HIGH ENERGY DEVICES LLC

Use of Triggered Spark Gaps
Application Note

Triggered spark gaps such as High Energy Devices' TA and TB Series can be used for a variety of applications where low levels of control energy are used to rapidly switch high levels of stored energy. Typical applications include:

- Active switch in exploding bridgewire (EBW) systems
  - Ordnance firing
  - Rocket ignition
  - Oil field exploration
- Active switch in flashlamp triggering
  - Provide high energy, high voltage trigger from low voltage, low energy control
- Active switch for capacitor bank discharging
- Electronic crowbar protection against current faults
  - Interelectrode arcs in magnetrons, TWTs, etc.
  - Power supply components

The triggered spark gap is an electrical component that permits high levels of stored energy to be switched in fractions of a microsecond. These high levels of stored energy can be switched on command by low energy control pulses. Triggered spark gaps require no standby power, are relatively small in size, and are extremely rugged for severe environmental requirements. Ambient temperature, humidity, and pressure variations do not affect the electrical characteristics. Triggered spark gaps are designed to operate after long periods of shelf life without need of electrode conditioning.

Modes of Operation

A triggered spark gap normally discharges energy through a pair of main electrodes[1]; triggered by a pulse applied to the trigger electrode relative to the adjacent main electrode. The four modes of operation, A through D, denote the four possible combinations of trigger pulse polarity (+/-) and main discharge polarity (+/-) as defined in the table below:

Mode	Trigger Pulse Polarity (rel. to adj. main electrode)	Main Discharge Polarity (rel. to opp. main electrode)
A	+	+
B	-	-
C	+	-
D	-	+

The positive trigger pulse and main discharge polarities of Mode A are depicted in the figure below

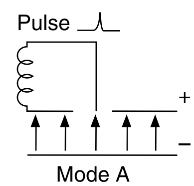

Figure 1 - Illustration of positive trigger pulse and main discharge polarity conventions.

Of the modes with a positive trigger pulse polarity (A and C), Mode A is the more commonly used - largely because the time delay is usually shorter and the minimum trigger voltage is usually lower in this mode.

However, Mode C is often chosen over Mode A for practical reasons. In Mode A, the direction of the gap field is the same as that of the trigger field. For relatively high adjacent main electrode voltages, the discharge of the trigger may take place at the opposite electrode which results in very efficient coupling of the charged products into the main gap. Mode A requires that the secondary of the pulse transformer be floating above ground or capacitively coupled. In Mode C, however, one side of the pulse transformer secondary can be tied to ground (along with the adjacent main electrode) for greatly simplified operation.

Of the modes with a negative trigger pulse (B and D), Mode B yields shorter time delays and smaller minimum trigger voltages.

Triggered Spark Gap Behavior in Circuits

As with two electrode spark gaps, the spark gap between the main electrodes of the triggered spark gap presents a near infinite impedance to the circuit when unfired. When voltage is applied across the main electrodes (less than the main static breakdown voltage of the main electrodes), the circuit operation is unaffected by the presence of the triggered spark gap. When a sufficiently large trigger pulse is applied and the main discharge takes place, the tube drop (the voltage across the main electrodes) falls to values on the order of tens of volts for currents of up to several kiloamperes.

The source energy that is available for discharge in the gap circuit will be dissipated totally in the triggered spark gap unless series resistance is included. By the inclusion of series resistance, the use of lower energy triggered spark gaps may be extended to higher energy circuits. For example, a typical tube drop might be 30V for a peak current of 3kA with a resultant effective main gap impedance of 0.01 ohms. Therefore, if a 1 ohm resistor was installed in series with the main gap, the triggered spark gap would only dissipate about 1% of the available energy (if the peak current is unchanged).

The trigger voltage required to cause main gap breakdown decreases as the applied voltage increases. A typical relationship between the minimum trigger voltage required for main gap breakdown and the voltage applied across the main gap is shown in Figure 2:

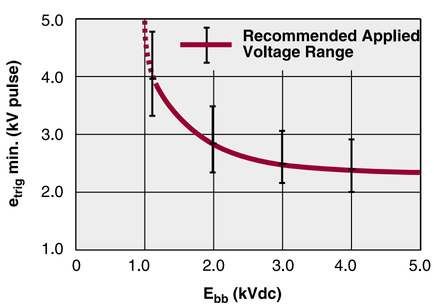

Figure 2 - Minimum trigger voltage versus applied voltage for operation of a TA5.0.

A typical electronic crowbar application is depicted in Figure 3A.

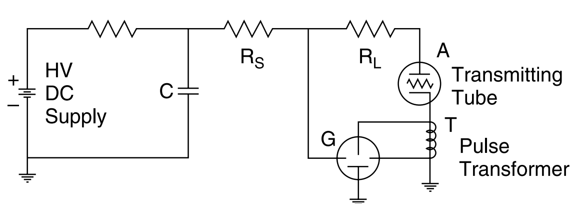

Figure 3A - Typical electronic crowbar application.

A grid-to-plate arc in the high vacuum transmitting tube, A, creates a fast-rising current arc. When this occurs, the capacitor, C, can supply enough current to totally destroy the tube unless the plate supply is crowbarred in a sufficiently short period of time. The initial rise of the current surge through the primary of the pulse transformer, T, creates a pulse across the secondary of the pulse transformer that triggers the triggered spark gap, G. {Though depicted in Mode A or D (depending on the trigger pulse polarity), a ground-referenced pulse transformer could be used in Mode B or C by connecting the plate supply to the *opposite* main electrode and ground to the *adjacent* main electrode.}

The fault current waveform, the trigger pulse waveform, and the main gap discharge current waveform are shown in Figure 3B. Crowbarring of the plate supply is accomplished in a total time of 0.5µs. The time delay of the triggered spark gap is shown as 0.2µs and a delay in the pulse transformer is shown as 0.3µs. The magnitude and duration of the fault current have been sufficiently limited within the transmitting tube to be harmless and the energy stored in the capacitor has been dissipated in the triggered spark gap and the source resistance, R_s, instead of the transmitting tube.

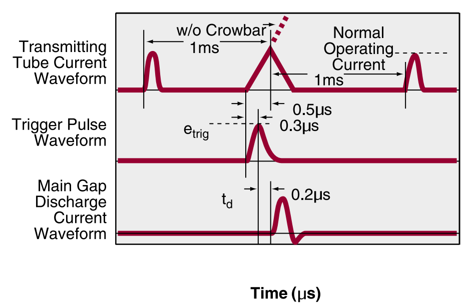

Figure 3B - Various waveforms of crowbar operation.

Notes:

(1) Triggered spark gaps consist of three electrodes including the trigger electrode and two main gap electrodes. The Adjacent Main Electrode is the main gap electrode adjacent to the trigger electrode. The Opposite Main Electrode is the main gap electrode opposite from the trigger electrode.

Contact Information:

High Energy Devices, LLC
26 Hollenberg Court
Bridgeton, MO 63044
Phone: 314.291.0030
Fax: 314.291.8184
E-mail: info@highenergydevices.com
www.highenergydevices.com

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