equipment. The conditions covered are surges due to lightning strikes on or near twisted pair and or plant equipment (this does not include a direct strike), short term induction of AC voltage from adjacent power lines or railway systems, and direct contact between telecommunication lines and power lines (this is often referred to as AC power cross).

The two applicable ITU-T standards for most telecommunications equipment to be connected to the network are ITU-T K.20 which is primarily for switching equipment powered by the central office, and ITU-T K.21 which focuses on customer premise equipment. However, for complex subscriber equipment, test administrators may choose either K.20 or K.21, depending on which they feel is most appropriate.

Note:
Both standards are meant to address equipment reliability versus equipment safety, so for specific concerns regarding equipment safety, national standards should be researched and followed for each country where the equipment is intended to be used.

ITU-T K.20

Covers telephone exchanges and switching centers. Equipment submitted under K.20 must meet one of two levels. The lower level is intended for equipment that is used in an unexposed environment where over-voltages and over-currents are expected to be small and external protectors omitted (similar to the intra-building scenario found in Bellcore 1089). The higher level is intended to cover more exposed environments where external line protectors are used. Guidelines for determining which environment the equipment under test (EUT) falls under can be found in ITU-T K.11, but it should be noted that the final authority rests with the test administrator. That being the case, and since equipment satisfying the requirements of the exposed criteria can also meet the requirements satisfying the non-exposed requirements, only the exposed level requirements are addressed in this document.

ITU-T K.21

Addresses desk-borne equipment that may or may not be used in an exposed environment. It is assumed that external line protectors are employed for equipment used in exposed areas and not used for unexposed environments. With this in mind, K.21 is conducted with and without external line protectors.

External Protectors

For equipment being tested to the exposed level, it is standard practice for external line protectors (typically gas tubes) to be used in order to handle the large surge currents generated during K.20 and K.21 qualification. Realizing that these protectors can affect the characteristics of the EUT, it is important that the protectors used be agreed upon by the principal parties involved (the equipment supplier and testing administrator). Once agreed upon, the protectors should be used when primary protection is specified, and allowance should be given for a new set of protectors after the completion of each test sequence.

Note:
An alternative to using external protectors is for the test administrator to simulate the conditions expected (as if the external protectors were used) by modifying the surges found in K.20 and K.21.

Equipment Boundaries

Because of the numerous types of equipment, during K.20 and K.21 testing ITU-T looks at each EUT as a “black box” with three terminals (A, B, and E). The applicant is expected to define the boundaries of this “black box”, and in doing so, should be aware that any protective device within these boundaries is considered an unchangeable part of that piece of equipment.

Permitted Malfunction or Damage

During K.20 and K.21 qualification, ITU-T recognizes two levels of malfunction or damage to the EUT:

- Level A states that equipment withstands the test without damage or disturbance and operates properly after the test. If specifically permitted, the administration may accept the opening of the fuse.
- Level B states that a fire hazard does not occur in the equipment as a result of the test, and that any permanent damage or malfunction is confined to a small number of external line interface circuits (as defined by the test administrator).

The acceptable level of malfunction for each test is specified under Acceptance Criteria.

Table 4-10 K.20 Lightning Simulation

Test Number	Connection (Note 1)	Open Circuit Voltage (V)	Short Circuit Current (A)	Number of Tests (Note 3)	Added Protection	Acceptance Criteria
1	A and E, B earthed	1000 10x700µs	25 5x310µs	10	None	A
2	B and E, A earthed	1000 10x700µs	25 5x310µs	10	None	A
3	A+B and E	1000 10x700µs	50 5x310µs (Note 2)	10	None	A
4	A and E, B earthed	4000 10x700µs	100 5x310µs	10	Primary	A
5	B and E, A earthed	4000 10x700µs	100 5x310µs	10	Primary	A
6	A+B and E	4000 10x700µs	200 5x310µs (Note 2)	10	Primary	A

Notes:

1. Connection appearances are shown in Figure 4-3
2. This is a simultaneous surge. The specified current is the resultant current (sum of terminal A and terminal B) with respect to ground (terminal E).
3. The time interval between multiple applications should be 1 minute. In the case of pulse tests, the polarity should be reversed between consecutive pulses.

Figure 4-3 Connection Appearances

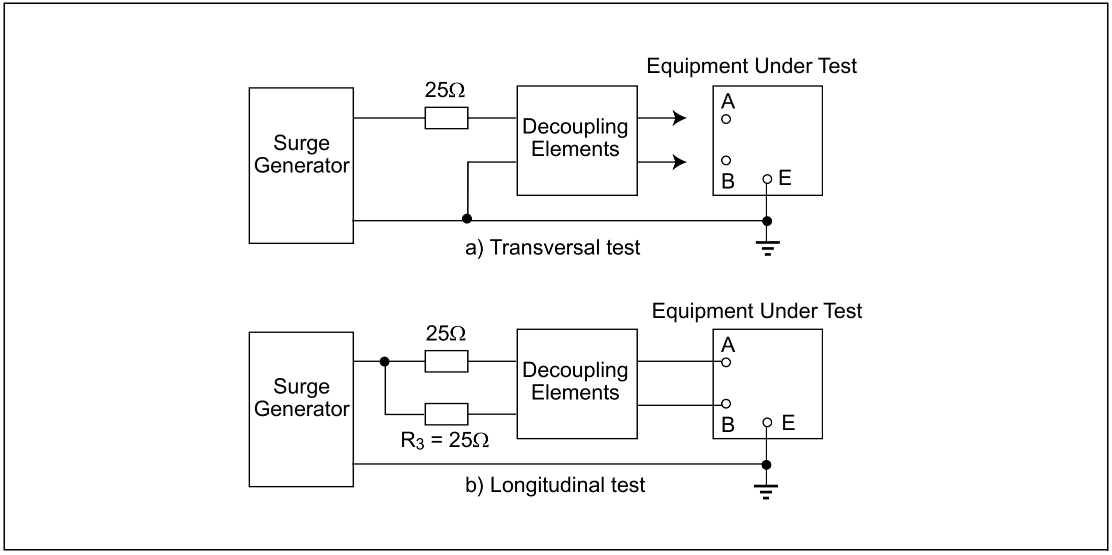


Table 4-11 K.20 Power Induction

Test Number	Connection (Note 1)	Open Circuit Voltage (V_{RMS})	Short Circuit Current (A)	Number of Tests (Note 2)	Added Protection	Acceptance Criteria
1	A+B and E	600 200ms	2 200ms	5	None	A
2	A+B and E	600 1s	2 1s	5	Primary	A

Notes:
1. Connection appearances are shown in Figure 4-4.
2. The time interval between multiple applications should be 1 minute. In the case of pulse tests, the polarity should be reversed between consecutive pulses.

Figure 4-4 Connection Appearances

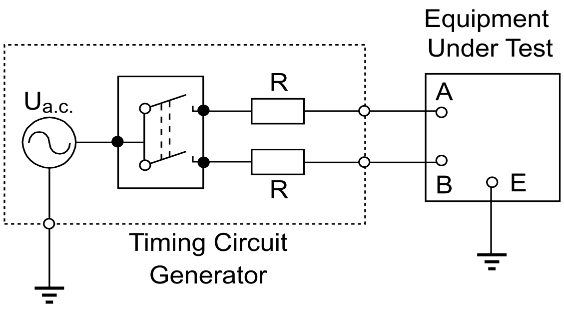


Table 4-12 K.20 Power Contact

Test Number	Connection (Note 1)	Open Circuit Voltage V_{RMS}	Short Circuit Current (A)	Number of Tests (Note 2)	Added Protection	Acceptance Criteria
1	A+B and E	230	46	1	Primary	B
2	A+B and E	230	2.3	1	Primary	B
3	A+B and E	230	.77	1	Primary	B

Notes:
1. Connection appearances are shown in Figure 4-5.
2. Each test is conducted for 15 minutes.
3. The time interval between multiple applications should be 1 minute.
4. In the case of pulse tests, the polarity should be reversed between consecutive pulses.

Figure 4-5 Connection Appearances

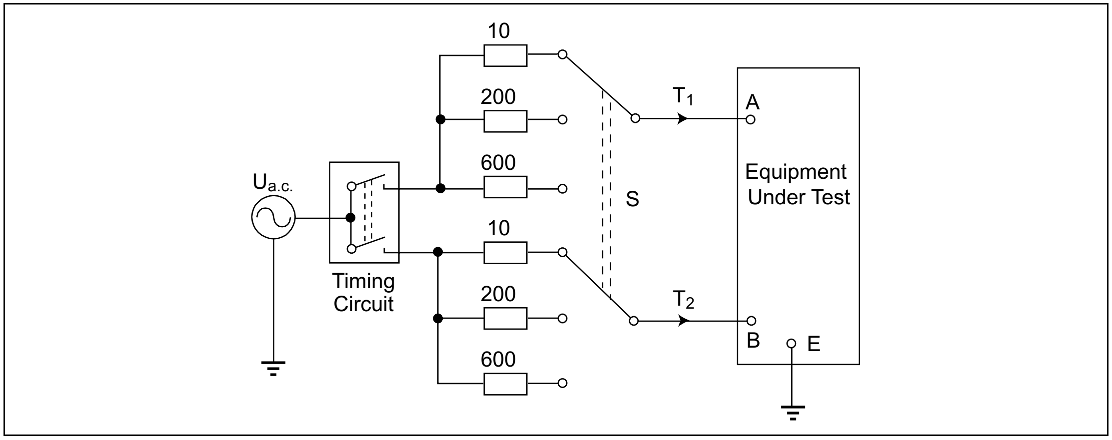


Table 4-13 K.21 Lightning Simulation

Test Number	Connection (Note 1)	Open Circuit Voltage (V)	Short Circuit Current (A)	Number of Tests	Added Protection	Acceptance Criteria
1	T_1 and A T_2 and B	1500 10x700µs	75 5x310µs (Note 2)	10	None	A
2	T_1 and A T_2 and B	4000 10x700µs	200 5x310µs (Note 2)	10	Primary	A
3	T_1 and A (Note 3)	1000 10x700µs	25 5x310µs	10	None	A
4	T_1 and B (Note 3)	1000 10x700µs	25 5x310µs	10	None	A
5	T_1 and A (Note 3)	4000 10x700µs	100 5x310µs	10	Primary	A
6	T_1 and B (Note 3)	4000 10x700µs	100 5x310µs	10	Primary	A

Notes:

1. Connection appearances are shown in Figure 4-6.
2. This is a simultaneous surge. The specified current is the resultant current (sum of terminal A and terminal B) with respect to ground (terminal E).
3. All other terminals are connected to earth ground.
4. Fuse links may be left in circuit during these tests. The current conducted shall not create a fire hazard within the premises where the equipment is located.

Figure 4-6 Connection Appearances

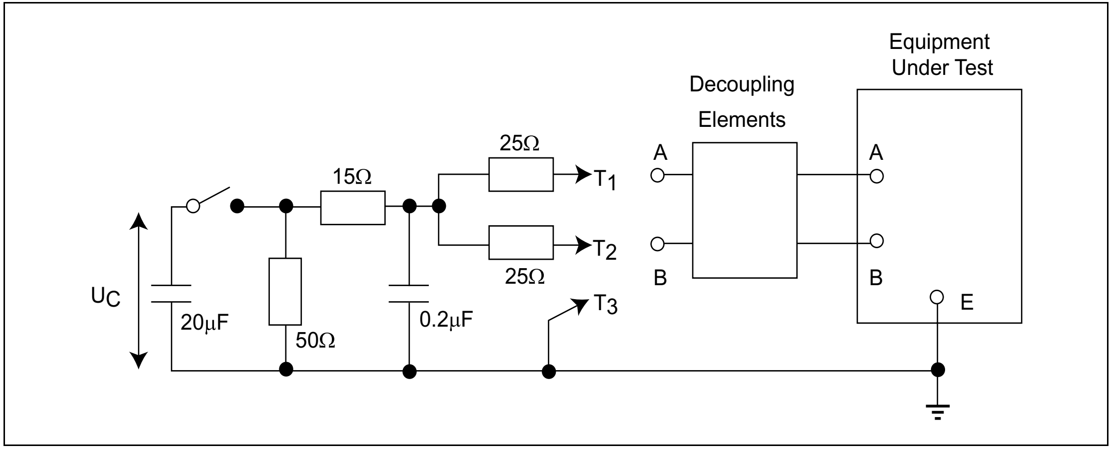


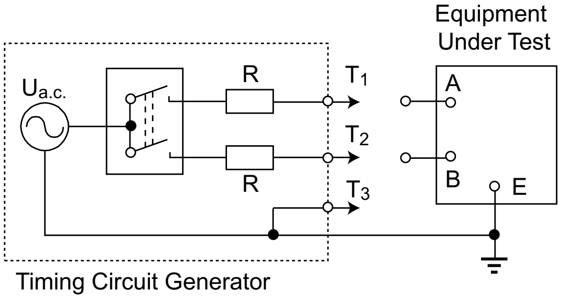
Table 4-14 K.21 Power Induction Simulation

Test Number	Connection (Note 1)	Open Circuit Voltage V_{RMS}	Short Circuit Current (A)	Number of Tests	Added Protection	Acceptance Criteria
1	T_1 and A T_2 and B	600 200ms	2	5	None	A
2	T_1 and A T_2 and B	600 1s	2	5	Primary	A
3	T_1 and A (Note 2)	600 200mS	1	5	None	A
4	T_1 and B (Note 2)	600 200mS	1	5	None	A
5	T_1 and A (Note 2)	600 1s	1	5	Primary	A
6	T_1 and B (Note 2)	600 1s	1	5	Primary	A

Notes:

1. Connection appearances are shown in Figure 4-7.
2. All other terminals are connected to earth ground.
3. Fuse links may be left in circuit during these tests. The current conducted shall not create a fire hazard within the premises where the equipment is located.
4. Administrators may choose other AC voltage and current values to suit local circumstances such that the resultant I^2t equals1A^2s.

Figure 4-7 Connection Appearances



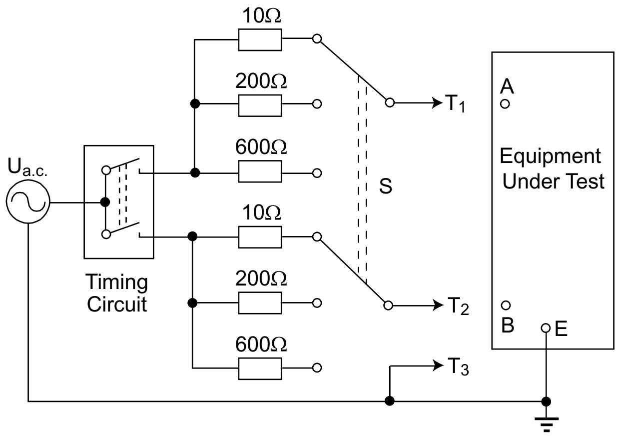
Regulatory Requirements

Table 4-15 K.21 Contact Simulation

Test Number	Connection (Note 1)	Open Circuit Voltage (V_{RMS})	Short Circuit Current (A)	Number of Tests	Added Protection	Acceptance Criteria
1	T_1 and A,T_2 and B	230,15 min	46	1	None	B
2	T_1 and A, T_2 and B	230, 15 min	2.3	1	None	B
3	T_1 and A, T_2 and B	230, 15 min	.77	1	None	B
4	T_1 and A, (Note 2)	230, 15 min	23	1	None	B
5	T_1 and B, (Note 2)	230, 15 min	23	1	None	B
6	T_1 and A, (Note 2)	230, 15 min	1.15	1	None	B
7	T_1 and B, (Note 2)	230, 15 min	1.15	1	None	B
8	T_1 and A, (Note 2)	230, 15 min	.38	1	None	B
9	T_1 and B, (Note 2)	230, 15 min	.38	1	None	B

Notes:
1. Connection appearances are shown in Figure 4-8.
2. All other terminals are connected to earth ground.
3. Fuse links may be left in circuit during these tests. The current conducted shall not create a fire hazard within the premises where the equipment is located.
4. Administrators may choose other AC voltage values to suit local circumstances.

