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**Components for low-voltage surge
protective devices—Part 341:
Specification for thyristor surge
suppressors (TSS)**

ICS 31.080.10

Reference number : JIS C 5381-341 : 2005 (E)

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal of establishing a Japanese Industrial Standard from Electronics Materials Manufacturers Association of Japan (EMAJ)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

This Standard has been made based on IEC 61643-341:2001 *Components for low-voltage surge protective devices – Part 341: Specification for thyristor surge suppressors (TSS)* for the purpose of making it easier to compare this Standard with International Standard; to prepare Japanese Industrial Standard conforming with International Standard; and to propose a draft of an International Standard which is based on Japanese Industrial Standard.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

Editor's notice: EMAJ, which had drafted this Standard, has been reorganized into JEITA.

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Components for low-voltage surgeprotective devices— Part 341: Specification for thyristor surge suppressors (TSS)

Introduction This Japanese Industrial Standard has been prepared based on the first edition of IEC 61643-341 *Components for low-voltage surge protective devices—Part 341: Specification for thyristor surge suppressors (TSS)* published in 2001 without modifying the technical contents of the original International Standard.

1 Scope This part of JIS C 5381 is a test specification standard for thyristor surge suppressor (TSS) components designed to limit overvoltages and divert surge currents by clipping and crowbarring actions. Such components are used in the construction of surge protective devices, particularly as they apply to telecommunications.

This standard contains information on

- terms, letter symbols, and definitions
- basic functions, configurations and component structure
- service conditions and fault modes
- rating verification and characteristic measurement

Remarks : The International Standard corresponding to this Standard is as follows.

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and JIS are IDT (identical), MOD (modified), and NEQ (not equivalent) according to ISO/IEC Guide 21.

IEC 61643-341:2001 *Components for low-voltage surge protective devices—Part 341: Specification for thyristor surge suppressors (TSS)* (IDT)

2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS C 60721-3-3 *Classification of environmental conditions—Part 3: Classification of groups of environmental parameters and their severities—Section 3: Stationary use at weatherprotected locations*

NOTE : IEC 60721-3-3:1994 *Classification of environmental conditions—Part 3: Classification of groups of environmental parameters and their severities—Section 3: Stationary use at weatherprotected locations* is identical with the said standard.

JIS C 60721-3-9 *Classification of environmental conditions—Part 3: Classification of groups of environmental parameters and their severities—Section 9: Microclimates inside products*

NOTE : IEC 60721-3-9:1993 *Classification of environmental conditions—Part 3: Classification of groups of environmental parameters and their severities—Section 9: Microclimates inside products* is identical with the said standard.

JIS C 61000-4-5 *Electromagnetic compatibility (EMC)—Part 4: Testing and measurement techniques—Section 5: Surge immunity test*

NOTE : IEC 61000-4-5:1995 *Electromagnetic compatibility (EMC)—Part 4: Testing and measurement techniques—Section 5: Surge immunity test* is identical with the said standard.

IEC 60050(191) *International Electrotechnical Vocabulary—Chapter 191: Dependability and quality of service*

IEC 60050(702) *International Electrotechnical Vocabulary—Chapter 702: Oscillations, signals and related devices*

IEC 60099-4 *Surge arrestors—Part 4: Metal-oxide surge arrestors without gaps for a.c. systems*

IEC 60747-1 *Semiconductor devices—Discrete devices and integrated circuits—Part 1: General*

IEC 60747-2 *Semiconductor devices Discrete devices and integrated circuits—Part 2: Rectifier diodes*

IEC 60747-6 *Semiconductor devices—Discrete devices and integrated circuits—Part 6: Thyristors*

NOTE : The TSS has substantially different characteristics and usage to the type of thyristor covered by IEC 60747-6. These differences necessitate the new establishment of this standard.

IEC 60749 *Semiconductor devices—Mechanical and climatic test methods*

IEC 61083-1 *Digital recorders for measurements in high-voltage impulse tests—Part 1: Requirements for digital recorders*

ITU-T Recommendation K.20 *Resistibility of telecommunication switching equipment to overvoltages and overcurrents*

ITU-T Recommendation K.21 *Resistibility of subscribers' terminal to overvoltages and overcurrents*

ITU-T Recommendation K.28 *Characteristics of semi-conductor arrester assemblies for the protection of telecommunications installations*

3 Terms, letter symbols and definitions For the purpose of this part of Standard, the following definitions apply.

3.1 Parametric terms, letter symbols and definitions Where appropriate, terms, letter symbols and definitions are used from existing thyristor (IEC 60747-6) and rectifier diode (IEC 60747-2) standards.

NOTES 1 IEC 60747-1, chapter V, clause 2.1.1, states "IEC 60027 recommends the letters V and v only as reserve symbols for voltage; however, in the field of semiconductor devices, they are so widely used that in this publication they are on the same plane as U and u ." This standard uses the letters V and v for voltage with the letters U and u as alternatives.

- 2 When several distinctive forms of letter symbol exist, the most commonly used form is given first.

