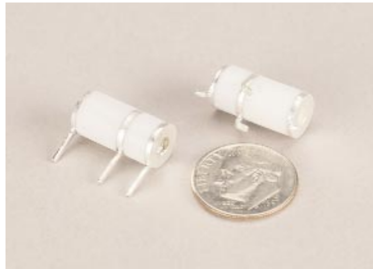


Introduction

The TX is a series of miniature triggered spark gaps designed for high reliability switching with Main Static Breakdown's between 2.0 and 10.0kVdc and are available at relatively low cost. This series of gaps is capable of switching stored energy in a fraction of a microsecond upon command. Trigger gaps use no standby power, are extremely rugged and require only a low energy high voltage trigger pulse. They are hermetically sealed at high braze temperatures and will withstand rugged environmental conditions.

The construction of the triggered gaps is such that the trigger electrode is mounted in the center of the adjacent electrode. The trigger electrode is insulated by a ceramic spacer from the adjacent electrode and is flush with the internal surface of that electrode. The spacing between the trigger and opposite electrode is the same as the spacing between the two main electrodes.

For reliable triggering, the TX gaps should be operated within 50 and 80% of the Main Static Breakdown. If the operating range is required to extend to 20-40% of the Main Static Breakdown, the reliability of triggering may be compromised. To insure main gap discharge, sufficient over voltage is needed for breakdown of the trigger gap, as well as adequate follow through of spark intensity in the trigger spark.

Mode of Operation

The triggered spark gap may be operated with the adjacent electrode either positive or negative with respect to the opposite electrode. The operation is defined as Mode A when the adjacent electrode is positive and the trigger pulse is positive. Mode C defines the operation when the adjacent electrode is negative and the trigger is positive. As an example, the performance characteristics contained in Table 2 were obtained with the gaps operated in Modes A and C on TX gaps having Main Static Breakdown's of 4.5kVdc.

In general, the affect of the operating Mode is to control the minimum cutoff voltage of the gap (see definition of cutoff voltage below). With regard to the cutoff voltage, Mode A will have a lower cutoff than Mode C and shorter delay times when operated near cutoff. Mode C can have long delay times when operated near cutoff; however the cutoff for Mode C may be more repeatable and precise.

Operation of the triggered gaps may also be obtained for negative trigger pulses; however cutoff voltages are higher and delay times are longer than for positive trigger pulses.

When the trigger pulse is negative and the adjacent electrode is negative, operation is defined as Mode B and operation for negative trigger pulses and positive adjacent electrode is defined as Mode D.

As the operating voltage increases, the delay time decreases and may approach 0.05 microseconds as indicated in Table 2 for Mode A operation. For very low levels of operating voltages, delay times of the main gap discharge may extend to 10's of milliseconds.

Life Ratings

The end of life of the spark gap is determined by non-conformance to the failure modes as described in the section below. The wear out mechanisms of the spark gap are due to several factors. The first of which is electrode wear, in which vaporization of the electrode occurs due to the high arc temperatures. The vaporization of the electrodes may result in increase in gap spacing and cause higher breakdown voltages. Two other factors affect the life of the gap. Fill-gas cleanup may occur due to chemical activity between the electrodes and the active fill-gas components. The third factor is vapor deposits from the electrodes on to the inner surfaces of the ceramic envelope which may result in reduction in the insulation resistance of the gap. At high levels of energy transfer, the electrodes may erode with resulting deformation of the electrode surfaces. In this case, the breakdown voltage may be reduced.

For low levels of energy storage (< 1.0 Joule), the arc resistance is in the order of 10's of milliohms. Since erosion of the gap electrodes is primarily related to the energy dissipated in the resistive component of the gap, slight differences in the resistive and inductive components of the discharge circuit will affect the discharge life of the spark gap. The ultimate determination of the life must be obtained by empirical means.

Since each customer circuit is unique, the only way to determine device life is by performing life tests in the actual circuit.