Figure 4-8 Connection Appearances



FCC PART 68

Overview

FCC Part 68 applies to all terminal equipment that is connected to the public network and is unique in the fact that it is mandated by U.S. law.

The purpose of FCC Part 68 is to provide a set of uniform standards that will protect the telephone network from any damage or interference caused by the connection of terminal equipment. The FCC standard includes environmental simulations such as vibration tests, temperature and humidity cycling, drop tests and tests for hazardous voltages and currents, as well as tests for signal power levels, line balance, on-hook impedance, and billing protection; all of which must be met before and after the environmental tests are applied.

Over-Voltage Test

FCC compliant equipment must undergo an over-voltage test that includes a Type A and Type B Metallic Voltage Surge and a Type A and Type B Longitudinal Voltage Surge. These surges are part of FCC's environmental simulation, and although there is a provision which allows the EUT to reach an open circuit failure mode during the Type A tests, failures must:

1. Arise from an intentional design which will cause the phone to be either disconnected from the public network or repaired rapidly.
2. Be designed such that it is substantially apparent to the end user that the terminal equipment is not operable. A common example of an acceptable failure would be an open circuit due to an open connection on either Tip or Ring.

For Type B surges, equipment protection circuitry is not allowed to fail. The EUT must be designed to withstand Type B surges and continue to function in all operational states.

Metallic Voltage Surge

The Type A and Type B Metallic Voltage Surges are applied in both the positive and negative polarity across Tip and Ring during all operational states (on-hook, off-hook, ringing, etc.). The Type A surge is an 800V, 100A peak surge while the Type B surge is a 1000V, 25A peak surge (Table 4-16).

Longitudinal Voltage Surge

The Type A and Type B Longitudinal Voltage Surges are applied in both positive and negative polarity during all operational states. The Type A surge is a 1500V, 200A peak surge applied to the EUT with Tip and Ring tied together with respect to ground. The Type B Longitudinal Voltage Surge is a simultaneous surge in which 1500V and 37.5A are applied to Tip with respect to ground and Ring with respect to ground concurrently (Table 4-16).

Table 4-16 FCC Voltage Surge

Surge Type	Peak Voltage (V_{PK})	Rise & Decay Time (Wave-form)	Peak Current (A)	Rise & Decay Time (Wave-form)	Repetitions Each Polarity
Metallic A	± 800	10x560µs	100	10x560µs	1
Longitudinal A	± 1500	10x160µs	200	10x160µs	1
Metallic B	± 1000	9x720µs	25	5x320µs	1
Longitudinal B	± 1500	9x720µs	37.5	5x320µs	1

Notes:

1. For Type A surges, the EUT may be pass either “operationally” or “non-operationally”.
2. For Type B surges, the EUT must pass operationally.
3. The Peak Current for the Type A longitudinal surge is the total available curent from the surge generator.
4. The Peak Current for the Type B longitudinal surge is the current supplied to each conductor.

Special Note:
FCC Type B surge requirements only guarantee a minimum level of surge protection. For long term reliability of terminal equipment, consideration should be given to complying with Type A surges operationally.

On-hook Impedance Limitations

Another important aspect of FCC Part 68 which is affected by transient protection is on hook impedance. On hook impedance is analogous to the leakage current between Tip and Ring, and Tip, Ring and ground conductors during various on hook conditions. Criteria for on hook impedance is outlined below and is listed as part of the Ringer Equivalent Number (REN) by the FCC. The REN is the largest of the unitless quotients not greater than 5, and the rating is specified as the actual quotient followed by the letter of the ringer classification, e.g., 2B.

On-hook Impedance Measurements

On-hook impedance measurements are made between Tip and Ring and between Tip and ground and Ring and ground. For all DC voltages up to and including 100V, the DC resistance measured must be greater than 5MΩ. For all DC voltages between 100 and 200V, the DC resistance must be greater than 30kΩ. The REN values are then determined by dividing 25MΩ by the minimum measured resistance up to 100V and by dividing 150kΩ by the minimum measured resistance between 100 and 200V.

On-hook impedance is also measured during the application of a simulated ringing signal. This consists of a 40 through 150V_{RMS} ringer signal at frequencies ranging from 15.3 to 68.0Hz superimposed on a 56.5VDC for a class “B” ringer. During this test, the total DC current may not exceed 3mA. In addition, the minimum DC resistance measured between Tip and Ring must be greater than 1600Ω while the DC resistance measured between the Tip and Ring conductors and ground must be greater than 100kΩ. The REN values for the simulated ringing test are determined by dividing the maximum DC current flowing between Tip and Ring by 0.6mA, and by dividing 8000Ω by the minimum impedance value measured.

UL 1459 2nd Edition

Overview

After the 1984 divestiture of the AT&T/Bell system, the National Electric Code (NEC) implemented Article 800-4 which mandates that “all equipment intended for connection to the public telephone network be listed for that purpose” to help ensure electrical safety. One way a manufacturer can meet this requirement is to “list” their product with Underwriters Laboratories under UL 1459 (also see UL1950).

UL 1459

Because telephone lines run in close proximity to AC power lines, the NEC requires that all telecommunication wiring that enters a building pass through a primary protector which is designed to limit AC transients in excess of $600V_{RMS}$. But because most telecommunication equipment incorporates a secondary over-voltage protector that is designed to shunt transient voltages in excess of $250V_{RMS}$, a potentially dangerous condition arises because of the voltage gap that exists between these two protectors.

Consider the following: a transient condition exists and the secondary over-voltage protector triggers, but the primary protector does not, i.e. a $440V_{RMS}$ power cross. The secondary protector will shunt the transient voltage for as long as the transient condition exists or until the current path is interrupted. Now assume a worse case scenario; that the resultant current path is not interrupted and the power cross is indefinite. The net result will be the ignition of the premises wiring, the equipment, or both.

To help minimize this likelihood, UL requires that all registered equipment comply with the over-voltage tests listed in UL 1459, section 50A.

Over-Voltage Tests

The over-voltage tests found in section 50A of UL 1459 use two separate test circuits to simulate a $600V_{RMS}$ crossover between an AC power line and a telecommunications line. The circuit used in Figure 4-9 simulates a metallic power cross by applying a voltage potential between Tip and Ring. The circuit used in Figure 4-10 simulates a longitudinal power cross by applying a voltage potential between Tip and Ring with respect to earth ground.

Table 4-17 outlines the applicable over-voltage tests which simulate long and short term induction as well as direct power contact. The most common approach to pass these tests is to add a series fuse element on Tip ***and*** Ring for applications that connect to earth ground, or add a series fuse element on ***either*** Tip ***or*** Ring for applications that do not connect to earth ground.

Note:
Because telephone circuits typically draw 40-100mA of current during normal operation, fuses should be selected to be large enough to prevent nuisance tripping yet small enough that they won’t allow the wiring simulator to open during test. Fuse values between 250mA and 1.25A meet this requirement.

Failure Modes

Equipment under test can fail the over-voltage tests listed in Table 4-17 one of two ways. The first is to allow the wire simulator (a 1.6A Type MDQ fuse by Bussman) in Figures 4-9 and 4-10 to open which indicates that enough current was drawn during test to actually cause ignition of premises wiring.

The second is to allow a piece of white, unbleached cheesecloth which is wrapped around the EUT to either ignite or show signs of charring, which indicates that the EUT may become a serious fire hazard under power cross conditions.

Notes Concerning the SIDACtor and UL 1459

- SIDACtors are recognized under UL 497B, file no. E133083 (Standard for Secondary protectors for data communications and fire alarm circuits).
- SIDACtors use epoxy that is UL recognized and the encapsulated body passes UL 94V-0 requirements for flammability.
- The only specific requirements of UL 1459 that pertain to the SIDACtor itself is the mandate that components be UL listed. All other UL 1459 requirements pertain to the equipment being evaluated.

Table 4-17 UL 1459

Test	Voltage Applied (V_{RMS})	Duration	Test Current (A)	Connection
M1	600	1.5s	40	Metallic
M2	600	5s	7	Metallic
M3A	600	30 min.	2.2	Metallic
M3B	600	30 min.	Just below the interrupt value of the current interrupting device	Metallic
M4	200V_{RMS} or just below the breakdown voltage of the over-voltage protection device	30 min.	Just below the interrupt value of the current interrupting device	Metallic
L1	600	1.5s	40	Longitudinal
L2	600	5s	7	Longitudinal
L3A	600	30 min.	2.2	Longitudinal
L3B	600	30 min.	Just below the interrupt value of the current interrupting device	Longitudinal
L4	200V_{RMS} or just below the breakdown voltage of the over-voltage protection device	30 min.	Just below the interrupt value of the current interrupting device	Longitudinal
L5	120	30 min.	25	Longitudinal

Notes:

1. As an alternative test procedure, for equipment that uses a fuse to limit the current, the fuse may be bypassed and the available short circuit current applied set to 135% of the fuse rating.
2. Tests M4 and L4 are intended to simulate the maximum heating affect.

Figure 4-9 Metallic Connection Appearances

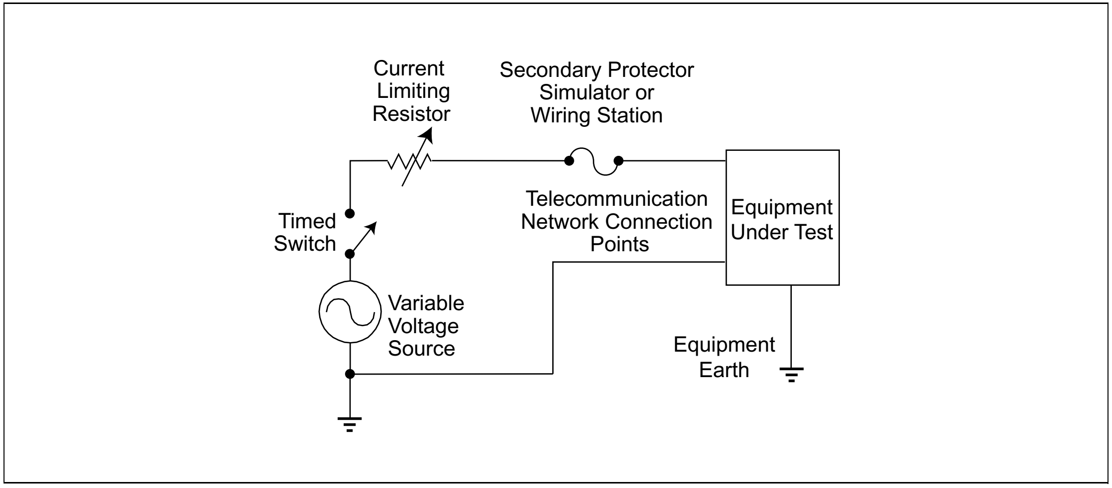
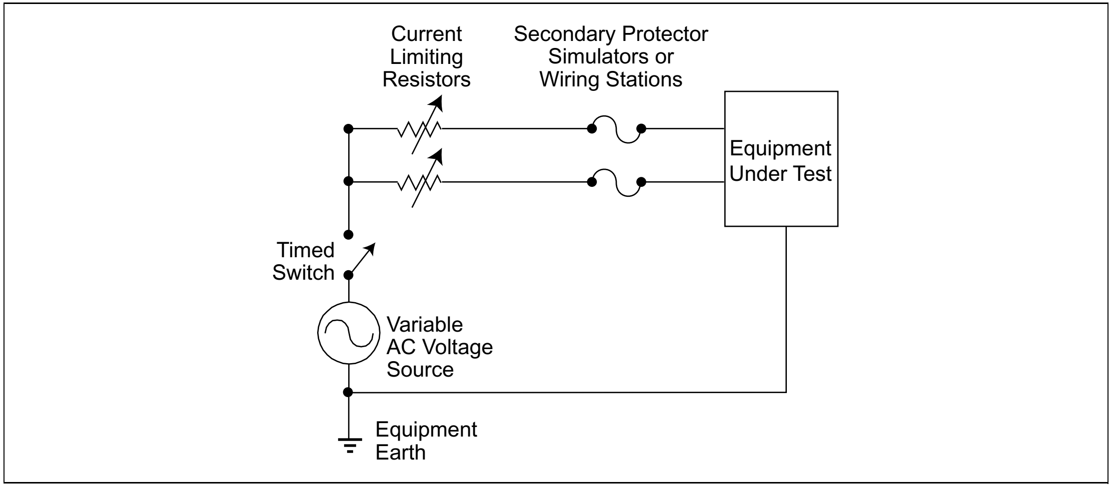


Figure 4-10 Longitudinal Connection Appearances



UL 1950 3RD Edition/CSA C22.2 No. 950-95

Overview

In an attempt to harmonize North American safety standards with Europe's IEC 950, Underwriters Laboratories and the Canadian Standards Association have adopted a bi-national standard, UL 1950 in the U.S and CSA C22.2 No. 950-95 in Canada, to replace UL1459 and CSA C22.2.

UL 1950 (CSA C22.2 No. 950-95) is applicable to "information technology equipment" with a rated voltage not exceeding 600V_{RMS}, that is intended to be powered by either a battery or electrical mains, and is designed to be installed in accordance with the Canadian Electric Code, the National Electric Code, and NFPA 70. Effective dates are as follows:

1. *July 28, 1995-April 1, 2000:* New product submittals will be evaluated against the requirements of UL 1950 (CSA C22.2 No. 950-95) unless use of another existing national standard is requested in writing by the manufacturer.
2. *From April 1st, 2000:* Products previously approved in accordance with existing national standards, i.e., UL 1459 and CSA 22.2, will continue to be considered approved until April, 1 2005.
3. *As of April 5th, 2005*: All products, whether new or previously approved, must comply with UL 1950 (CSA C22.2 No. 950-95).