3.1.1 main terminal ratings listed ratings cover the appropriate requirements of the blocking, conducting and switching quadrants

3.1.1.1 repetitive peak off-state voltage, V_{DRM} rated maximum (peak) instantaneous voltage that may be applied in the off-state conditions including all d.c. and repetitive voltage components

3.1.1.2 repetitive peak on-state current, I_{TRM} rated maximum (peak) value of a.c. power frequency on-state current of specified waveshape and frequency which may be applied continuously

3.1.1.3 non-repetitive peak on-state current, I_{TSM} rated maximum (peak) value of a.c. power frequency on-state surge current of specified waveshape and frequency which may be applied for a specified time or number of a.c. cycles

3.1.1.4 non-repetitive peak impulse current, I_{PPSM} , I_{TSM} rated maximum value of peak impulse current of specified amplitude and waveshape that may be applied

NOTE : There are several symbols that are used for this rating. The merits of these symbols are as follows:

I_{PPSM} This is technically correct as it is the maximum or peak (M) non-repetitive (S) value of I_{PP} .

I_{TSM} For short duration impulses this is not technically correct as the maximum (M) value of non-repetitive (S) current may not occur when the device is in the on-state (T) condition.

I_{PPM} The use of this symbol for a non-repetitive value is discouraged. This symbol is the rated maximum (M) repetitive value of I_{PP} .

I_{PP} The use of this symbol for a rated value is discouraged. The term peak impulse current is a circuit parameter and is defined as the peak current for a series of essentially identical pulses.

3.1.1.5 repetitive peak reverse voltage, V_{RRM} rated maximum (peak) instantaneous voltage that may be applied in the reverse blocking direction including all d.c. and repetitive voltage components

3.1.1.6 non-repetitive peak forward current, I_{FSM} rated maximum (peak) value of a.c. power frequency forward surge current of specified waveshape and frequency which may be applied for a specified time or number of a.c. cycles

3.1.1.7 repetitive peak forward current, I_{FRM} rated maximum (peak) value of a.c. power frequency forward current of specified waveshape and frequency which may be applied continuously

3.1.1.8 critical rate of rise of on-state current, di/dt , $(di_T/dt)_{cr}$ rated value of the rate of rise of current which the device can withstand without damage

3.1.2 Main terminal characteristics

3.1.2.1 off-state voltage, V_D d.c. voltage when the device is in the off-state

3.1.2.2 off-state current, I_D d.c. value of current that results from the application of the off-state voltage, V_D

3.1.2.3 repetitive peak off-state current, I_{DRM} maximum (peak) value of off-state current that results from the application of the repetitive peak off-state voltage, V_{DRM}

3.1.2.4 breakover voltage, $V_{(BO)}$ maximum voltage across the device in or at the breakdown region measured under specified voltage rate of rise and current rate of rise

NOTE : Where a breakdown characteristic has several $V_{(BO)}$ values that need to be referenced, a numeric suffix can be added and the relevant part of the breakdown current range specified, e.g.

$$V_{(BO)1} : 0 < I_{(BR)} < 10 \text{ mA}$$

3.1.2.5 holding current, I_H minimum anode, principal, or thyristor current that maintains the thyristor in the on-state

3.1.2.6 off-state capacitance, C_o , C_j differential capacitance at the specified terminals in the off-state measured at specified frequency, f , amplitude, V_a and d.c. bias, V_D

3.1.2.7 repetitive peak reverse current, I_{RRM} maximum (peak) value of reverse current that results from the application of the repetitive peak reverse voltage, V_{RRM}

3.1.2.8 peak forward recovery voltage, V_{FRM} maximum value of forward conduction voltage across the device upon the application of a specified voltage rate of rise and current rate of rise following a zero or specified reverse-voltage condition

3.1.2.9 critical rate of rise of off-state voltage, dV/dt , $(dV_D/dt)_{cr}$ maximum rate of rise of voltage (below V_{DRM}) that does not cause switching from the off state to the on state

3.1.3 Additional and derived parameters The following derived and measured parameters may be necessary or useful for comparison, certain applications or statistical process controls.

3.1.3.1 breakdown voltage, $V_{(BR)}$ voltage across the device in the breakdown region (prior to the switching point) at a specified breakdown current, $I_{(BR)}$

NOTE : For positive breakdown slope devices, $V_{(BR)}$ may be used as an alternative to V_{DRM} .

3.1.3.2 breakdown current, $I_{(BR)}$ current through the device in the breakdown region

3.1.3.3 breakover current, $I_{(BO)}$ instantaneous current flowing at the breakover voltage, $V_{(BO)}$

3.1.3.4 switching voltage, V_S instantaneous voltage across the device at the final point in the breakdown region prior to switching into the on-state

3.1.3.5 switching current, I_S instantaneous current flowing through the device at the switching voltage, V_S

3.1.3.6 on-state voltage, V_T voltage across the device in the on-state condition at a specified current I_T

3.1.3.7 on-state current, I_T current through the device in the on-state condition

3.1.3.8 forward voltage, V_F voltage across the device in the forward conducting state at a specified current I_F

3.1.3.9 forward current, I_F current through the device in the forward conducting state

3.1.3.10 switching resistance, R_S derived equivalent slope resistance of the breakdown region, R_S , computed by:

$$\frac{V_{(BO)} - V_S}{I_S - I_{(BO)}}$$

3.1.3.11 insulation resistance derived equivalent insulation resistance of the device, computed by:

$$\frac{V_D}{I_D}$$

3.1.4 Temperature related parameters All the semiconductor-related TSS parameters are temperature dependent. The need for temperature dependence information can often be removed by specifying that a parameter's maximum or minimum value should be valid over the intended operating temperature range. Some common temperature related terms are shown hereafter.