Lifetime

The lifetime of the triggered gap can be approximated in terms of the cumulative charge, in coulombs (Q), that can be passed through the device without changing its main static breakdown voltage by more than 20 percent. Expressing the height of the current pulse in amperes and the duration in seconds, the area under the pulse is the coulomb of charge contained in it.

Example 1:
A triggered gap is required to pass a 20,000 peak amp pulse having a 10μs pulse half-width. Approximating the pulse shape by a triangle, the charge contained in the pulse is:

$$q = 20{,}000 \text{ amps} \times 10^{-5} \text{ sec} = 0.2 \text{ coulombs}$$

If the Coulomb Rating (Q) is given as 100 coulombs, the life under these conditions is approximately:
Life = Q/q = 100/0.2 = 500 discharges

Example 2:
A 10kV main static breakdown triggered gap must dump a 2.0μF capacitor charged to 8kV. The charge stored in the capacitor is:

$$q = CV = 2.0 \times 10^{-6} \text{ farads} \times 8{,}000 \text{ Volts}$$
$$q = 0.016 \text{ coulombs}$$

If the Coulomb Rating (Q) is given as 100 coulombs, the life under these conditions is approximately:

Life = Q/q = 100/0.016 = 6,250 discharges

Definitions Applied to Triggered Gaps

Main Static Breakdown (MSB) is the breakdown voltage between the adjacent and opposite electrode of the triggered gap when the applied ramp voltage is less than or equal to 2,000V/s. When referring to triggered gaps, terms like Self Breakdown, Static Breakdown and Nominal Static Breakdown have been used interchangeably with the Main Static Breakdown.

Self Breakdown Voltage (E_z) of the main gap is the same as the Main Static Breakdown Voltage between the adjacent and opposite electrodes.

Operating Voltage (E_{bb}) is the applied main gap voltage.

Delay Time (t_d) is the time required for the main discharge to occur after the application of the trigger pulse. Specifically, the time is measured from 10% of the leading edge of the trigger pulse to 10% of the leading edge of the main gap discharge.

Cutoff Voltage is defined as that level of applied voltage below which the operation of the gap may result in less than 100% reliability of the main gap breakdown. Cutoff voltage can be determined by reducing the operating voltage in increments below the Main Static Breakdown and observing the voltage level at which the discharge of the main gap does not occur with each application of the trigger pulse.

Main Gap Current (I_b) is the peak value of the current which flows between the two main electrodes.

Failure Modes During Life Tests

A. Short circuit failure mode - In this mode, the gap shall become permanently short-circuited.
B. Low breakdown voltage failure mode - In this mode, the gap shall have a main static breakdown voltage less than 80% of the minimum main static breakdown voltage.
C. High breakdown voltage failure mode – In this mode, a gap shall have a main static breakdown voltage of greater than 20% of the maximum main static breakdown voltage.
D. Low insulation resistance failure mode - In this mode, the gap shall have a resistance of less than 1 megohm.

Applications

For all applications in which a pulse voltage is applied to the trigger electrode, the voltage at which the trigger gap breaks down is a function of the pulse rise time. As the rise time decreases, the trigger pulse breakdown voltage increases. Conversely, if the rise time increases, the trigger pulse voltage breakdown decreases. The delay of the discharge in the main gap is related to three factors; the energy of the trigger spark, the applied main gap voltage and the polarization of the gap. Operation of the triggered gaps may be obtained over a range of 25% - 80% of the main static breakdown voltage (E_z); however, since the probability of premature discharge is increased at higher percentages of applied voltages, for applications requiring extreme reliability, values higher than 80% of E_z are not recommended. Below the limit of 50% of E_z, the reliability of performance may be adversely affected by excessive delay times. Delay times in the order of ten's of milliseconds may occur at low levels of applied voltage. The reliable occurrence of the main gap discharge depends not only on reliable breakdown of the trigger electrode, but also of the adequate charge (coulombs) in the trigger spark.

Availability

The TX gaps are available with Main Static Breakdown voltages of 2.0 to 10.0kVdc as shown in Table 1. The range of operation for the applied voltages for reliable operation is shown to be 50-80% of the Main Static Breakdown (MSB).

