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# Fast electronically triggered spark gap for HV applications

***Abstract**. The article describes the design, construction and test process of the electronically triggered module of the three-electrode spark gap for a high-voltage applications. This system allows for precise remote triggering of the spark gap using optical fiber. Very good technical parameters such as small span times and a short self-time allow to use the device in applications where precise synchronization of many high-voltage devices is needed, for example triggering several impact generators at specific time intervals.*

***Streszczenie.** W artykule opisano projekt, budowę oraz badania elektronicznego modułu wyzwalania do iskierników trójelektrodowych w zastosowaniach wysokonapięciowych. Układ ten pozwala na precyzyjne zdalne wyzwolenie iskiernika za pomocą światłowodowego układu optycznego. Bardzo dobre parametry techniczne takie jak małe rozrzuty czasu zadziałania oraz krótki czas własny pozwalają na wykorzystanie tego urządzenia w zastosowaniach wszędzie tam gdzie jest potrzebna precyzyjna synchronizacja wielu obiektów wysokonapięciowych lub na przykład wyzwolenie kilku generatorów udarów w określonych odstępach czasu. **Elektroniczny moduł wyzwalania do iskierników trójelektrodowych w zastosowaniach wysokonapięciowych***

**Keywords:** triggering system , control three-electrode spark gap, fiber optic triggering for three-electrode spark gap.
**Słowa kluczowe:** system wyzwalania, sterowanie iskiernikiem 3-elektrodowym, wyzwalanie światłowodowe dla iskiernika trójelektrodowego.

## Introduction

In the high-voltage technology during high-voltage tests it is very often necessary to trigger systems that is at a high potential, at least several kilovolts. A fairly common solution is the use of a three-electrode spark gap construction triggered by the command system, among others due to low construction costs and the possibility of brake-down voltage regulation in a wide range. However, always the problem of the triggering system ocures, due to the fact that it may operate at high potential. That causes the problem of galvanic isolation between the testing system and the control system.

## Construction

The overriding goal in design process of the high-voltage triggering system was to develop a construction characterized by repeatability and a short self-time. The next step was to achieve as small dimensions as possible of the designing device and good energy efficiency. Very important, from the controlling device point of view, was also to ensure the maintenance of galvanic isolation between the control system and the trigger. The assumed goals were achieved by building an electronic triggering system based on the basic topology of flyback converters [1]. However, in this case, instead of the rectifier the ends of the secondary winding (L2) are connected to the auxiliary electrode and one of the main electrodes (Fig. 2). This solution was chosen due to the small number of necessary elements, which is associated with small dimensions of the entire device. The galvanic isolation between the control system and the trigger was implemented by usage of fiber optic transmitters and receivers. Additionally, as a power source for entire system a battery which provide direct current of voltage 12 V was used. This solution eliminates the problem of isolation in the power supply from the high voltage at which the device operates, and also provides versatility, because the trigger system can work on both the earthed and high potential side.

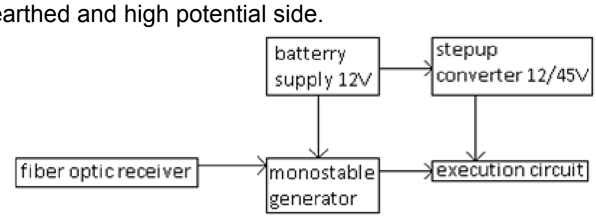


Fig. 1 The basic block diagram of the HV trigger unit

Another unique solution that was implemented during the design of this system was the use of a monostable generator as an intermediate element between the optical receiver and the executive system (Fig. 1). This resulted in the independence of the device self-time from the duration of the triggering pulse.

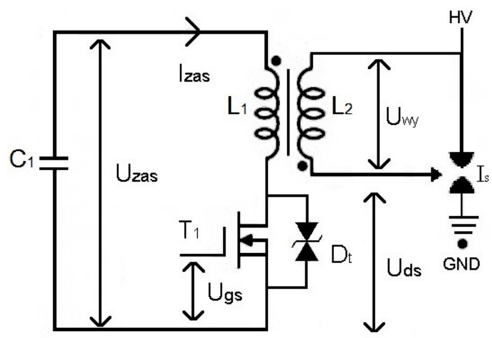


Fig. 2 The basic circuit diagram of the HV trigger; where: C1 - capacitor bank of total capacity 4000μF / 63V, L1, L2 - pulse transformer coils with turns ratio 10/480, T1 - chopping transistor, Dt - overvoltage protection, Is - controlled three-electrode spark gap.