3.1.4.1 temperature coefficient of breakdown voltage, $\alpha V_{(BR)}$, $dV_{(BR)}/dT_j$ ratio of the change in breakdown voltage, $V_{(BR)}$, to changes in temperature

NOTE : Expressed as either millivolts per Kelvin (mV/K) or per cent per Kelvin (%/K) with reference to the 25 °C value of breakdown voltage. Alternatives to mV/K and %/K are mV/°C and %/°C.

3.1.4.2 variation of holding current with temperature change in holding current, I_H , with changes in temperature and shown as a graph

3.1.4.3 temperature derating derating with temperature above a specified base temperature, expressed as a percentage, such as may be applied to peak pulse current

3.1.4.4 thermal resistance, R_{thJL} , R_{thJC} , R_{thJA} (R_{qJL} , R_{qJC} , R_{qJA}) effective temperature rise per unit power dissipation of a designated junction, above the temperature of a stated external reference point (lead, case or ambient) under conditions of thermal equilibrium

NOTE : Thermal resistance is usually expressed as K/W with °C/W as an alternative.

3.1.4.5 transient thermal impedance, $Z_{thJL(t)}$, $Z_{thJC(t)}$, $Z_{thJA(t)}$ ($Z_{\theta JL(t)}$, $Z_{\theta JC(t)}$, $Z_{\theta JA(t)}$) change in the difference between the virtual junction temperature and the temperature of a specified reference point or region (lead, case, or ambient) at the end of a time interval, divided by the step function change in power dissipation at the beginning of the same time interval which causes the change of temperature difference

NOTES 1 Thermal impedance is usually expressed as K/W with °C/W as an alternative.

2 It is the thermal impedance of the junction under conditions of change and is generally given in the form of a curve as a function of the duration of an applied power pulse.

3.1.4.6 (virtual) junction temperature, T_j , T_{Vj} theoretical temperature representing the temperature of the junction(s) calculated on the basis of a simplified model of the thermal and electrical behaviour of the device

NOTE : The term "virtual-junction temperature" is particularly applicable to multi-junction semiconductors and is used to denote the temperature of the active semiconductor element when required in specifications and test methods. The term "junction temperature", T_j , is used interchangeably with the term "virtual junction temperature", T_{Vj} , in this Standard.

3.1.4.7 maximum junction temperature, T_{JM} maximum value of permissible junction temperature, due to self heating, which a TSS can withstand without degradation

3.1.4.8 storage temperature range, $T_{stg\ min.}$ to $T_{stg\ max.}$ temperature range over which the device can be stored without any voltage applied

NOTE : Preferred temperature ranges (selected from IEC 60747-1, chapter VI, clause 5 and IEC 60749, chapter III, 1.2) are

0 °C to 125 °C

–55 °C to 125 °C

–65 °C to 150 °C

3.1.5 Gate terminal parameters

3.1.5.1 gate trigger current, I_{GT} lowest gate current required to switch a device from the off-state to the on-state

3.1.5.2 gate trigger voltage, V_{GT} gate voltage required to produce the gate trigger current, I_{GT}

3.1.5.3 gate-to-adjacent terminal peak off-state voltage, maximum gate to cathode voltage for a P-gate device or gate to anode voltage for an N-gate device that may be applied such that a specified off-state current, I_D , at a rated off-state voltage, V_D , is not exceeded

3.1.5.4 peak off-state gate current, I_{GDM} maximum gate current that results from the application of the peak off-state gate voltage, V_{GDM}

3.1.5.5 gate reverse current, adjacent terminal open, I_{GAO} , I_{GKO} current through the gate terminal when a specified gate bias voltage, V_G , is applied and the cathode terminal for a P-gate device or anode terminal for an N-gate device is open-circuited

3.1.5.6 gate reverse current, main terminals short-circuited, I_{GAS} , I_{GKS} current through the gate terminal when a specified gate bias voltage, V_G , is applied and the cathode terminal for a P-gate device or anode terminal for an N-gate device is short-circuited to the third terminal

NOTE : This definition only applies to devices with integrated series gate blocking diodes.

3.1.5.7 gate reverse current, on-state, I_{GAT} , I_{GKT} current through the gate terminal when a specified gate bias voltage, V_G , is applied and a specified on-state current, I_T , is flowing

NOTE : This definition only applies to devices with integrated series gate blocking diodes.

3.1.5.8 gate reverse current, forward conducting state, I_{GAF} , I_{GKF} current through the gate terminal when a specified gate bias voltage, V_{G} , is applied and a specified forward conduction current, I_{F} , is flowing

NOTE : This definition only applies to conducting unidirectional devices with integrated series gate blocking diodes.

3.1.5.9 gate switching charge, Q_{GS} charge through the gate terminal, under impulse conditions, during the transition from the off-state to the switching point, when a specified gate bias voltage, V_{G} , is applied

3.1.5.10 peak gate switching current, I_{GSM} maximum value of current through the gate terminal during the transition from the off state to the switching point, when a specified gate bias voltage, V_{G} , is applied

3.1.5.11 gate-to-adjacent terminal breakover voltage, $V_{\text{GK(BO)}}$, $V_{\text{GA(BO)}}$ gate-to-cathode voltage for a P-type device or gate to anode voltage for an N-gate device at the break-over point

NOTE : This is equivalent to the voltage difference between the breakover voltage, $V_{\text{(BO)}}$, and the specified gate voltage, V_{G} .