Table 1
Operating Specifications @25^{0}C

High Energy Devices Part Number	Applied Voltage Operating Range		Main Static Breakdown (kV)	Trigger Voltage Min - Max (kV)	Peak Pulse Current 8/20 (kA)
	Min (kV)	Max (kV)			
TX2.5	1.25	2,00	2.5	3.1 - 1.8	10
TX4.5	2.25	3.60	4.5	3.5 - 2.0	10
TX7.5	3.75	6.00	7.5	3.9 - 2.0	10
TX10.0	5.00	8.00	10.0	4.7 - 2.0	10

TX4.5 Characteristics

Operating characteristics, discharge life and environmental ratings of the TX4.5 are shown in Table 2. Included are delay times for operation in both Mode A and C and operation life for energies of 0.7 and 1.6 Joules.

Table 2
Operating Characteristics @25^{0}C[(2)]

Parameter	Mode	Conditions	Symbol	Min	Nom	Max	Units
Main Static Breakdown	A/C	100V/s	E_z	4.05	4.50	4.95	kVdc
Operating Voltage	A/C		E_{bb}	2,250	-	3,600	V
Trigger Voltage[(3)]	A/C		E_{trig}	2,000	-	3,500	V
Delay Time[(4)]	C C A A	$E_{bb\ min}$ $E_{bb\ max}$ $E_{bb\ min}$ $E_{bb\ max}$	t_d - - -	- - - -	- - - -	1,000 150 75 50	ns
Peak Pulse Current	A/C		-	-	-	10	kA
Insulation Resistance		100Vdc	IR	200	-	-	GΩ

Life Ratings[1]

Parameter	Mode	Test Conditions	Min	Nom	Max	Units
Discharge Life	A/C	I_b = 5kA (main gap current) Pulse Energy (1.6 Joules) E_{bb} = 4,000 Load = 0.25Ω	2,500	-	-	shots
Discharge Life	A/C	I_b = 5kA (main gap current) Pulse Energy (0.7 Joules) E_{bb} = 3,000 Load = 0.25Ω	10,000	-	-	shots
Cumulative Charge	A/C	Coulomb Rating	-	5	-	Q

Environmental Ratings

Parameter	Test Specifications	Test Conditions
Vibration Mil-Std 202D	Method 107 Condition A	Test at 10g's, 3 axis, 3 hours/axis 10Hz - 500Hz
Shock Mil-Std 202D	Method 204 Condition A	Test at 100g's, 6 milliseconds, 3 axis 3 shocks each direction 18 shocks total
Altitude Test Mil-Std 202D	Method 105 Condition A	No degradation at 30,000 ft. non-operating No degradation at 15,000 ft. operating

Notes:

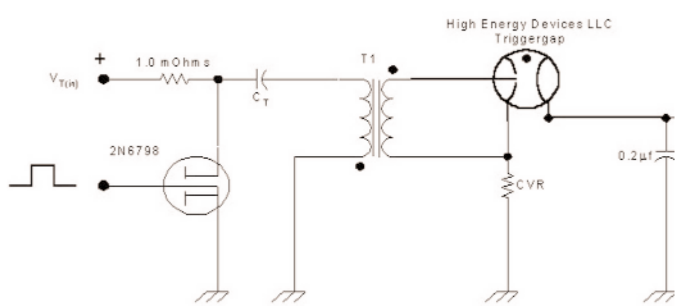
(1) Characteristics are determined by testing in the circuit shown in Figure 1.

(2) The operating characteristics, as well as Life Ratings, apply to both Mode A and C. Delay time measurements are shown separately for Modes A and C.

(3) The trigger voltages given in this table are the minimum triggering voltages necessary for reliable triggering at the corresponding operation voltages. As the applied operating voltage increased, the trigger voltage required for triggering decreased.

(4) Delay times are defined in the section on Definitions Applied to Triggered Gaps and further discussed in the section on Mode of Operation.

Figure 1 - Test Circuit for TX Gaps



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