UL 1950

Like UL 1459, UL 1950 is intended to help ensure the electrical safety of equipment that is connected to the public switched telecommunications network (PSTN). And although the over-voltage requirements are somewhat similar, UL1950 permits design engineers a much greater degree of flexibility through the use of design exceptions found in the Over-Voltage Flowchart (Figure 4-11*).*

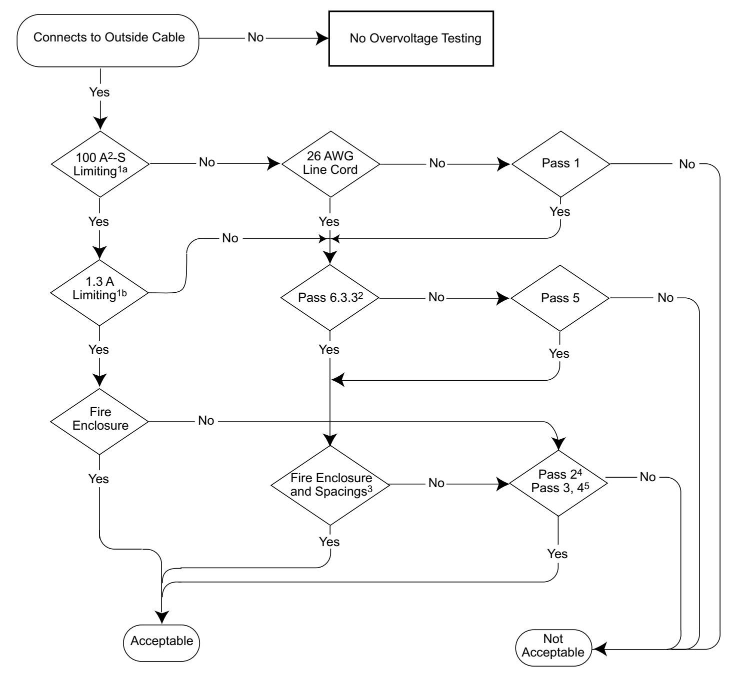
Over-Voltage Flowchart

The Over-Voltage Flowchart contains specific guidelines that determine which over-voltage requirements are applicable to specific designs. Applicable information that pertains to the Over-Voltage Flowchart is:

1. *Current Limiting* - Equipment that has a fire enclosure along with methods for limiting current to an I^2t rating of 100A^2s or 1.3A steady state, is not subject to over-voltage testing.
2. *26 AWG Line Cord* - This refers to a 26 American Wire Gauge (AWG) telecommunications line cord that is either supplied with the equipment or is described in the safety instructions.
3. *Clause 6.3.3* - The telephone line must be adequately isolated from earth for the operating mode being considered and at a voltage of 120V_{RMS}. Refer to section 6.3.3 of UL1950.
4. *Fire Enclosure* - Fire enclosures minimize fire hazards by containing any emission of flame, molten metal, flaming drops, or glowing particles that could be emitted by the equipment under fault conditions. Fire enclosure construction is covered in section 4.4.6 of UL 1950.

5. *Spacing* - Applies to parts in the TNV circuits that might ignite under over-voltage conditions. Spacing requirements mandate that parts be separated from internal materials of flammability class V-2 or lower, by at least 25mm of air or a barrier material of flammability class V-1 or better. Parts should also be separated from openings in the top or sides of the enclosure by at least 25mm of air or a material barrier.
6. *Over-Voltage Tests* - Equipment may be subject to the tests in Table 4-18 which are designed to simulate contact with primary power, short term induction as a result of a primary power fault to a multi-earth neutral, a long duration power fault to ground, and direct contact between the power mains and a telecommunications cable.

Figure 4-11 Over-Voltage Flowchart



Over-Voltage Test Procedures

The following criteria is used when applying the over-voltage tests found in Table 4-18:

1. *Test Set-Up* - Equipment is to be mounted as it is intended to be used. Tests may be conducted on either the equipment as an assembly, individual subassemblies, or a partial assembly containing those components which may be exposed to an over-voltage condition.
2. *Indicators* - Before testing, two single pieces of cheesecloth are to be wrapped tightly around the assembly, subassembly, or partial assembly. The cheesecloth acts as an indicator for conditions that may result in fire.

3. *Line Cords* - Equipment that has a removable telecommunications line cord is to be connected to the test circuit with a line cord having 0.4mm (26 AWG) or larger copper wire conductors and not more than 1Ω total resistance.
4. *Functional Circuitry* - UL mandates that functional circuitry must be used for each over-voltage test conducted. This allows damaged circuitry to be repaired or replaced before subsequent testing. Alternatively, separate samples may be used for each test.
5. *Wiring Simulators* - A wiring simulator is used to indicate whether the maximum I^2t imposed upon telecommunications wiring has been exceeded. For Tests 1 & 5, a wiring simulator is to be used unless the equipment is specified for use with a suitable secondary protector or a secondary protector simulator. The wiring simulator can consist of one of the following:
   a. A 50mm length of .2mm (32 AWG) bare or enameled solid copper wire (for Test condition 1).
   b. A Bussman Mfg. Co. Type MDL-2A fuse (for Test condition 1).
   c. A 300mm length of .4mm (no. 26 AWG) solid copper wire which connects to a representative installation (includes wiring an connectors). This option is used when the manufacturer specifies the complete installation from the network interface to the equipment.
   d. Current probe used with a 300mm length of .5mm (24 AWG) copper wire (for Test condition 1).

Note:
Test conditions 2, 3, & 4 do not require the use of a wiring simulator or a secondary protector simulator. Any secondary protection simulators used in Tests 1 & 5 should be similar to the test fuse used in UL 497A, Standard for Secondary Protectors for Communications Circuits.

Over-Voltage Test Compliance

Equipment is deemed compliant if both of the following conditions are met during test:

1. An absence of ignition or charring of the cheesecloth indicator (charring is deemed to have occurred when the threads have been reduced to char by a glowing or flaming condition).
2. The wiring simulator (Figures 4-12 & 4-13) does not open during the appropriate test, or for test condition 1 (Table 4-18), the integral I^2t measured with a current probe is less than $100A^2s$.

After completion of the Over-Voltage Tests, equipment must comply with either the Dielectric Voltage-Withstand Test requirements or Leakage Current Test requirements listed in sections 6.3 and 6.4 of UL 1950.

Special Considerations Regarding the SIDACtor and UL 1950.

- SIDACtors are recognized under UL 497B
- SIDACtor epoxy used is UL recognized and the encapsulated body passes UL 94V-0 requirements for flammability.
- The only specific requirements of UL 1950 that pertains to the SIDACtor itself is the mandate that components be UL listed. All other UL 1950 requirements pertain to the equipment being evaluated.

Table 4-18 UL 1950 Over-Voltage Test

Test	Voltage (V_{RMS})	Current (A)	Time	Comments
1	600	40	1.5s	Tests applied as shown in Figures: 4-12 & 4-13
2	600	7	5s	Tests applied as shown in Figures: 4-12 & 4-13
3	600 (Note 1)	2.2A or just below the interrupt value of the current interrupting device (Note 2)	30 min.	Test applied as shown in Figures: 4-12 & 4-13
4	(Note1)	(Note 2)	30 min.	Tests applied as shown in Figures: 4-12 & 4-13
5	120	25	30 min.	Test applied as shown in Figure: 4-13

Notes:

1. If the equipment design uses a voltage limiter designed to breakdown at a level of greater than $285V_{PK}$, then a voltage below this level is to be used during this test.
2. As an alternative test procedure, where a fuse causes an open circuit during test, the fuse may be bypassed and the available short circuit current applied set to 135% of the fuse rating.

Figure 4-12 Metallic Connection Appearances

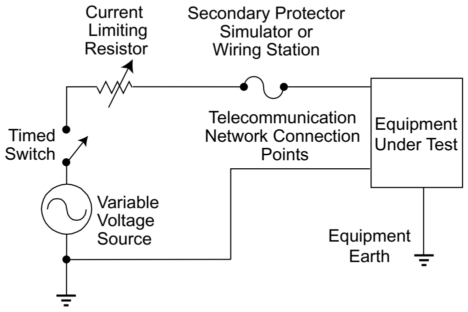
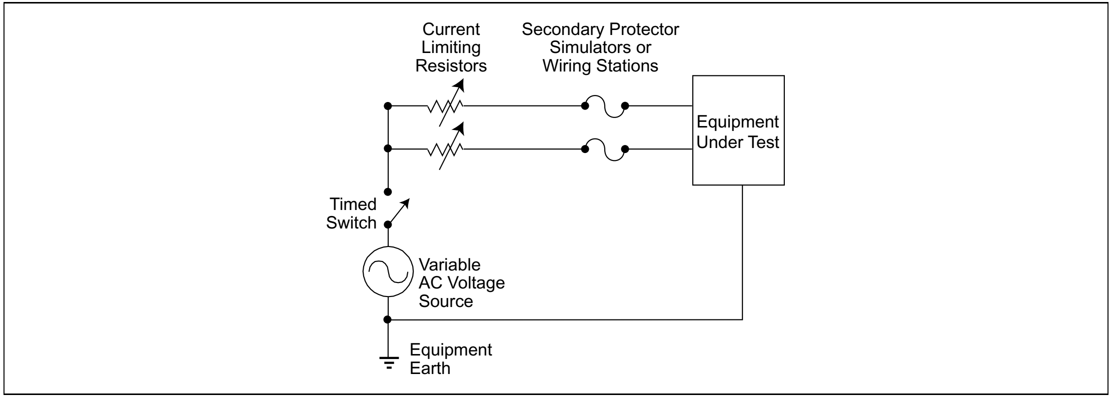


Figure 4-13 Longitudinal Connection Appearances



UL 497

UL 497 Series of Safety Standards

The UL 497 series is a family of three safety standards which provide requirements for protection devices used in low voltage circuits.

- *UL 497* issues requirements for primary protectors used in paired communications circuits
- *UL 497A* covers secondary protectors for use in single or multiple pair-type communications circuits
- *UL 497B* addresses protectors used in data communication and fire alarm circuits

Overview

The focus of *UL 497* is to ensure that paired communication circuit protectors do not become a fire or safety hazard. The requirements in *UL 497* cover any protector that is designed for paired communications circuits and is employed in accordance with article 800 of the National Electric Code. The protectors covered in *UL 497* include solid state primary and station protectors. These circuit protectors are intended to protect equipment, wiring, and service personnel against the effects of excessive voltage potential and currents in the telephone lines caused by lightning, power cross, power induction and rises in ground potential.

Construction and Performance

UL 497 is divided into two sections which cover construction and performance. Table 4-19 lists the content of each section.

Performance Tests

Key performance tests which concern over-voltage protectors are detailed in the arrestor test section. Specific requirements are:

- *Breakdown Voltage Measurement* - Arrestors are to be tested in the protector blocks or panels in which they are intended to be employed. Arrestors are required to breakdown within ± 25% of the manufacturers specified breakdown rating. In no case shall the breakdown voltage exceed $750V_{PK}$ when subjected to the strike voltage test shown in Figure 4-14. At no time during this test will the supply voltage be increased at a rate greater than 2000Vµs.
- *Impulse Spark-Over Voltage Measurement* - The arrestor must breakdown at less than $1000V_{PK}$ when subjected to a single impulse potential. Arrestors are to be tested in each polarity with a rate of voltage rise of 100V/µs, ± 10%.
- *Abnormal Operation* - Single pair fuse-less arrestors must be able to simultaneously carry $30A_{RMS}$ at $480V_{RMS}$ for 15 minutes without becoming a fire hazard. A fire hazard is determined by mounting the arrestor on a vertical soft wood surface and covering the unit with cheesecloth. Any charring or burning of the cheesecloth results in test failure. During this test, although the arrestors may short, they must not have an impulse spark-over voltage or dc breakdown voltage greater than $1500V_{PK}$.
- *Discharge Test* - Protectors must comply with the strike voltage requirements after being subjected to five successive discharges from a 2µF capacitor charged to $1000V_{DC}$ (Figure 4-15).
- *Repeated Discharge Test* - The arrestor must continue to breakdown at or below its

maximum rated breakdown voltage after being subjected to 500 discharges from a .001µF capacitor charged to a potential of 10,000V_{DC}. The interval between pulses is 5 seconds. Arrestors are to be tested in each polarity and it is acceptable for the protector to short circuit following the discharge testing (Figure 4-15).

Table 4-19 ***UL 497***

Construction	Performance
General requirements	General
Enclosures	Line Fuse Tests
Protection against corrosion	Instrument Fuse Tests
Field-Wiring Connections	Arrestor Tests
Components	Polymeric Material Tests
Spacing	Rubber Materials Tests
Fuses	Corrosion Test, Outdoor Use Protector
	Jarring Test
	Water Spray Test
	Drop Test
	Cover Replacement Test
	Stain Relief Test
	Replacement Arrestors Installation Test
	Appliqué Assemblies Installation Test
	Dielectric Voltage-Withstand Test
	Manufacturing and Production Tests
	Marking

Figure 4-14   Breakdown Voltage Measurement

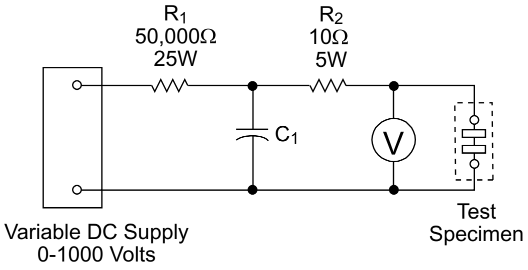
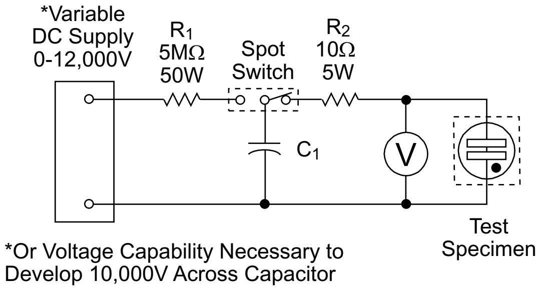


Figure 4-15   Discharge Test



UL 497A

Overview

UL 497A addresses secondary protectors for use in single or multiple pair-type communication circuits that are intended to be installed in accordance with Article 800 of the National Electric Code and have an operating voltage of less than 150V_{RMS} with respect to ground. The purpose of UL 497A is to help reduce the risk of fire, electric shock, or injury resulting from the deployment and use of these protectors.

Construction and Performance

UL 497A is divided into three sections covering construction, risk of injury, and performance requirements. Table 4-20 lists the contents of each section.

Table 4-20 UL 497A

Construction	Risk of injury to persons	Performance
General	Modular Jacks	General
Product Assembly	Sharp Edges	Impulse Voltage Measurement
Enclosures	Stability	Over-Voltage Test
Internal Material	Protection of service personnel	Endurance Conditioning
Accessibility and Electric Shock		Component Temperature Test
Protection against Corrosion		Drop Test
Cords		Crush Test
Current-Carrying Parts		Leakage Current Test
Internal wiring		Dielectric Voltage-Withstand Test
Interconnecting Cords and Cables		Rain Test
Insulating Material		Maximum Moment Measurement Test
Printed Wiring		Weather-o-meter and Micro Tensile Strength Test
Spacing		Thermal Aging and Flame Test
		Electric Shock Current Test
		Manufacturing an Production Line Test
		Marking, Installation & Instructions

Performance Tests

Key performance tests which concern over-voltage protection of the secondary protectors are:

1. *Impulse Voltage Measurement Test* - Secondary protectors must breakdown within ± 25% of the manufacturers breakdown rating when tested in each polarity with a rate of voltage rise of 100V/µs, ± 10%. It should be noted that the manufacturer may assign separate breakdown voltage ratings for the Breakdown Voltage Measurement Test. This requirement only applies to secondary protectors that connect between Tip and Ring of the telephone loop.
2. *Breakdown Voltage Measurement Test* - Secondary protectors must breakdown within ± 25% of the manufacturers breakdown rating when tested in each polarity with a rate of voltage rise no greater than 2000V/s. The secondary protector is to be mounted in accordance with the manufacturer’s installation instructions and then subjected to the test circuit in Figure 4-16. This requirement only applies to secondary protectors connected between Tip and Ring or Tip/Ring and ground of the telephone loop.
3. *Over-Voltage Test* - Secondary protectors must limit current and extinguish or open the telephone loop without loss of its over-voltage protector, indication of fire risk, or electric shock. Upon completion of this test, samples must comply with the dielectric voltage-withstand test.