3.2 Terms and definitions for TSS, terminals and characteristic terminology

3.2.1 TSS

3.2.1.1 asymmetrical bidirectional TSS thyristor having substantially different switching behaviour in the first and third quadrants of the principal voltage-current characteristic

3.2.1.2 bidirectional TSS thyristor having switching behaviour in the first and third quadrants of the principal voltage-current characteristic

3.2.1.3 forward-blocking TSS TSS that switches only for negative main terminal-2 (cathode) voltage and exhibits a blocking state for positive main terminal-2 voltage

3.2.1.4 forward-conducting TSS TSS that switches only for negative main terminal-2 (cathode) voltage and conducts large currents at positive main terminal-2 voltage comparable in magnitude to the on-state voltage

3.2.1.5 negative breakdown resistance TSS TSS, whose static breakdown characteristic has a net negative resistance slope prior to switching

3.2.1.6 N-gate thyristor gated thyristor in which the gate terminal is connected to the N-region adjacent to the P-region to which the anode is connected and that is normally switched to the on-state by applying a negative signal between the gate and anode terminals

3.2.1.7 P-gate thyristor gated thyristor in which the gate terminal is connected to the P-region adjacent to the N-region to which the cathode is connected and that is normally switched to the on-state by applying a positive signal between the gate and cathode terminals

3.2.1.8 positive-breakdown-resistance TSS TSS whose static breakdown characteristic has a net positive-resistance slope prior to switching

3.2.1.9 reverse-blocking TSS TSS that exhibits a blocking state for positive cathode voltage

3.2.1.10 reverse-conducting TSS TSS that exhibits a conducting state for positive cathode voltage

3.2.1.11 symmetrical bidirectional TSS thyristor having substantially the same switching behaviour in the first and third quadrants of the principal voltage-current characteristic

3.2.1.12 thyristor bistable semiconductor device comprising three or more junctions that can be switched from the off state to the on state or vice versa, such switching occurring within at least one quadrant of the principal voltage-current characteristic

3.2.1.13 unidirectional TSS TSS that has switching characteristics in only one quadrant of the principal voltage-current characteristic

3.2.2 Terminals

3.2.2.1 anode electrode by which current enters the thyristor, when the thyristor is in the on-state with the gate open-circuited [IEC 60747-6]

NOTE : This term does not apply to bidirectional thyristors.

3.2.2.2 cathode electrode by which current leaves the thyristor, when the thyristor is in the on-state with the gate open-circuited

NOTE : This term does not apply to bidirectional thyristors.

3.2.2.3 gate electrode connected to one of the semiconductor regions to introduce a control current

3.2.2.4 main terminals the two terminals through which the principal current flows

NOTE : The main terminals may be named by application usage, e.g. in telecommunications, terminals may be named after line connections: R (ring), T (tip) and G (ground) or A, B and C (common)

3.2.2.5 main terminal 1 main terminal that is named 1 by the device manufacturer

3.2.2.6 main terminal 2 main terminal that is named 2 by the device manufacturer

3.2.2.7 (electrical) terminal externally available point of connection

3.2.3 Characteristic terminology

3.2.3.1 blocking term describing the state of a semiconductor device or junction that imposes high resistance to the passage of current

3.2.3.2 breakdown phenomena occurring in a reverse biased semiconductor junction, the initiation of which is observed as a transition from a region of high dynamic resistance to a region of substantially lower dynamic resistance for increasing magnitude of reverse current

3.2.3.3 breakdown region portion of the characteristic that starts with the transition from the high dynamic resistance off-state to a substantially lower dynamic resistance and extending to the switching point

3.2.3.4 breakover point any point in the breakdown region voltage-current characteristic for which the differential resistance is zero and where the principal voltage reaches a maximum value [IEC 60747-6, definition 2.16, modified]

NOTE: If more than one breakover point exists in the breakdown region, the one with the highest voltage value is characterized.

3.2.3.5 characteristic inherent and measurable property of a device

NOTE: Such a property may be electrical, mechanical, thermal, hydraulic, electromagnetic or nuclear and can be expressed as a value for stated or recognized conditions. A characteristic may also be a set of related values, usually shown in graphical form.

3.2.3.6 clipping (clamping) form of limiting in which all the instantaneous values of a signal exceeding a predetermined threshold value are reduced to values close to that of the threshold, all other instantaneous values of the signal being preserved [IEV 702-04-33]

NOTE: The word clamping is often used instead of clipping, although IEC 702-04-37 defines clamping as "a process in which some feature of a recurrent signal, for instance its d.c. component, is held at a reference value".

3.2.3.7 crowbarring form of limiting whereby when the instantaneous value of a signal becomes greater than a predetermined threshold value a low impedance shunt is activated. When active, the shunt, in conjunction with the signal source impedance, reduces the signal amplitude

3.2.3.8 forward/reverse blocking quadrant quadrant of the principal voltage-current characteristic in which the device exhibits a reverse blocking state [IEC 60747-6, modified]

NOTE : This will be the first quadrant for a forward blocking TSS and the third quadrant for a reverse blocking TSS.

3.2.3.9 forward/reverse conducting quadrant quadrant of the principal voltage-current characteristic in which the device exhibits a forward direction conduction state [IEC 60747-6, modified]

NOTE : This will be the first quadrant for a forward conducting TSS and the third quadrant for a reverse conducting TSS.

3.2.3.10 forward direction

- 1) direction of current in a P-N junction that results when the P-type semiconductor region is at a positive potential relative to the N-type region
- 2) direction of current in a semiconductor device that results when the P-type semiconductor region connected to one terminal is at a positive potential relative to the N-type region connected to the other terminal

NOTE : This definition does not apply if one or more junctions are connected in series with at least one other junction whose P and N regions are reversed.

3.2.3.11 maximum rating (absolute maximum rating) rating that establishes either a limiting capability or a limiting condition beyond which damage to the device may occur

NOTE : A limiting condition may be either a maximum or a minimum.

3.2.3.12 negative differential-resistance (region) region of the principal voltage-current characteristic in the switching quadrant where the differential resistance is negative and the thyristor switches between the breakdown and on-state regions [IEC 60747-6, modified]

3.2.3.13 non-repetitive current rating maximum rating that may be applied to the device for a minimum of 100 times over the life of the device without failure

NOTE : During the rated condition, the device is permitted to exceed its maximum rated junction temperature for short periods of time. The device is not required to block voltage or retain any gate control during or immediately following this rated condition until the device has returned to the original equilibrium conditions. This rated condition may be repeated after the device has returned to the original thermal equilibrium conditions.

3.2.3.14 off state (region) state of the TSS in a quadrant in which switching can occur, that corresponds to the high dynamic-resistance portion of the characteristic between the origin and the beginning of the breakdown region [IEC 60747-6, modified]

3.2.3.15 on state (region) condition of the TSS corresponding to the low-resistance low-voltage portion of the principal voltage-current characteristic in the switching quadrant(s)

3.2.3.16 parameter device descriptor that is measurable or quantifiable, such as a characteristic or rating

3.2.3.17 principal current generic term for the current through the device excluding any gate current

NOTE : It is the current through both main terminals.

3.2.3.18 principal voltage voltage between the main terminals

NOTES 1 In the case of reverse blocking and reverse conducting thyristors, the principal voltage is called positive when the anode potential is higher than the cathode potential, and called negative when the anode potential is lower than the cathode potential.

2 For bidirectional thyristors, the principal voltage is called positive when the potential of main terminal 2 is higher than the potential of main terminal 1.

3 For forward-conducting thyristors the principal voltage is called positive when the cathode potential is higher than the anode potential, and called negative when the cathode potential is lower than the anode potential.

3.2.3.19 principal voltage-current characteristic (principal characteristic) function, usually represented graphically, relating the principal voltage to the principal current

3.2.3.20 quadrant when the principal voltage-current characteristic is expressed graphically, the voltage, v , and current, i , axes create four areas called quadrants. These quadrants are termed counter clockwise as first, second, third and forth quadrants. The characteristic occurs in the first quadrant, $+v$ and $+i$, and the third quadrant, $-v$ and $-i$

3.2.3.21 rating nominal value of any electrical, thermal, mechanical, or environmental quantity assigned to define the operating conditions under which a component, machine, apparatus, electronic device, etc., is expected to give satisfactory service

NOTE : 'Rating' is a generic term. See also maximum rating (3.2.3.11).

3.2.3.22 repetitive rating maximum rating that may be continuously applied to the thyristor

3.2.3.23 reverse direction

- 1) direction of current in a P-N junction that results when the N-type semiconductor region is at a positive potential relative to the P-type region
- 2) direction of current in a semiconductor device that results when the N-type semiconductor region connected to one terminal is at a positive potential relative to the P-type region connected to the other terminal

NOTE : This definition may not apply if one or more junctions are connected in series with at least one other junction whose P and N regions are reversed.

3.2.3.24 switching point point in the principal voltage-current characteristic at which the thyristor regenerates and initiates switching into the on-state

NOTE : This point occurs at the termination of the breakdown region and the start of the negative differential-resistance region

3.2.3.25 switching quadrant quadrant of the principal voltage-current characteristic in which the device is intended to switch between the off-state and the on-state

NOTE : For a bidirectional thyristor the switching quadrants are the first quadrant and the third quadrant. For a reverse blocking or reverse conducting thyristor the switching quadrant is the first quadrant. For a forward conducting or reverse conducting thyristor the switching quadrant is the third quadrant.

4 Basic function and component description This clause covers the TSS types, basic device structure, its equivalent circuit, characteristic values, operational parameters and structures with increased functions.

4.1 TSS types The TSS is classified by the type of characteristic in the first and third quadrants), and the number of terminals. At least one quadrant will have a switching characteristic (see figure 1). The other quadrant may have a switching, blocking or diode conduction characteristic (see figures 1 and 2). Devices with only one switching quadrant are called unidirectional and may have two (diode), three (triode) or four (tetrode) terminals. In addition, devices with two switching quadrants are called bidirectional and may have up to five (pentode) terminals (see table 1).