The Over-Voltage Test is used to determine the effects on secondary protectors and is shown in Table 4-21. Test connections are shown in Figure 4-17.

Test Compliance

Compliance with the Over-Voltage Test is determined by meeting the following criteria:

- The cheesecloth indicator may not be either charred or ignited.
- The wiring simulator (1.6A Type MDQ fuse or 26 AWG line cord) may not be interrupted.
- The protector will meet the applicable dielectric voltage withstand requirements after the completion of the over-voltage tests.

Table 4-21 Over-Voltage Test

Test	Voltage (V_{RMS})	Current (A)	Time	Connection
L1	600	40	1.5 s	(Note 1, Fig. 4-17)
L2	600	7	5 s	(Note 1, Fig. 4-17)
L3	600	2.2, 1.0, 0.5, 0.25	30 min. at each current level	(Note 2, Fig. 4-17)
L4	$200V_{RMS}$ or just below the breakdown voltage of the over-voltage protection device	2.2A or just below the interrupt value of the current interrupting device	30 min.	(Note 2, Fig. 4-17)
L5	240	24	30 min.	(Note 1, Fig 4-17)

Notes:
1. Tests L1, L2, and L5 are to be applied between Tip and ground or Ring and ground.
2. Tests L3 and L4 are applied simultaneously from both Tip and Ring to ground.

Figure 4-16   Breakdown Voltage Measurement Test

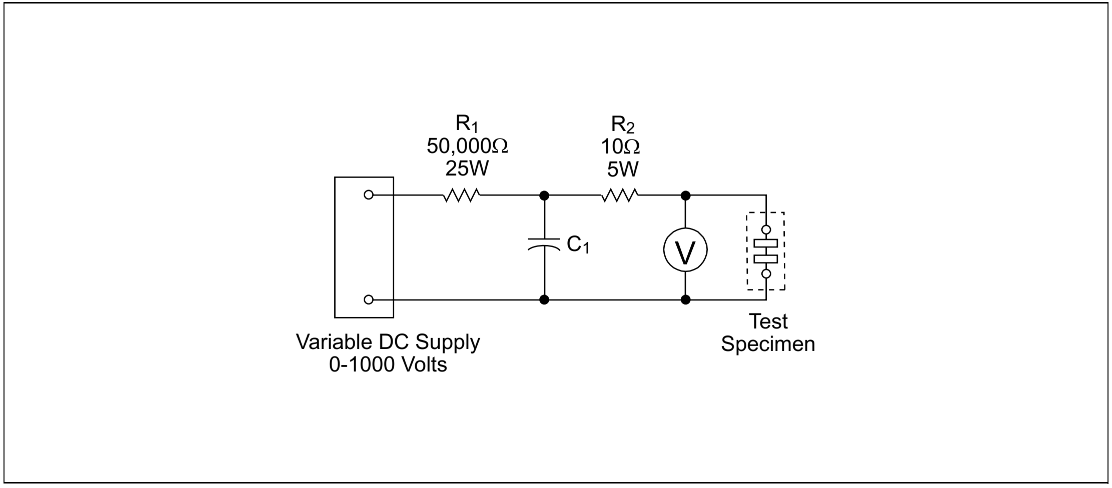
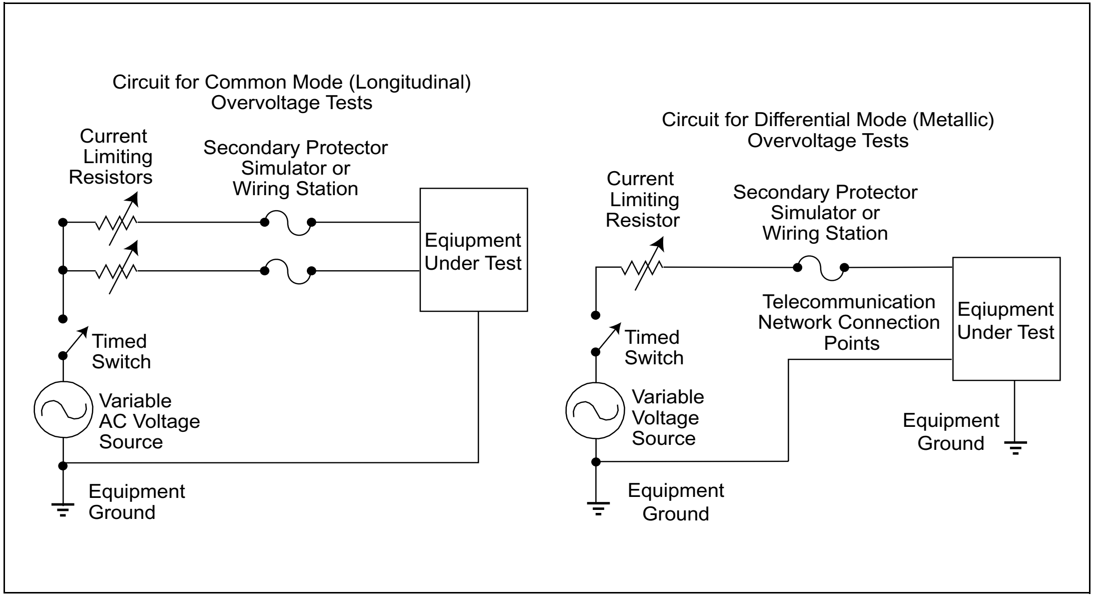


Figure 4-17   Over-Voltage Test



UL 497B

Overview

UL 497B provides requirements for protectors which are used in communication and fire alarm circuits. All SIDACtors are evaluated against this standard as individual components and are listed as UL 497B compliant devices under UL file No. E133083.

Construction and Performance

UL 497B is divided into two sections covering construction and performance requirements. Table 4-22 lists the contents of each main section.

Table 4-22 UL497B

Construction	Performance
General	General
Corrosion protection	Strike Voltage Breakdown
Field-Wiring Connections	Endurance Conditioning
Components	Temperature Test
Spacing	Dielectric Voltage-Withstand test
Fuses	Vibration Conditioning
	Jarring Test
	Discharge Test
	Repeated Discharge Test
	Polymeric Materials Test
	High Temperature Test
	Marking

Performance Requirements Specific to the SIDACtor

1. *Strike Voltage Breakdown Test* - Protectors are required to breakdown within the manufacturers specified breakdown range or within 10% of a nominal single breakdown voltage rating (Figure 4-18).
2. *Endurance Conditioning* - Protectors are subjected to 50 impulse cycles. Each cycle is a $1000V_{PK}$, 10A, 10x1000µs pulse. Pulses are applied in one polarity at 10 second intervals, and then repeated in the opposite polarity.
3. *Variable Ambient Conditioning* - Protectors must comply with the strike voltage requirements after being subjected to an ambient temperature of 0°C for 4 hours and again after being subjected to an ambient temperature of 49°C for an additional 4 hours.
4. *Discharge Test* - Protectors must comply with strike voltage requirements after being subjected to five successive discharges from a 2µF capacitor charged to $1000V_{DC}$ (Figure 4-19).

5. *Repeated Discharge Test* - Protectors must not break down at a voltage higher than the manufacturers maximum rated breakdown voltage nor lower than rated stand-off voltage after being subjected to 500 discharges from a .001µF capacitor charged to 10000V_{DC}. The discharges are applied in 5 second intervals between one side of the protector and ground. Upon completion of the discharge tests, protectors are once again required to meet the strike voltage requirement (Figure 4-19).

NOTE:
The epoxy used to construct the SIDACtor body meets UL 94V-0 requirements for flammability.

Figure 4-18 Strike Voltage Breakdown Test

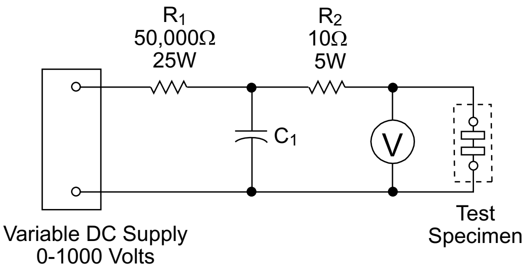
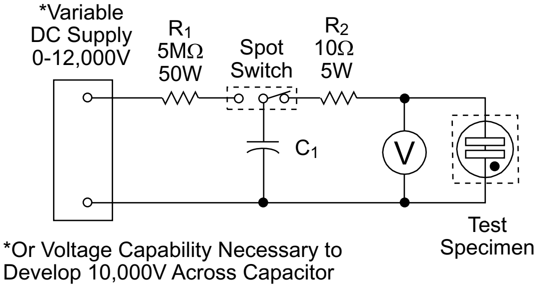


Figure 4-19 Discharge Test



Regulatory Compliant Solutions

Overview

When determining the most appropriate solution to meet the lightning and AC power fault conditions for regulatory requirements, coordination between the SIDACtor, fuse, and any series impedance that may be used is essential.

The following figures have taken this coordination into consideration and are offered as templates for the most cost effective and reliable solutions available. For exact design criteria and information regarding the applicable regulatory requirements, please refer to the SIDACtor and fuse selection criteria in Chapter 5 and the previous sections in Regulatory Requirements.

GR 1089 and ITU-T K.20 and K.21

Figures 4-20 and 4-21 are line interface protection circuits to meet Bellcore 1089 surge immunity requirements without the additional use of series resistance. To meet Bellcore 1089 surge immunity requirements, the "C" series SIDACtor and F1250T should be used. To meet ITU-T K.20 and K.21 surge immunity requirements without the additional use of resistance, the "A" series SIDACtor and F0500T should be used.

Figure 4-20

Balanced line protection using Teccor's "AC" or "AA" series.

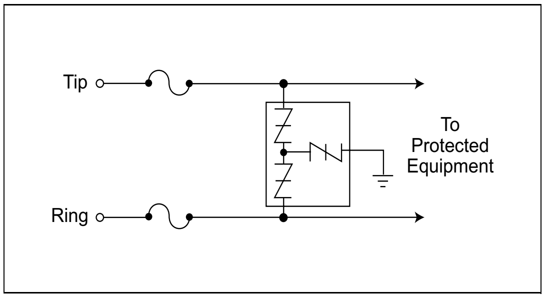
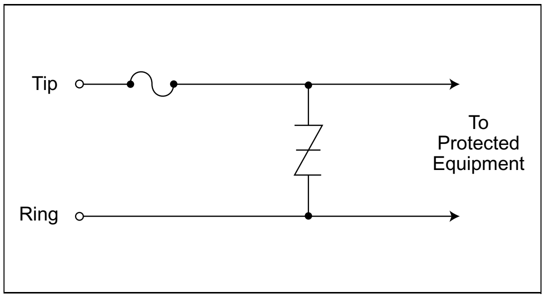


Figure 4-21

Metallic solution using Teccor's "SC" or "SA" series.



FCC Part 68 and UL 1459/UL 1950

Because equipment that is tested to FCC Part 68 specifications is also generally tested to UL specifications, it is easiest to look at a solution that meets both FCC and UL requirements simultaneously.

FCC Part 68 Operational Solution and UL 1459/UL 1950

Figures 4-22 and 4-23 are line interface protection circuits that meet both UL 1459 and UL1950 power cross requirements and pass FCC Part 68 Type A and Type B lightning immunity tests operationally.

FCC Part 68 Non-Operational Solution and UL 1459/UL 1950

Although Figures 4-22 and 4-23 provide an operational solution for FCC Part 68, FCC Part 68 allows telecommunications equipment to pass Type A surges non-operationally as well. For non-operational FCC Part 68 solutions, the I_{PP} rating of the SIDACtor and the I^2t rating of the fuse should be coordinated such that both will withstand the FCC Part 68 Type B surge, but during the Type A surge, the fuse will open.

Figures 4-24 and 4-25 are line interface protection circuits that meet UL power cross requirements and pass FCC Part 68 lightning immunity tests non-operationally.

Figure 4-22

Balanced line protection using Teccor's "AC" series.

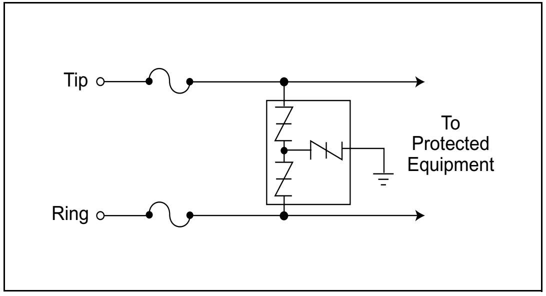


Figure 4-23

Metallic solution using Teccor's "SB" or "EB" series.

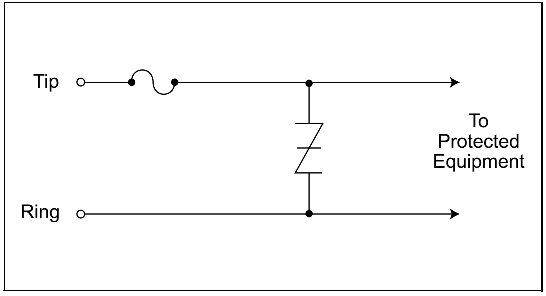


Figure 4-24

Balanced line protection using Teccor's "AA" series.

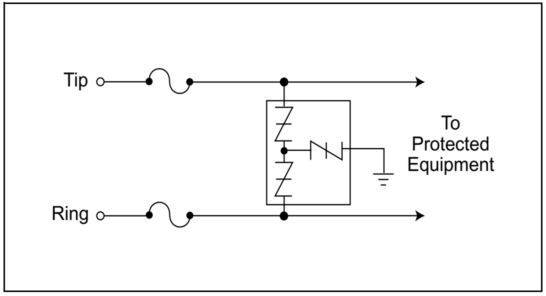
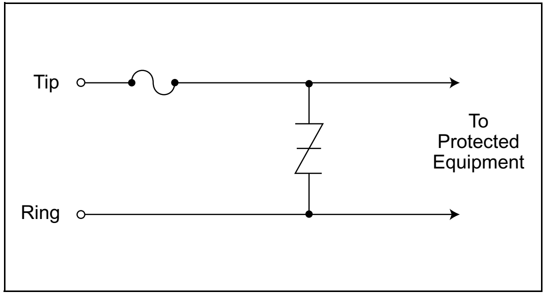


Figure 4-25

Metallic solution using Teccor's "SA" or "EA" series.



FCC Part 68 and UL 1950

In some instances, compliance with UL 1950 does not require a current limiting or fusing element. Figures 4-26 and 4-27 are line interface protection circuits that meet FCC Part 68 operationally and the requirements of UL 1950.

FCC Part 68 Only

In some instances, equipment intended for connection to the public network may only require FCC Part 68 approval. For equipment that only needs to meet FCC Part 68, Figures 4-26 and 4-27 should be referenced.

Figure 4-26

Balanced solution using Teccor's "AC" series.