Table 1 Types of TSS

Number of terminals	Other quadrant characteristics		
	Blocking	Conducting	Switching
2 (diode)	Reverse blocking or forward block- ing diode TSS	Reverse conduct- ing or forward con- ducting diode TSS	Bidirectional di- ode TSS
3 (triode)	Reverse blocking or forward block- ing triode TSS P-gate or N-gate	Reverse conduct- ing or forward con- ducting triode TSS P-gate or N-gate	Bidirectional tri- ode TSS P-gate or N-gate or com- bined P-gate and N-gate (TRIAC)
4 (tetrode)	Reverse blocking or forward block- ing tetrode TSS P-gate and N-gate	Reverse conduct- ing or forward con- ducting tetrode TSS P-gate and N-gate	Bidirectional tet- rode TSS 2 gates
5 (pentode)			Bidirectional pen- tode TSS 3 gates

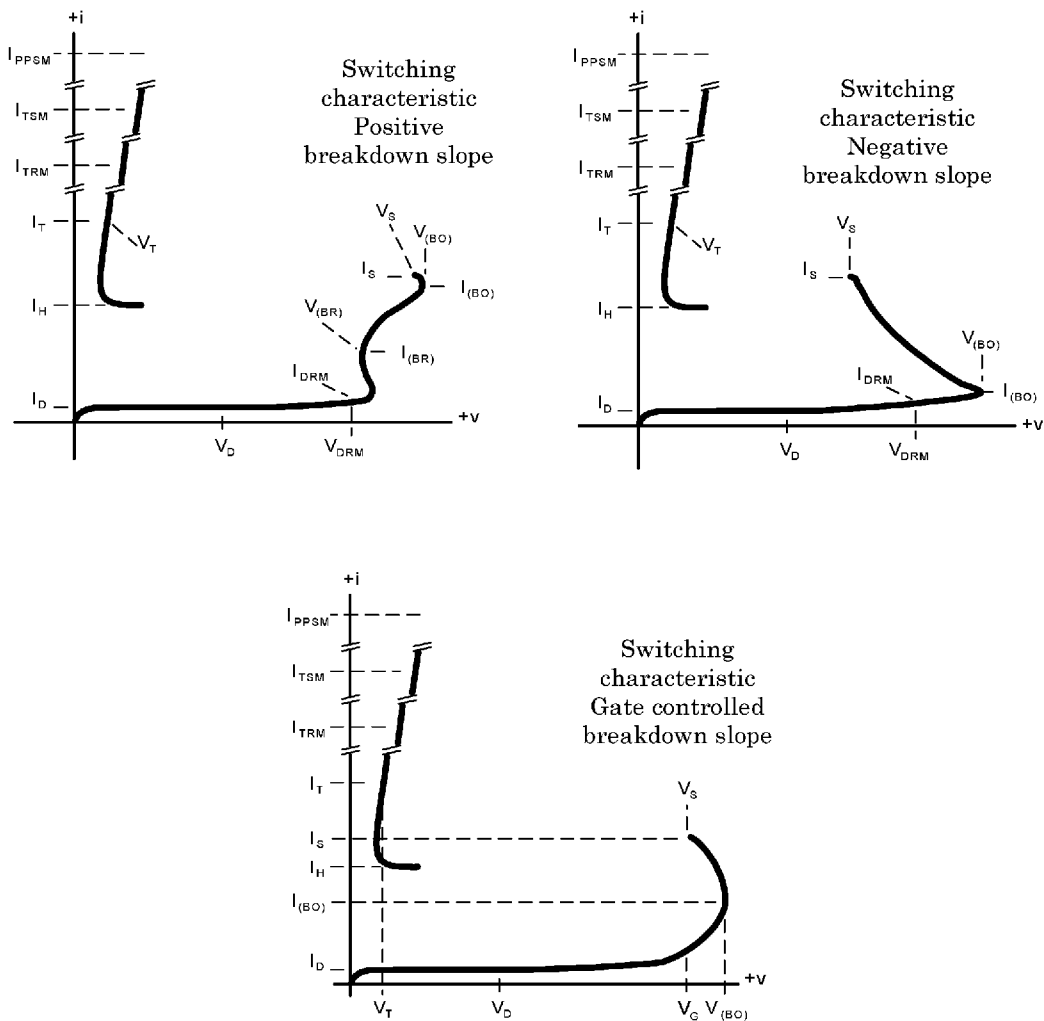


Figure 1 Switching characteristics

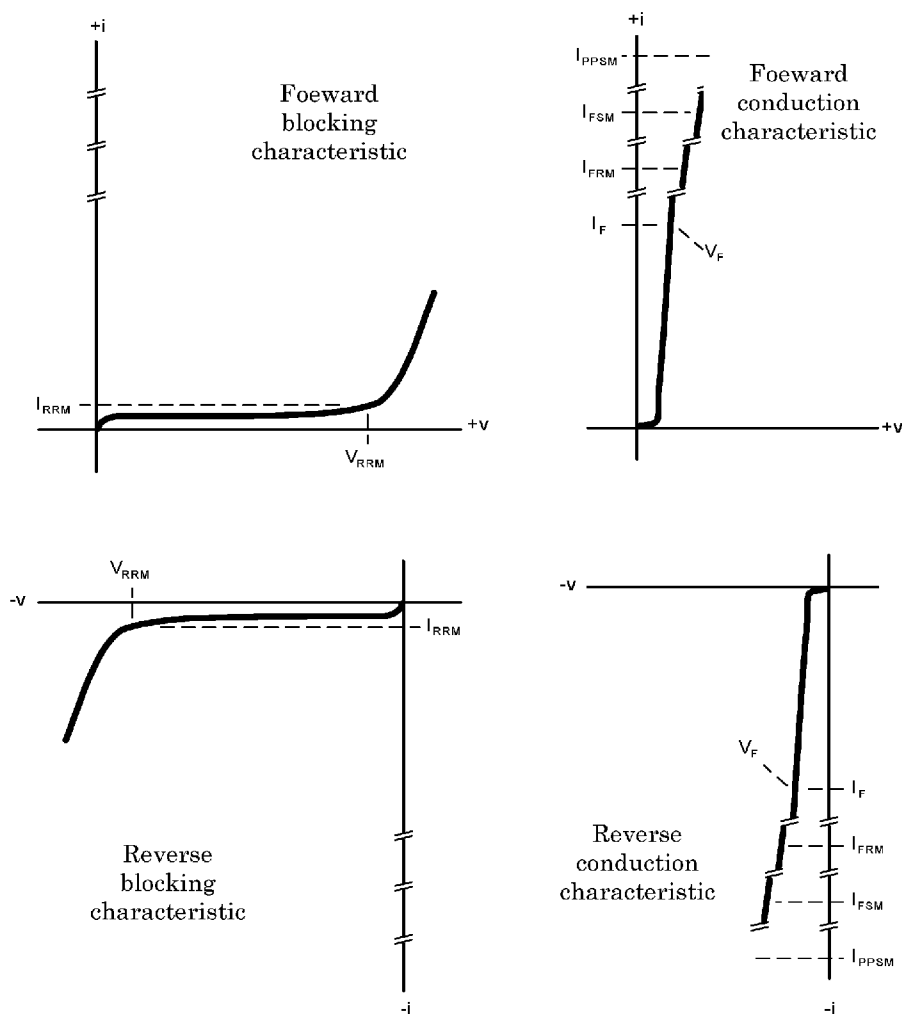


Figure 2 Non-switching characteristics

4.2 Basic device structure Thyristor overvoltage protectors are manufactured by creating a series of N-type and P-type layers in a silicon chip. The basic thyristor structure has three PN junctions which requires four layers (PNPN), see figure 3a. As one layer can be the starting silicon itself (P-type or N-type silicon) a further three layers have to be made to produce a PNPN structure. Electrical contact to the P-type and N-type layers is made by metal electrodes (illustrated by the top and bottom hatched blocks in figure 3).

Figure 3 shows the simplified structure of three unidirectional thyristors. Once switched on, the basic thyristor remains in conduction to very low values of current. A TSS is required to switch off at much higher values of current. A higher value of switch-off current can be achieved by resistively shunting an electrode PN junction. Figure 3b shows a P-type material resistive shunt to the cathode electrode and figure 3c shows an N-type material resistive shunt to the anode electrode. The switching quadrant occurs when the top anode electrode is positive with respect to the bottom cathode contact.

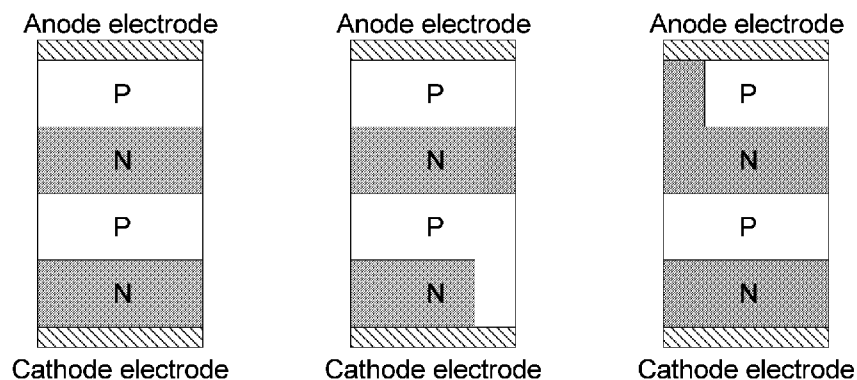


Figure 3 Simplified thyristor structures

4.3 Device equivalent circuit Based on the structures shown in figure 3, figure 4 shows how the equivalent circuits are derived for the P-type shunt TSS and N-type shunt TSS. Only the P-type shunt TSS, figure 4a, will be discussed as the description for the N-type shunt TSS, figure 4b, is similar.

In the structure component parts illustration, the simplified structure has been split up into four silicon blocks. The first NPN block, connected to the cathode electrode, forms an NPN transistor TR1. The second NP block forms a breakdown diode D1. The third PNP block, connected to the anode electrode, forms a PNP transistor TR2. Finally, the P block, connected to the cathode electrode, forms a resistive shunt R1. The block interconnections are shown by the thick horizontal lines.