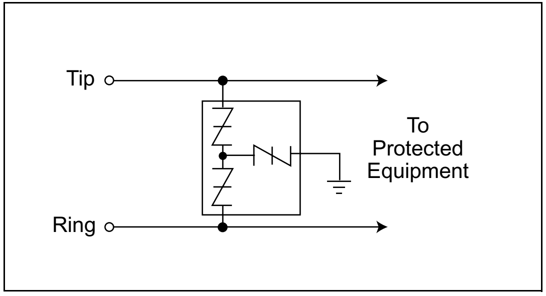
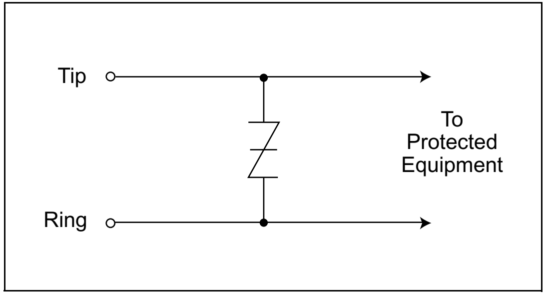


Figure 4-27

Metallic solution using Teccor's "SB" or "EB" series.



Surge Waveforms for Various Standards

Standard	**Voltage Volts**	**Waveform µsec**	**Current amps**	**Waveform µsec**	**SIDACtor w/o series R**
FCC Part 68					
Surge A Metallic	800	10x560	100	10x560	B or C
Surge A Longitudinal	1500	10x160	200	10x160	C
Surge B Metallic	1000	9x720	25	5x320	A, B or C
Surge B Longitudinal	1500	9x720	37.5	5x320	A, B or C
GR 1089					
1	600	10x1000	100	10x1000	C
2	1000	10x360	100	10x360	B or C
3	1000	10x1000	100	10x1000	C
4	2500	2x10	500	2x10	C
5	1000	10x360	25	10x360	A, B or C
ITU K.17	1500	10x700	37.5	5x310	A, B or C
ITU K.20	1000	10x700	25/100	5x310	A, B or C/C
ITU K.21	1500	10x700	37.5	5x310	A, B or C
	4000	10x700	100	5x310	B or C
RLM 88, CNET	1500	.5x700	38	.2x310	A, B or C
CNET 131-24	1000	.5x700	25	.8x310	A, B or C
VDE 0433	2000	10x700	50	5x310	A, B or C
VDE 0878	2000	1.2x50	50	1x20	A, B or C
IEC 61000-4-5	Level 3	10x700	50	5x310	A, B or C
	Level 4	1.2x50	100	8x20	A, B or C
FTZ R12	2000	10x700	50	5x310	A, B or C

5 Technical Notes

The following section is offered to help answer any questions regarding the SIDACtor and its implementation that have not been previously addressed.

Construction and Operation

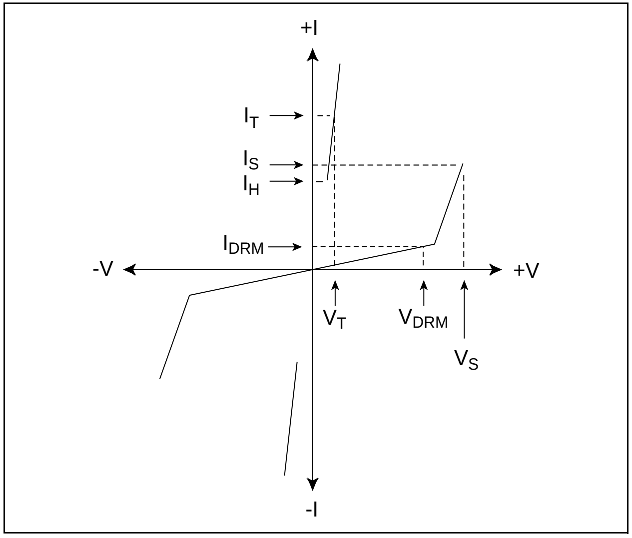
Overview

SIDACtors are thyristor devices used to protect sensitive circuits from electrical disturbances caused by lightning and AC power cross conditions. The unique structure and characteristics of the thyristor are used to create an over-voltage protection device with precise and repeatable turn-on characteristics with low voltage overshoot and high surge current capabilities.

Key Parameters

Key parameters for SIDACtors are V_{DRM}, I_{DRM}, V_S, I_H, and V_T. V_{DRM} is the repetitive peak off-state voltage rating of the device (also know as stand-off voltage) and is the continuous peak combination of AC and DC voltage that may be applied to the SIDACtor 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 (100V/µs) over-voltage condition. Holding current (I_H) is the minimum current required to maintain the device in the on-state. And on-state voltage (V_T) is the maximum voltage across the the device during full conduction.

Figure 5-1 V-I Characteristics



Operation

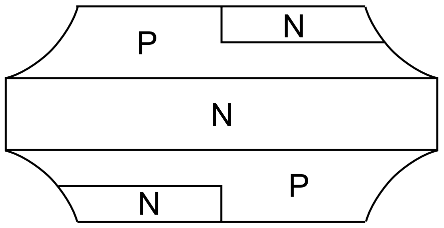
The SIDACtor operates much like a switch. In the off-state, the device exhibits leakage currents (I_{DRM}) less than 5µA making it invisible to the circuit it is protecting. As a transient voltage exceeds the SIDACtors V_{DRM}, the device will begin to enter its protective mode with characteristics similar to an avalanche diode. When supplied with enough current (I_S), the SIDACtor will switch to an on-state, shunting the surge from the circuit it is protecting. While in the on-state, the SIDACtor 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 resets, returning to its off-state.

Physics

The SIDACtor is a semiconductor device which is characterized as having four layers of alternating conductivity; PNPN. 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.

As the voltage across the SIDACtor increases and exceeds the devices 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's current gain exceeds unity. Once unity is exceeded, the SIDACtor 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 it's holding current (I_H).

Figure 5-2 Geometric Structure of Bidirectional SIDACtors



SIDACtor Selection Criteria

When selecting a SIDACtor, the following criteria should be used:

Off-state Voltage (V_{DRM})

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

Example 1: For a POTS (Plain Old Telephone Service) application, convert the maximum operating ring voltage ($150V_{RMS}$) to a peak voltage and add the maximum DC bias of the central office battery:

$$150V_{RMS}\sqrt{2} + 56.6V_{PK} = 268.8V_{PK}$$

$$\therefore\ V_{DRM} > 268.8V$$

Example 2: For an ISDN application, add the maximum voltage of the DC power supply to the maximum voltage of the transmission signal:

$$150V_{PK} + 3V_{PK} = 153V_{PK}$$

$$\therefore\ V_{DRM} > 153V$$

Switching Voltage (V_S)

The V_S of the SIDACtor 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: $V_S \leq \text{SLIC } V_{PK}$

Peak Pulse Current (I_{PP})

For circuits that do not require additional series resistance, the surge current rating (I_{PP}) of the SIDACtor 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 utilize additional series resistance, the surge current rating (I_{PP}) of the SIDACtor 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-GND, RING-GND), 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 FCC Part 68 without any series resistance.

I_{PK} = 100A, 10 x 560 µs

$\therefore\ I_{PP} \geq$ 100A, 10 x 560 µs

Example 2: A line card manufacturer must pass the surge requirements of Bellcore 1089 with 30 Ω on Tip and 30 Ω on Ring.

I_{PK} = 100A, 10 x 1000 µs

V_{PK} = 1000V

$R_{SOURCE} = V_{PK}/I_{PK\,=}$ 10 Ω

$R_{TOTAL} = R_{SOURCE\,+}\ R_{TIP}$ = 40 Ω

$I_{PK\ (available)} = V_{PK}/R_{TOTAL}$ = 100V/40Ω

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

Holding Current (I_H)

Because FCC Part 68.306.A.6.iii specifies that registered terminal equipment not exceed 140mA of DC current per conductor under short circuit conditions, the holding current of the SIDACtor is set at 150mA.

For specific design criteria, the holding current (I_H) of the SIDACtor 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% of the original signal value, the SIDACtor can be used in most applications with transmission speeds of up to 30MHz. For transmission speeds greater than 30MHz, a compensation circuit may be required.

Fuse Selection Criteria

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. In an attempt to simplify this process, Teccor has worked with several fuse manufacturers to compile Table 5-1.

Table 5-1:

	Equivalent I_{PP} Rating		
Fuse Rating (mA)	**10X160µs (A)**	**10X560µs (A)**	**10X1000µs (A)**
250	30	15	10
350	45	25	20
400	50	30	25
500	65	35	30
600	75	45	35
750	90	65	50
1000	130	85	65
1250	160	115	100

Notes:

1. The I_{PP} ratings apply to a 2AG slow blow fuse only.
2. Because there is a high degree of variance in the fusing characteristics, the I_{PP} ratings listed should only be used as approximations.

When selecting a fuse the following criteria should be used:

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 utilize 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-GND, RING-GND), 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):

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

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

Over-Voltage Protection Comparison

There are principally four different technologies used for over-voltage protection: Gas Discharge Tubes (GDTs), Metal Oxide Varistors (MOVs), TVS diodes, and SIDACtors. 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.

Gas Discharge Tubes

Overview

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

Restrictions

Gas tubes have a limited shelf life, their performance degrades with usage, and out of the four devices discussed, gas tubes exhibit the slowest response time and highest peak voltage measurement (Figure 5-3).

Applications

Because gas tubes are large and require a substantial amount of time to reach full conduction, they are rarely used as board level components. Consequently, gas tubes are not usually used in telecommunications applications other than station protection modules.

Metal Oxide Varistors

Overview

Metal Oxide Varistors (MOV's) 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, MOV's shunt transients by decreasing their resistance as voltage is applied.

Advantages

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

Restrictions

Like gas tubes, MOV's have slow response times resulting in peak clamping voltages which can be greater than twice the devices voltage rating (Figure 5-3). MOV's also have long term reliability and performance issues due to their tendency to fatigue, high capacitance and limited packaging options.

Applications

Although MOV's are restricted from being used 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

Overview

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.

Restrictions

Because TVS diodes are clamping devices, they have two inherent weaknesses. The first is that TVS diodes are both voltage and current limited, so careful consideration should be given to using these in applications that require large amounts of energy to be shunted. The second is that as the amount of current flowing through the device increases, so does its maximum clamping voltage.

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.

SIDACtors

Overview

A SIDACtor 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 will clamp a transient voltage to within the devices switching voltage (V_S) rating. Then, once the current flowing through the SIDACtor exceeds its switching current, the device will crowbar and simulate a short circuit condition. Once the current flowing through the SIDACtor is less than the devices holding current (I_H), the SIDACtor will reset and return to its high off-state impedance.

Advantages

Advantages of the SIDACtor include its fast response time (Figure 5-3), stable electrical characteristics, long term reliability, and low capacitance. Also, because the SIDACtor is a crowbar device, it can not be damaged by voltage and it has extremely high surge current ratings.

Restrictions

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

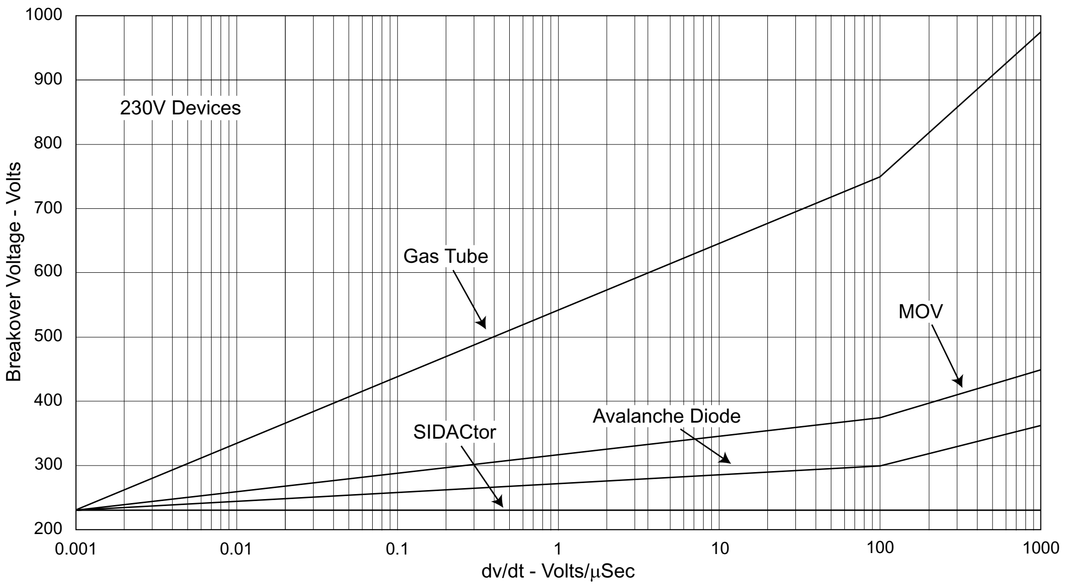
Applications

Although found in other applications, SIDACtors are primarily used as the principle over-voltage protector in telecommunications and data communications circuits. For applications outside this realm, the design criteria on pages 5-5 and 5-6 should be followed.

dV/dt Chart

Figure 5-3 is a peak voltage comparison between gas discharge tubes, MOV's, TVS diodes, and SIDACtors all with a nominal stand-off voltage rating of 230V. 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 5-3



Over-Current Protection

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

PTC's

Overview

PTC's 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 will increase its resistance asymptotically until the device simulates an open, 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 PTC's are resettable devices, they work well in a variety of industrial applications where electrical components can not withstand multiple, low current faults.

Restrictions

Although PTC's are well suited for the industrial environment and in many telecom applications, they exhibit some limitations that have prevented them from being endorsed by the entire telecommunications industry. Limitations include low surge current ratings, unstable resistance, and poor packaging options.

Applications

PTC's are used in a variety of applications. In addition to protecting telecommunications equipment, PTC's are also used to prevent damage to rechargeable battery packs, interrupt the current flow during a motor lock condition, and limit the sneak currents that may cause damage to a 5-pin module.

Fuses

Overview

Due to their stability, fuses are one of the most popular solutions for meeting AC power cross requirements for telecommunications equipment. Similar to PTC's, fuses function by reacting to the heat generated due to excessive current flow. Once the fuses I^2t rating is exceeded, the center conductor will open.

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 will only interrupt a circuit when extreme fault conditions exist, and when coordinated properly with an over-voltage protector, offer a very competitive and effective solution for transient immunity needs.

Weaknesses

Because a fuse will not reset, consideration should be given to their use in applications where multiple fault occurrences are likely. Examples such as AC strip protectors and ground fault interrupting circuits (GFIC) are applications where an alternative solution might be more prudent.

Applications

Telecommunications equipment that is 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.

Power/Line Feed Resistors

Overview

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 cross 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 cross condition.

Applications

Power and line feed resistors are typically found on line cards that use over-voltage protectors that can not withstand the surge currents associated with applicable regulatory requirements.