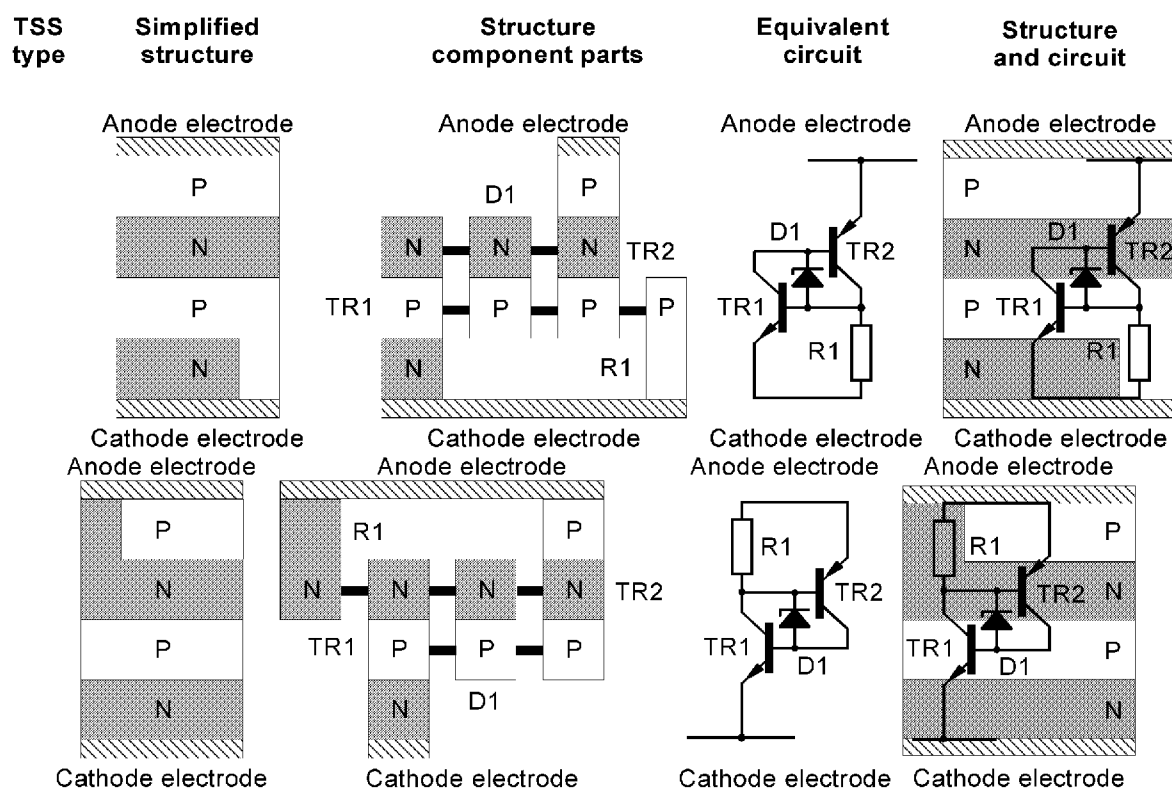


Figure 4 Equivalent circuits of TSS structures

The equivalent circuit illustration is the circuit diagram that results from the circuit elements defined in the structure component parts illustration. Transistors TR1 and TR2 are connected as a regenerative pair. In an inactive condition these transistors will be in an off-state and present a high circuit impedance. If sufficient positive voltage is applied, diode D1 will break down and supply current to the transistor base regions. Initially only transistor TR2 will conduct as the base-emitter shunt resistance, R1, of transistor TR1 will bypass the current. In this condition, the device VI characteristic will be determined by the BV_{CEO} characteristic of transistor TR2. When sufficient current flows through the shunt resistance, R1, to initiate conduction of transistor TR1, the transistor pair will regenerate and switch (crowbar) to a low voltage on-state condition. The transistor pair will remain in this condition until the conducted current is too small to maintain sufficient voltage across the shunt resistance to activate transistor TR1. The current at which the transistor pair begins to switch off (de-latch) is called the holding current.

The structure and circuit illustrations, superimpose the equivalent circuit over the simplified structure with the appropriate positions of circuit elements to the structure.

4.4 Switching quadrant characteristics The switching characteristic of a TSS consists of four regions: a) off-state; b) breakdown; c) negative resistance and d) on-state (see figure 5).

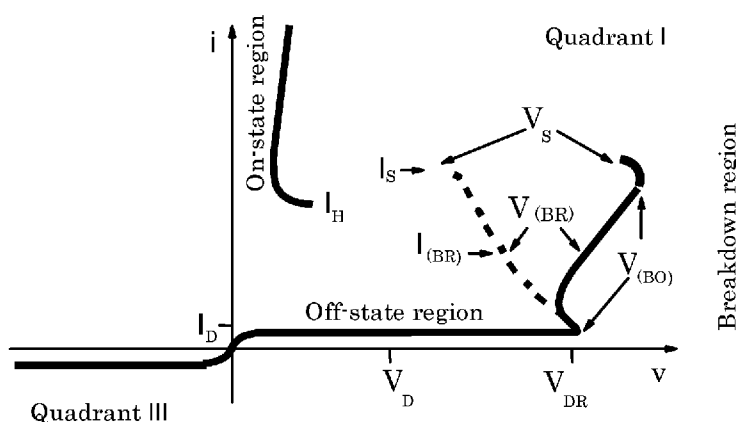


Figure 5 TSS switching characteristic

4.4.1 Off-state region The off-state region is the high-resistance, low-current portion of the voltage-current characteristic. This region extends from the origin to commencement of breakdown. The off-state current is the sum of junction reverse current and any surface leakage current. Two measurements are typically made in this region: off-state current (I_D), measured with the d.c. off-state voltage (V_D) applied and repetitive peak off-state current (I_{DRM}) measured with the rated repetitive peak off-state voltage (V_{DRM}) applied.