Flameproof Resistors

Overview

For cost sensitive designs, small, 1/8W - 1/4W flameproof metal film resistors are often used in lieu of PTC’s, 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 cheap 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

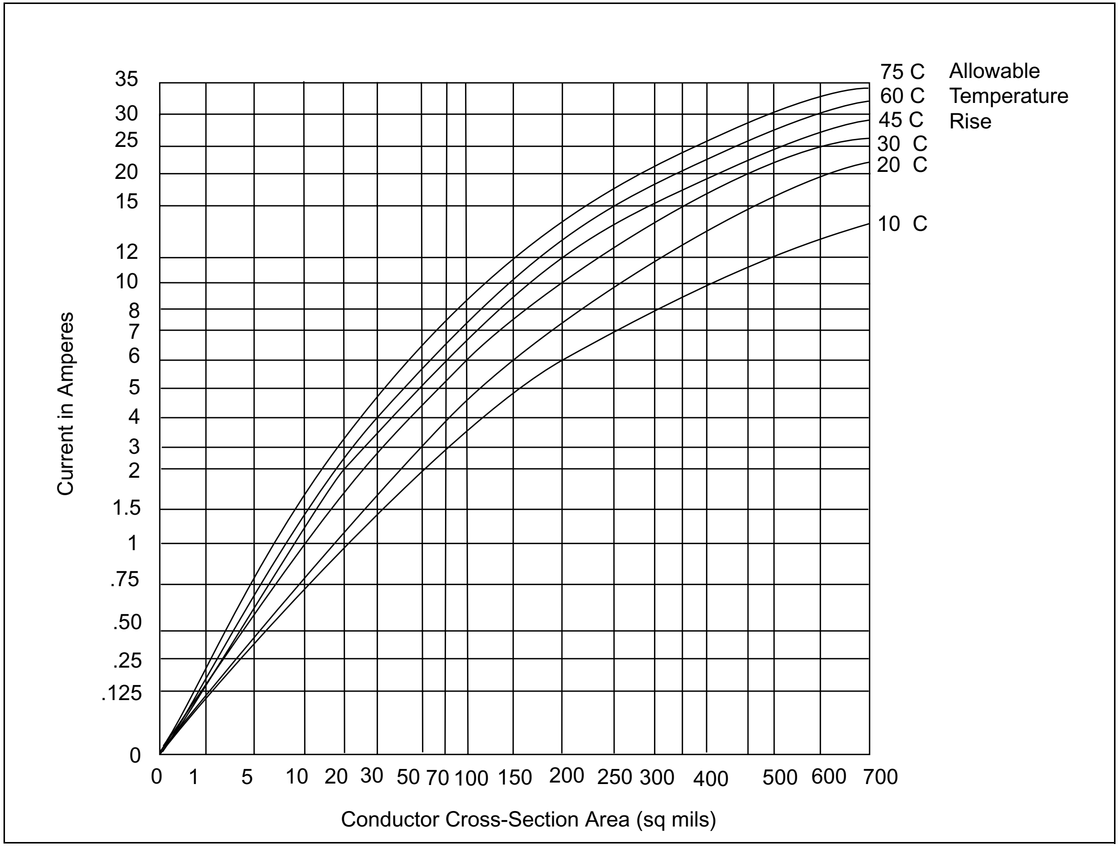
Overview

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

Trace Widths

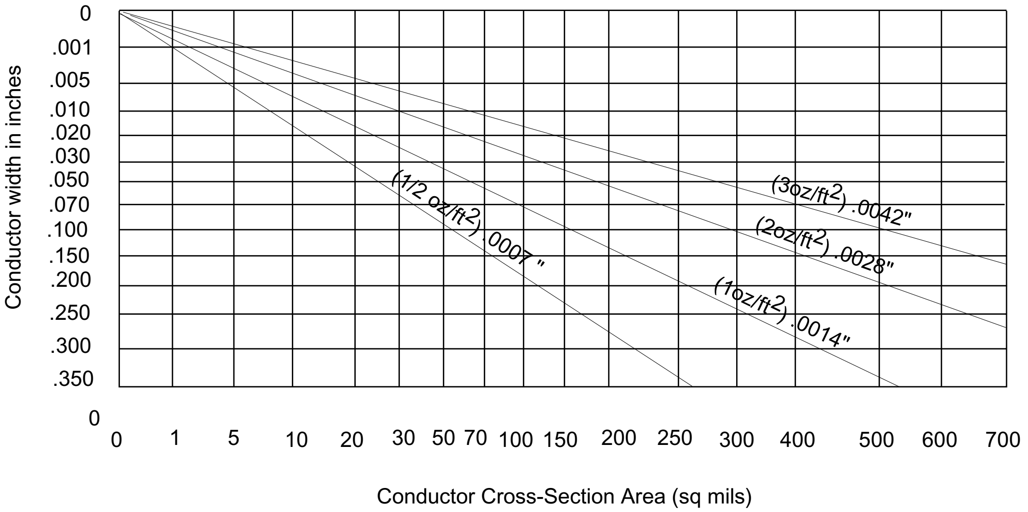
IPC-D- 275 specifies the trace widths required for various current carrying capacities. This is very important for grounding conditions to insure the integrity of the trace during a surge event. The required width is dependent on the amount of copper used for the trace and the acceptable temperature rise which can be tolerated. Teccor recommends a .025 inch trace width with 1oz. copper.

Figure 5-4 Current vs. 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 Figure 5-4 to calculate the conductor cross sectional area required. Once this has been done, Figure 5-5 converts the cross sectional area to the required conductor width dependent on the copper foil thickness of the trace.

Figure 5-5 Conductor Width vs. Area



Trace Separation

Because Tip and Ring traces are subjected to transient conditions, they should be routed towards the edge of the PCB away from sensitive areas, and should maintain a minimum separation of 2.5mm between themselves and other traces. A good rule of thumb for separation of non-coated top layer traces is to maintain spacing equal to .010mm per volt.

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.

The first is that a large copper plane should be provided using a grid pattern for the ground reference point.

Next, it should be decided if a single point or a multi point grounding scheme is to be used. A single-point (also called centralized) grounding scheme is used for circuit dimensions smaller than one-tenth of a wavelength ($\lambda = 300{,}000/F_{kHz}$) and a multi point (also called distributed) grounding scheme is used for circuit trace lengths greater than one-fourth of a wavelength.

Finally, because traces exhibit a certain level of inductance, the length of the ground trace on the PCB should be kept 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:

1. $V=L\,(dI/dt)$
2. $L=0.0051\rho\,[\log_e 2\rho/(t+w) + ½ - \log_e G]$ in µH

ρ = length of trace
G = is a function thickness and width as is given below
t = trace thickness
w = trace width

As an example, assume circuit A is protected by a P3100SC with a V_S equal to 300V and a ground trace one inch in length and a self-inductance equal to 2.4µH/inch. Assume circuit B has the identical characteristics as the first, except the ground trace is 5 inches in length instead of 1 inch in length. If both circuits are surged with a 100A, 10x1000µs wave-form, the results would be as follows:

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

Other practices to ensure sound grounding techniques are:

1. Always cross signal grounds and earth grounds perpendicularly in order to minimize the field effects of "noisy" power supplies.
2. Always 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 is invariably connected first.

Values Of Constants For The Geometric Mean Distance Of A Rectangle

t/w or w/t	**K**	**Log_eG**	**t/w or w/t**	**K**	**Log_eG**	**t/w or w/t**	**K**	**Log_eG**
.0	0.22313	.0	0.350	0.22366	0.00236	0.70	0.22355	0.00187
0.025	0.22333	0.00089	0.400	0.22364	0.00228	0.75	0.22354	0.00184
0.050	0.22346	0.00146	0.450	0.22362	0.00219	0.80	0.22353	0.00181
0.100	0.22360	0.00210	0.500	0.22360	0.00211	0.85	0.22353	0.00179
0.150	0.22366	0.00239	0.50	0.22360	0.00211	0.90	0.22353	0.00178
0.200	0.22369	0.00249	0.55	0.22358	0.00203	0.95	0.223525	0.00177
0.250	0.22369	0.00249	0.60	0.22357	0.00197	1.00	0.223525	0.00177
0.300	0.22368	0.00244	0.65	0.22356	0.00192	.0	.0	.0

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

Soldering Recommendations

Overview

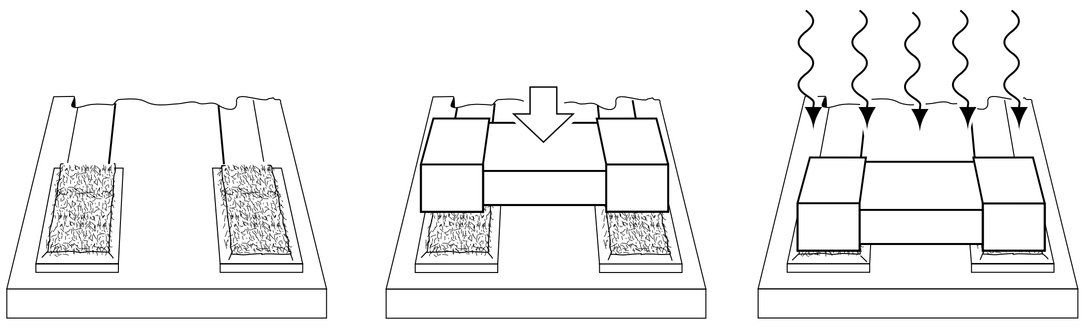
When placing surface mount components, a good solder bond is critical because:

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

Reflow Soldering

The preferred technique for mounting the DO-214 package is to reflow-solder the device onto a PCB - printed circuit board. (Figure 5-6).

Figure 5-6 Reflow Soldering Procedure



1. Screen print solder paste (or flux)

2. Place component (allow flux to dry)

3. Reflow solder

For reliable connections, the PCB should first be screen printed with a solder paste or fluxed with a reliable solution that is easily removed 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. 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 such that the maximum temperature of the leads does not exceed 275°C and the maximum temperature of the plastic body does not exceed 250°C (Figure 5-8).

Figure 5-7 Principle of Vapor Phase Soldering

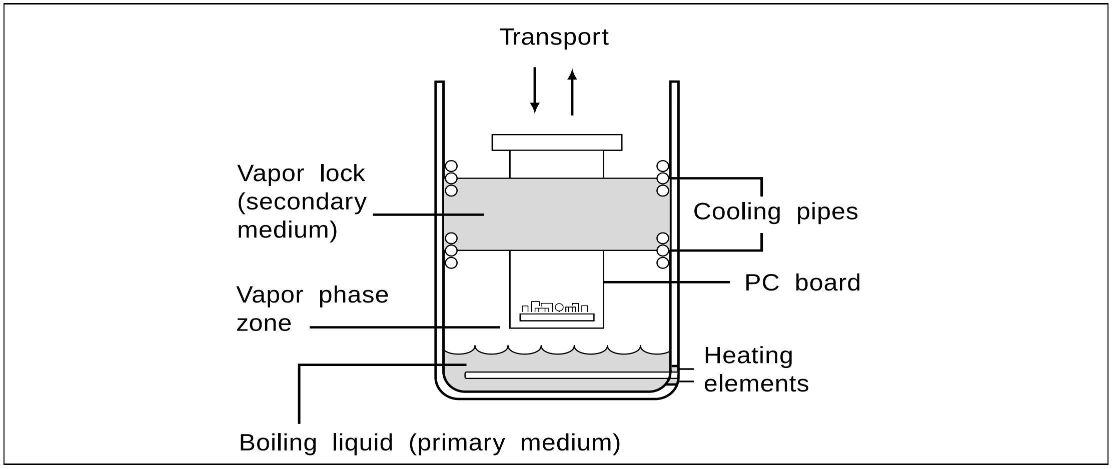
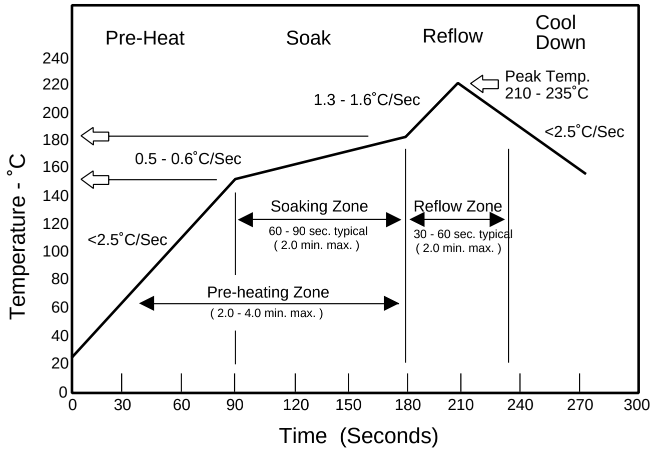


Figure 5-8 Reflow Soldering Profile



During reflow, the surface tension of the liquid solder will draw 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. However, if the footprints of the pad are not concentrically aligned, the same effect can result in undesirable shifts as well, hence the importance of using a standard contact pattern which leaves sufficient room for self-positioning.

After the solder has cooled, 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 adhesive is applied to the respective footprints such that components can be glued in place. Once the adhesive has cured, the board is pre-heated and then placed in contact with a molten wave of solder which has a temperature between 240°C - 260°C and permanently affixes the component to the PCB.

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

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

Figure 5-9 Wave Soldering Surface Mount Components Only

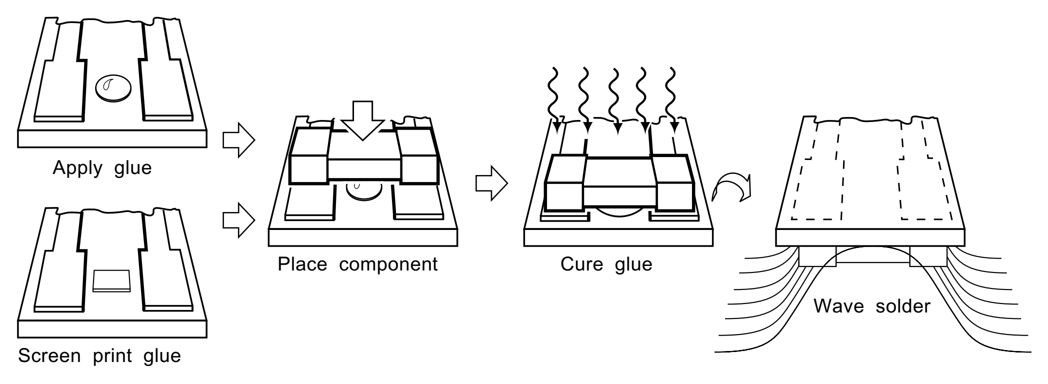
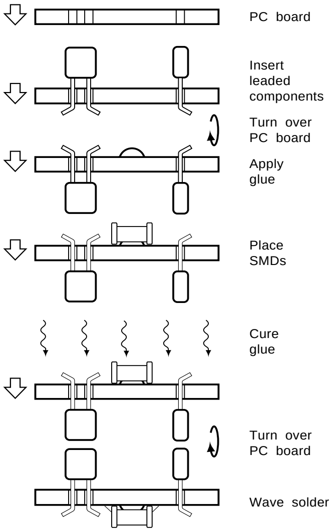


Figure 5-10 Wave Soldering Surface Mount and Leaded Components



Telecommunications Protection

Overview

Because early telecommunications equipment was constructed with components such as mechanical relays, coils, and vacuum tubes, it was somewhat immune to lightning and power cross 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.

System Transients

Telecommunications equipment connected to power and telephone cables is exposed to system transients caused by lightning and power cross conditions.

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 wave-form 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 by terminating equipment and is the primary reason most regulatory agencies require telecom equipment to have both longitudinal and metallic surge protection.

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 cross, power induction and ground potential rise.

Direct power cross occurs when a power line makes direct contact to a telecommunications cables. Direct contact is commonly caused by falling trees, winter icing, severe thunderstorms and vehicle accidents. Direct power cross 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

Overview

Lightning is one of nature's most common and dangerous phenomena. At any one time, there are approximately 2,000 thunderstorms in progress around the globe with lightning striking the earth over 100 times per second. During a single year in United States, lightning will strike 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

The formation of 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.

The Formation of Lightning

Cloud to ground lightning will begin 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 will begin 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 and can rise up out of a tree, roof of a house, or even the top of your head. 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.

The 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 500ms and 1 second.

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

Notes

6 *Mechanical Data*

The following section describes the mechanical specifications of SIDACtor products. Package dimensions, tape and reel dimensions and lead form options are included.

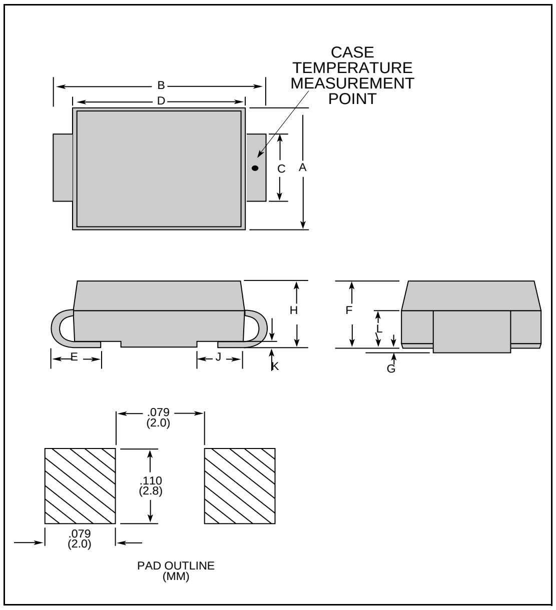
Package Dimensions

Tape and Reel Dimensions

Lead Form Options

DO-214

The DO-214 package is designed to meet mechanical standards as set forth in JEDEC publication number 95.



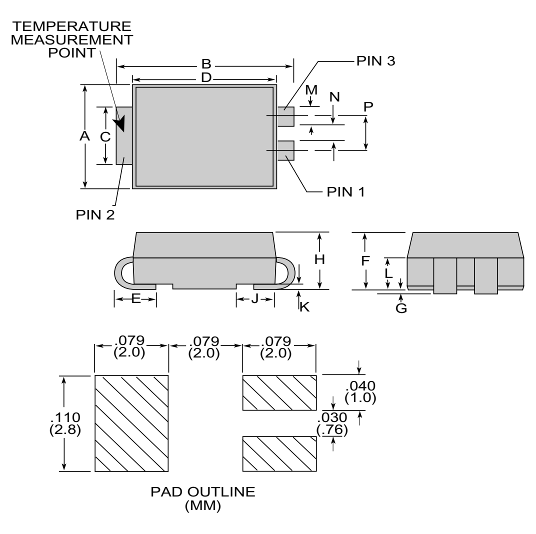
Dimension	Inches		Millimeters	
	Min	Max	Min	Max
A	.140	.155	3.56	3.94
B	.205	.220	5.21	5.59
C	.077	.083	1.96	2.11
D	.166	.180	4.22	4.57
E	.036	.056	.91	1.42
F	.073	.083	1.85	2.11
G	.004	.008	.10	.20
H	.082	.094	2.08	2.39
J	.043	.053	1.09	1.35
K	.008	.012	.20	.30
L	.039	.049	.99	1.24

NOTES:
Parts with stripe indicate cathode.

NOTES:
Dimensions and tolerances per ASME Y14.5M-1994.
Mold flash shall not exceed 0.13 mm per side.
Dimensions B and C apply to plated leads.
All leads are insulated from case. Case is electrically non-conductive. (Rated at 1600VAC RMS for 1 minute from leads to case over the operating temperature range.)

Modified DO-214

The Modified DO-214 package is a three leaded surface mount package.

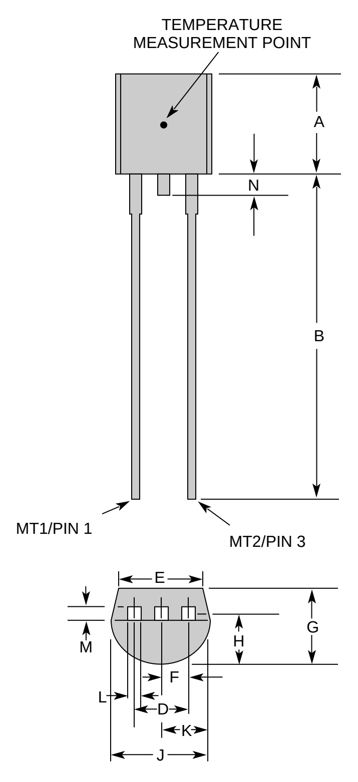


Dimension	Inches		Millimeters	
	Min	Max	Min	Max
A	.140	.155	3.56	3.94
B	.205	.220	5.21	5.59
C	.077	.083	1.96	2.11
D	.166	.180	4.22	4.57
E	.036	.056	.91	1.42
F	.073	.083	1.85	2.11
G	.004	.008	.10	.20
H	.082	.094	2.08	2.39
J	.043	.053	1.09	1.35
K	.008	.012	.20	.30
L	.039	.049	.99	1.24
M	.022	.028	.56	.71
N	.027	.033	.69	.84
P	.052	.058	1.32	1.47

NOTES:
Dimensions and tolerancing per ASME Y14.5M-1994.
Mold flash shall not exceed 0.13 mm per side.
Dimensions B and C apply to plated leads.
All leads are insulated from case. Case is electrically non-conductive. (Rated at 1600VAC RMS for 1 minute from leads to case over the operating temperature range.)

TO-92

The TO-92 is designed to meet mechanical standards as set forth in JEDEC publication number 95.

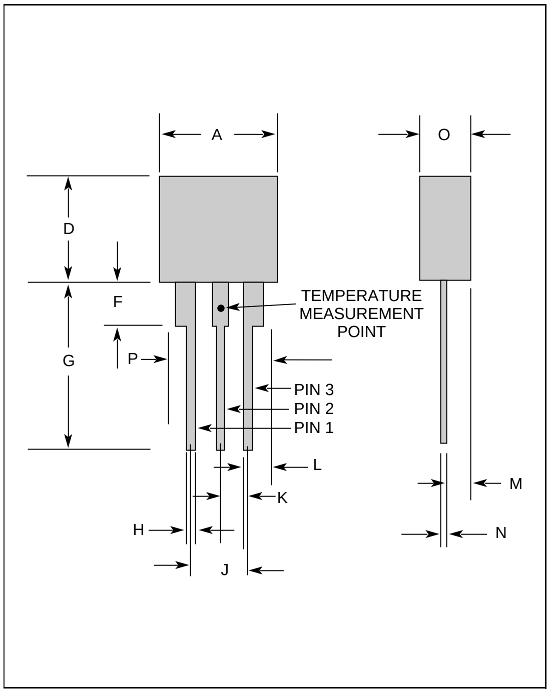


Dimension	Inches		Millimeters	
	Min	Max	Min	Max
A	.176	.196	4.47	4.98
B	.500		12.70	
D	.095	.105	2.41	2.67
E	.150		3.81	
F	.046	.054	1.16	1.37
G	.135	.145	3.43	3.68
H	.088	.096	2.23	2.44
J	.176	.186	4.47	4.73
K	.088	.096	2.23	2.44
L	.013	.019	0.33	0.48
M	.013	.017	0.33	0.43
N		.060		1.52

NOTES:
Type 70 lead form as shown is standard for the E package.
All leads are insulated from case. Case is electrically non-conductive. (Rated at 1600VAC RMS for 1 minute from leads to case over the operating temperature range.)
Mold flash shall not exceed 0.13 mm per side.

Modified TO-220

The Modified TO-220 package is designed to meet mechanical standards as set forth in JEDEC publication number 95.

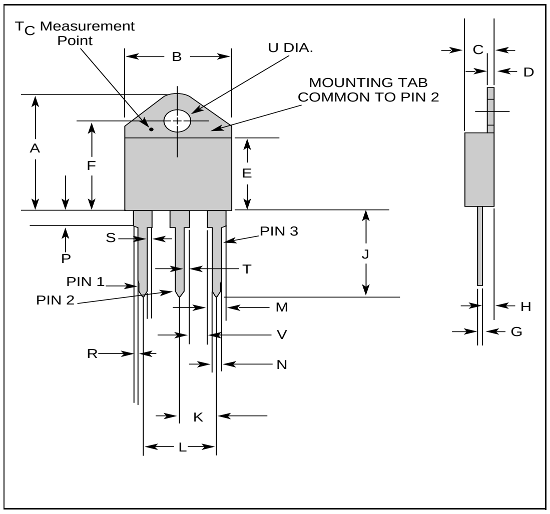


Dimension	Inches		Millimeters	
	Min	Max	Min	Max
A	0.400	0.410	10.16	10.42
D	0.360	0.375	9.14	9.53
F	0.110	0.130	2.80	3.30
G	0.540	0.575	13.71	14.61
H	0.025	0.035	0.63	0.89
J	0.195	0.205	4.95	5.21
K	0.095	0.105	2.41	2.67
L	0.075	0.085	1.90	2.16
M	0.070	0.085	1.78	2.16
N	0.018	0.024	0.46	0.61
O	0.178	0.188	4.52	4.78
P	0.310		7.87	

NOTES:
All leads are insulated from case. Case is electrically non-conductive. (Rated at 1600VAC RMS for 1 minute from leads to case over the operating temperature range.)
Mold flash shall not exceed 0.13 mm per side.

TO-218

The TO-218 package is designed to meet mechanical standards as set forth in JEDEC publication number 95.

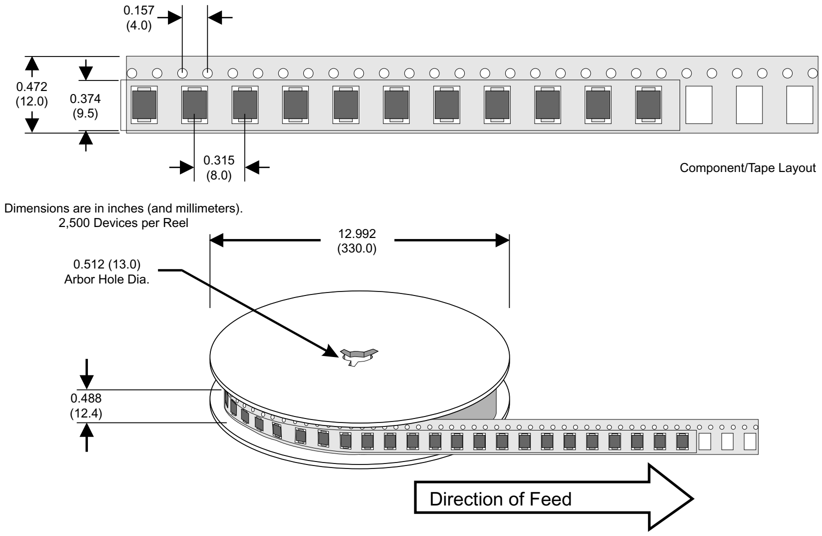


Dimension	Inches		Millimeters	
	Min	Max	Min	Max
A	.810	.835	20.57	21.21
B	.610	.630	15.49	16.00
C	.178	.188	4.52	4.78
D	.055	.070	1.40	1.78
E	.487	.497	12.37	12.62
F	.635	.655	16.13	16.64
G	.022	.029	0.56	0.74
H	.075	.095	1.91	2.41
J	.575	.625	14.61	15.88
K	.211	.219	5.36	5.56
L	.422	.437	10.72	11.10
M	.100	.110	2.54	2.79
N	.045	.055	1.14	1.40
P	.095	.115	2.41	2.92
R	.008	.016	0.20	0.41
S	.038	.048	0.97	1.22
T	.025	.032	0.64	0.81
U	.159	.163	4.04	4.14
V	.090	.100	2.29	2.54

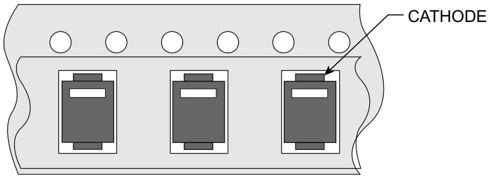
NOTES:
Mold flash shall not exceed 0.13 mm per side.
Maximum torque to be applied to mounting tab is 8 in-lbs. (0.904Nm).
Pin 3 has no connection.
Tab is non-isolated. (Connects to middle pin.)

DO-214 Tape and Reel

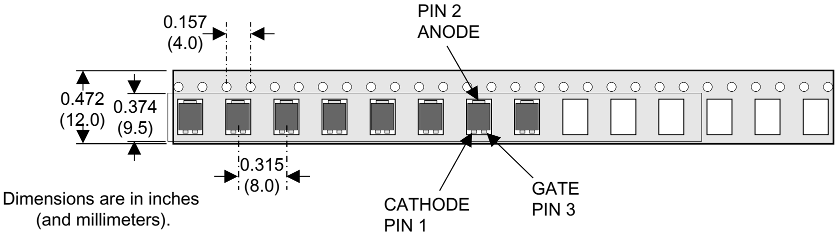
Tape and reel meets all specifications as set forth in EIA-481-1.
Standard reel pack quantity is 2500.



P0641_ and/or P0721_ DO-214 component orientation

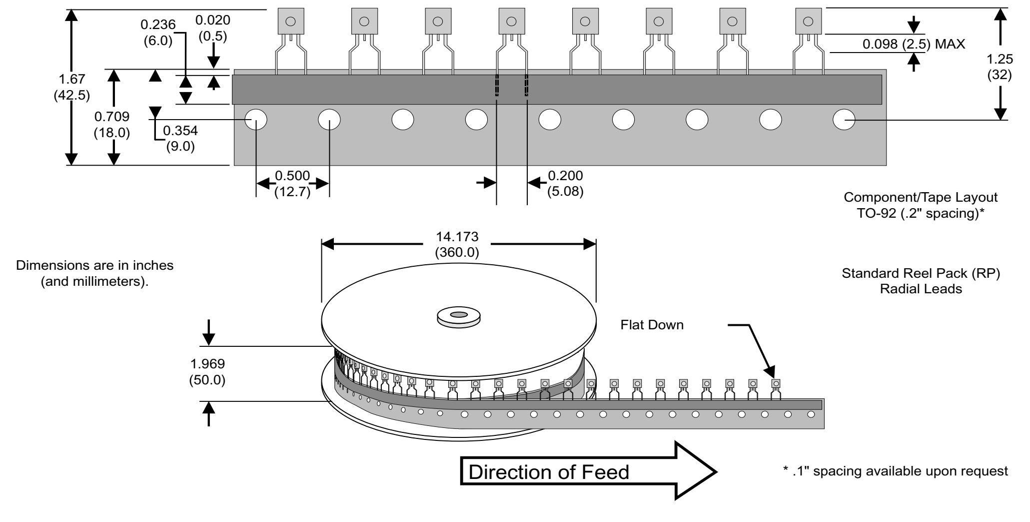


Modified DO-214 Tape and Reel



TO-92 Tape and Reel

Tape and reel meets all specifications as set forth in EIA-468-B.
Standard reel pack quantity is 2000.



Component/Tape Layout
TO-92 (.2" spacing)*

Dimensions are in inches
(and millimeters).

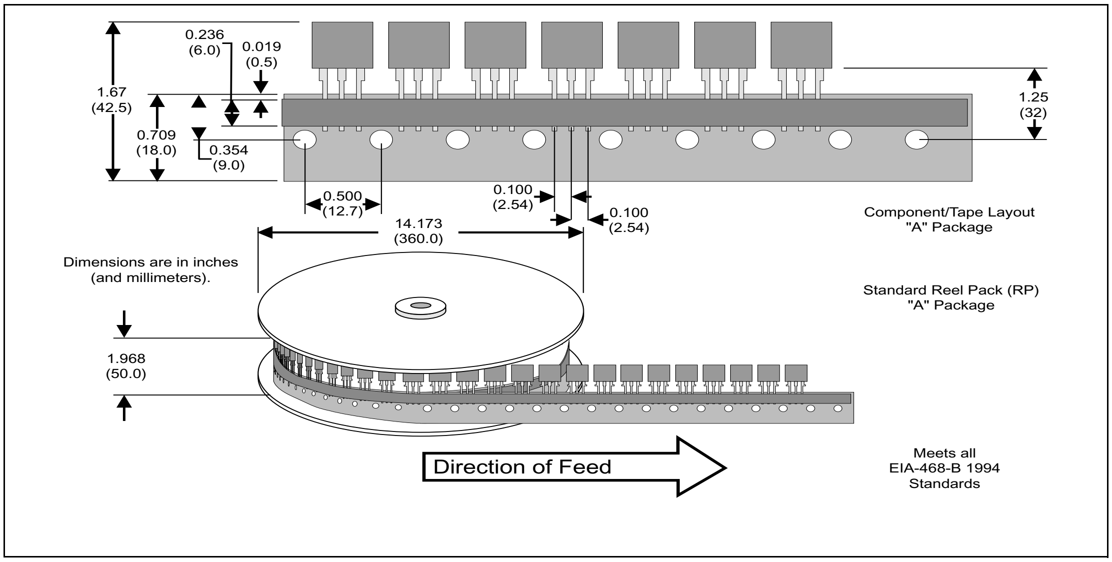
Standard Reel Pack (RP)
Radial Leads

* .1" spacing available upon request

NOTE: RP2 denotes .200” (5mm) lead spacing and is Teccor’s default value.
RP1 denotes .100” (2.54mm) lead spacing and is available upon request.

Modified TO-220 Tape and Reel

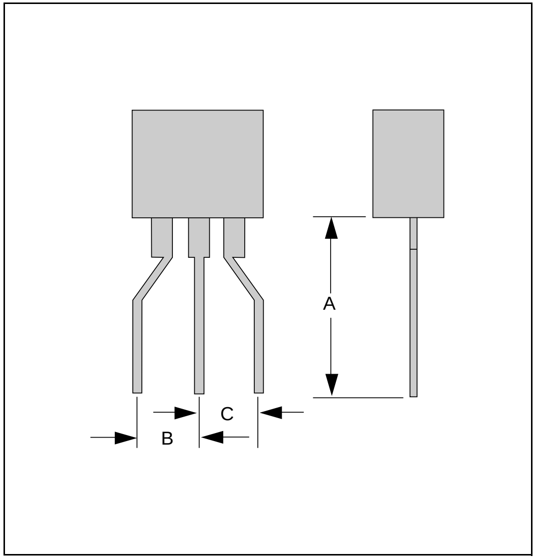
Tape and reel meets all specifications as set forth in EIA-468-B.
Standard reel pack quantity is 700.



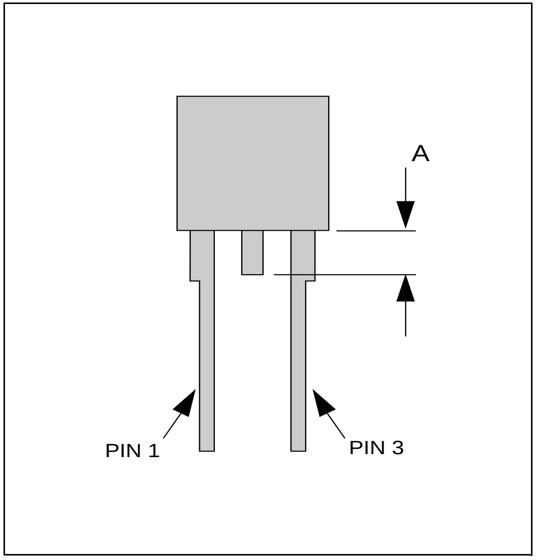
Modified TO-220 Leadform Options

Lead form options include:

Type 60 A Package



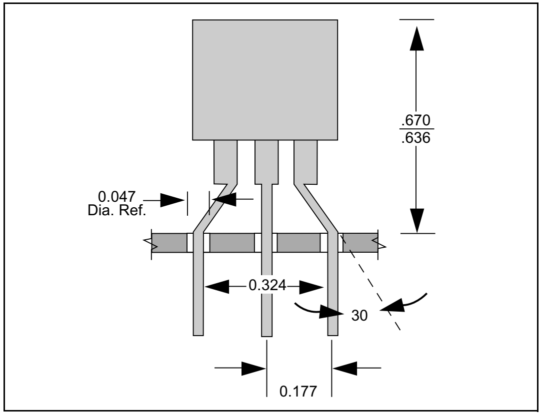
Type 61 A Package



Dimension	Inches		Millimeters	
	Min	Max	Min	Max
A	0.485		12.32	
B	0.162	0.192	4.11	4.88
C	0.162	0.192	4.11	4.88

Dimension	Inches		Millimeters	
	Min	Max	Min	Max
A	0.030	0.060	.762	1.52

PCB Layout Dimension for an A Pack Type 60 Part



Notes

7

Standard Terms and Conditions

TECCOR® ELECTRONICS

Standard Terms and Conditions

Supplier shall not be bound by any term proposed by Buyer in the absence of written agreement to such term signed by an authorized officer of Supplier.

(1) PRICE:

(A) Supplier reserves the right to change product prices at any time but, whenever practicable, Supplier will give Buyer at least thirty (30) days written notice before the effective date of any price change. Unless Supplier has specifically agreed in writing, signed by an authorized officer of Supplier, that a quoted price shall not be subject to change for a certain time, all products shipped on or after the effective date of a price change may be billed at the new price level.

(B) Whenever Supplier agrees to a modification of Buyer's order (which modification must be in writing and signed by an authorized officer of Supplier), Supplier reserves the right to alter its price, whether or not such price was quoted as “firm”.

(C) Prices do not include federal, state or local taxes, now or hereafter enacted, applicable to the goods sold. Taxes will be added by Supplier to the sales prices whenever Supplier has legal obligation to collect them and will be paid by Buyer as invoiced unless Buyer provides Supplier with a proper tax exemption certificate.

(2) PRODUCTION: Supplier may, at its sole discretion and at any time, withdraw any catalog item from further production without notice or liability to Buyer.

(3) INTEREST:

(A) All late payments shall bear interest thirty (30) days after the due date stated on the invoice until paid at the lower of one and one-half percent per month or the maximum rate permitted by law. All interest becoming due shall, if not paid when due, be added to principal and bear interest from the due date. At Supplier's option, any payment shall be applied first to interest and then to principal.

(B) It is the intention of the parties to comply with the laws of the jurisdiction governing any agreement between the parties relating to interest. If any construction of the agreement between the parties indicates a different right given to Supplier to demand or receive any sum greater than that permissible by law as interest, such as a mistake in calculation or wording, this paragraph shall override. In any contingency which will cause the interest paid or agreed to be paid to exceed the maximum rate permitted by law, such excess will be applied to the reduction of any principal amount due, or if there is no principal amount due, shall be refunded.

(4) TITLE AND DELIVERY: Title to goods ordered by Buyer and risk of loss or damage in transit or thereafter shall pass to Buyer upon Supplier's delivery of the goods at Supplier's plant or to a common carrier for shipment to Buyer.

(5) CONTINGENCIES: Supplier shall not be responsible for any failure to perform due to causes reasonably beyond its control. These causes shall include, but not be restricted to, fire, storm, flood, earthquake, explosion, accident, acts of public enemy, war rebellion, insurrection, sabotage, epidemic, quarantine restrictions, labor disputes, labor shortages, labor slow downs and sit downs, transportation embargoes, failure or delays in transportation, inability to secure raw materials or machinery for the manufacture of its devices, acts of God, acts of the Federal Government or any agency thereof, acts of any state or local government or agency thereof, and judicial action. Similar causes shall excuse Buyer for failure to take goods ordered by Buyer, from the time Supplier receives written notice from Buyer and for as long as the disabling cause continues, other than for goods already in transit or specially fabricated and not readily saleable to other buyers.

Supplier assumes no responsibility for any tools, dies, and other equipment furnished Supplier by Buyer.

(6) LIMITED WARRANTY AND EXCLUSIVE REMEDY: Supplier warrants all catalog products to be free from defects in materials and workmanship under normal and proper use and application for a period of twelve (12) months from the date code on the product in question (or if none, from the date of delivery to Buyer.) With respect to products assembled, prepared, or manufactured to Buyer's specifications, Supplier warrants only that such products will meet Buyer's specifications upon delivery. As the party responsible for the specifications, Buyer shall be responsible for testing and inspecting the products for adherence to specifications, and Supplier shall have no liability in the absence of such testing and inspection or if the product passes such testing or inspection. THE ABOVE WARRANTY IS THE ONLY WARRANTY EXTENDED BY SUPPLIER, AND IS IN LIEU OF AND EXCLUDES ALL OTHER WARRANTIES AND CONDITIONS, EXPRESSED OR IMPLIED (EXCEPT AS PROVIDED HEREIN AS TO TITLE), ON ANY GOODS OR SERVICES SOLD OR RENDERED BY SUPPLIER, INCLUDING ANY IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. THIS WARRANTY WILL NOT CREATE WARRANTY COVERAGE FOR ANY ITEM INTO WHICH ANY PRODUCT SOLD BY SUPPLIER MAY HAVE BEEN INCORPORATED OR ADDED.

SUPPLIER'S ENTIRE LIABILITY AND BUYER'S EXCLUSIVE REMEDY UNDER THIS WARRANTY SHALL BE, AT SUPPLIER'S OPTION, EITHER THE REPLACEMENT OF, REPAIR OF, OR ISSUANCE OF CREDIT TO BUYER'S ACCOUNT WITH SUPPLIER FOR ANY PRODUCTS WHICH ARE PROPERLY RETURNED BY BUYER DURING THE WARRANTY PERIOD. All returns must comply with the following conditions:

(A) Supplier is to be promptly notified in writing upon discovery of defects by Buyer.
(B) Buyer must obtain a Return Material Authorization (RMA) number from the Supplier prior to returning product.
(C) The defective product is returned to Supplier, transportation charges prepaid by Buyer.
(D) Supplier's examination of such product discloses, to its satisfaction, that such defects have not been caused by misuse, neglect, improper installation, repair, alteration, or accident.
(E) The product is returned in the form it was delivered with any necessary disassembly carried out by Buyer at Buyer's expense.

IN NO EVENT SHALL SUPPLIER, OR ANYONE ELSE ASSOCIATED IN THE CREATION OF ANY OF SUPPLIER'S PRODUCTS OR SERVICES, BE LIABLE TO BUYER FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY NATURE INCLUDING LOSS OF PROFITS, LOSS OF USE, BUSINESS INTERUPTION, AND THE LIKE. BUYER ACKNOWLEDGES THAT THE ABOVE WARRANTIES AND LIMITATIONS THEREON ARE APPROPRIATE AND REASONABLE IN EFFECTUATING SUPPLIER'S AND BUYER'S MUTUAL INTENTION TO CONDUCT AN EFFICIENT TRANSACTION AT PRICES MORE ADVANTAGEOUS TO BUYER THAN WOULD BE AVAILABLE IN THE PRESENCE OF OTHER WARRANTIES AND ASSURANCES.

(7) PATENTS: Buyer shall notify Supplier in writing of any claim that any product or any part of use thereof furnished under this agreement constitutes an infringement of any U.S. patent, copyright, trade secret, or other proprietary rights of a third party. Notice shall be given within a reasonable period of time which should in most cases be within ten (10) days of receipt by Buyer of any letter, summons, or complaint pertaining to such a claim. At its option, Supplier may defend at its expense any action brought against Buyer to the extent that it is based on such a claim. Should Supplier choose to defend any such claim, Supplier may fully participate in the defense, settlement, or appeal of any action based on such claim.

Should any product become, or in Supplier's opinion be likely to become, the subject of an action based on any such claim, Supplier may, at its option, as the Buyer's exclusive remedy, either procure for the Buyer the right to continue using the product, replace the product or modify the product to make it noninfringing. IN NO EVENT SHALL SUPPLIER BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES BASED ON ANY CLAIM OF INFRINGEMENT.

Supplier shall have no liability for any claim based on modifications of a product made by any person or entity other than Supplier, or based on use of a product in conjunction with any other item, unless expressly approved by Supplier. Supplier does not warrant goods against claims of infringement which are assembled, prepared, or manufactured to Buyer's specifications.

(8) NON-WAIVER OF DEFAULT: Each shipment made under any order shall be treated as a separate transaction, but in the event of any default by Buyer, Supplier may decline to make further shipments without in any way affecting its rights under such order. If, despite any default by Buyer, Supplier elects to continue to make shipments, its action shall not constitute a waiver of that or any default by Buyer or in any way affect Supplier's legal remedies for any such default. At any time, Supplier's failure to exercise any right to remedy available to it shall not constitute a waiver of that right or remedy.

(9) TERMINATION: If the products to be furnished under this order are to be used in the performance of a Government contract or subcontract, and the Government terminates such contract in whole or part, this order may be canceled to the extent it was to be used in the canceled portion of said Government contract and the liability of Buyer for termination allowances shall be determined by the then applicable regulations of the Government regarding termination of contracts. Supplier may cancel any unfilled orders unless Buyer shall, upon written notice, immediately pay for all goods delivered or shall pay in advance for all goods ordered but not delivered, or both, at Supplier's option.

(10) LAW: The validity, performance and construction of these terms and conditions and any sale made hereunder shall be governed by the laws of the state of Texas.

(11) ASSIGNS: This agreement shall not be assignable by either Supplier or Buyer. However, should either Supplier or Buyer be sold or transferred in its entirety and as an ongoing business, or should Supplier or Buyer sell or transfer in its entirety and as an ongoing concern, any division, department, or subsidiary responsible in whole or in part for the performance of this Agreement, this Agreement shall be binding upon and inure to the benefit of those successors and assigns of Supplier, Buyer, or such division, department, or subsidiary.

(12) MODIFICATION OF STANDARD TERMS AND CONDITIONS: No attempted or suggested modification of or addition to any of the provisions upon the face or reverse of this form, whether contained or arising in correspondence and/or documents passing between Supplier and Buyer, in any course of dealing between Supplier or Buyer, or in any customary usage prevalent among businesses comparable to those of Supplier and/or Buyer, shall be binding upon Supplier unless made and agreed to in writing and signed by an officer of Supplier.

(13) QUANTITIES: Any variation in quantities of electronic components, or other goods shipped over or under the quantities ordered (not to exceed 5%) shall constitute compliance with Buyer's order and the unit price will continue to apply.