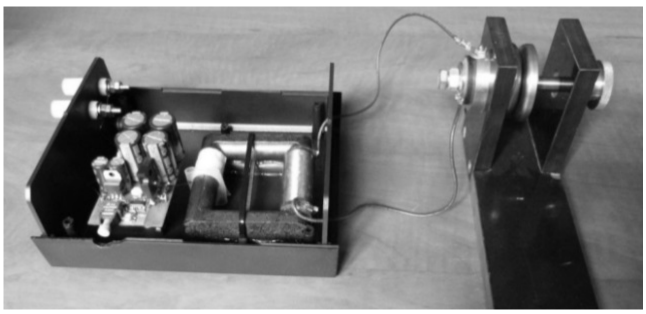

Fig. 3 HV trigger with a three-electrode spark gap

Flyback converters are two-stroke converters. This means that in the first step, when transistor T1 (Fig. 2) is turn on (saturation mode) the energy is accumulated in the magnetic field of the pulse transformer core (L1, L2 – Fig. 2) according to the equation [2]:

(1) $$W = \frac{1}{2} L I_{\max}^{2}$$

where: $W$ - energy accumulated in the inductance of the primary winding of the pulse transformer, $L$ -inductance of the primary winding of the pulse transformer, $I_{max}$ - peak value of the current

Then, after turning the transistor from the saturation mode to the cutoff state, the energy accumulated in the core of the pulse transformer is transferred through the secondary winding to the load circuit, eg to the spark gap electrodes. Due to the proper selection of elements of this system, mainly primary and secondary inductance of the pulse transformer and the gap width in the core, achieved self-time of the above-mentioned system has been limited to the level of about 15μs [4,5]. It the execution circuit a U-type core was used (Fig. 4). This allowed to make low-loss windings [4,5,6] and to maintain the dielectric strength between the primary and the secondary winding at level of 70kV. Additionally, to ensure that the transformer core does not reach saturation during operation, an air gap of 0,4mm was used. The size of the air gap in the core and the parameters of the windings were selected in such a way as to obtain as shortest as possible self-time of the HV triggering system [3,4,7].

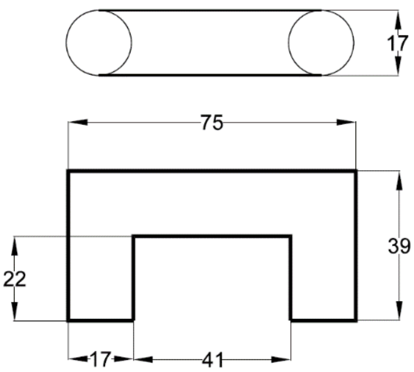


Fig. 4. Geometric dimensions of the ferrite core used for the construction of the pulse transformer (all dimension are given in mm)

The graphs show the inductance and resistance of the primary and secondary windings of pulse transformer as a function of frequency for different variants of the HV trigger.

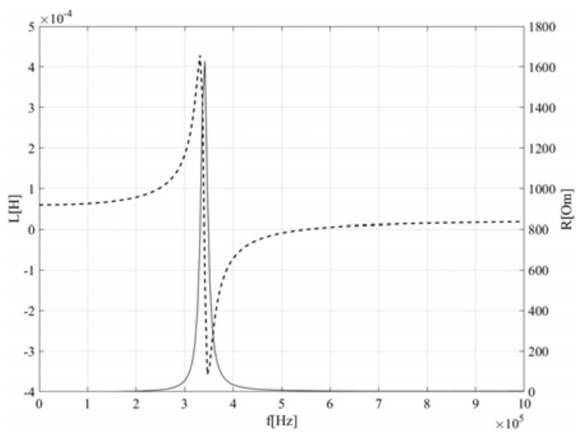


Fig. 5. The results of the measurement of inductance and resistance of the primary winding as a function of frequency (secondary winding opened ,“-“ – resistance, “- -“ – inductance)

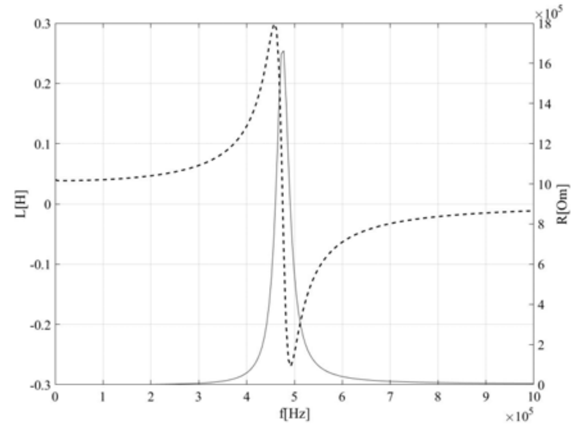


Fig. 6. The results of the measurement of inductance and resistance of the secondary winding as a function of frequency (secondary winding opened,“-“ – resistance, “- -“ – inductance)

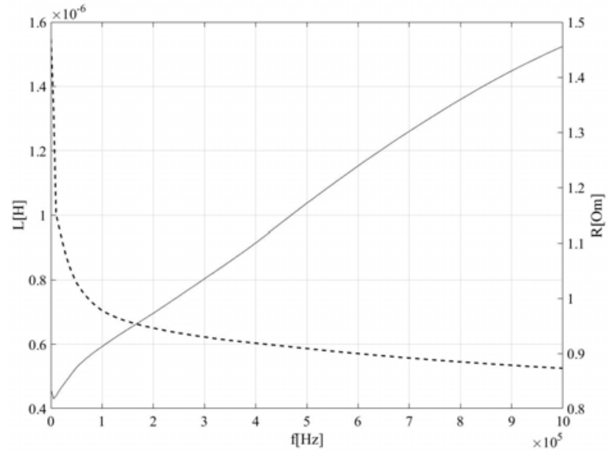


Fig. 7. The results of the measurement of inductance and resistance of the primary winding as a function of frequency (secondary winding shorted,“-“ – resistance, “- -“ – inductance)

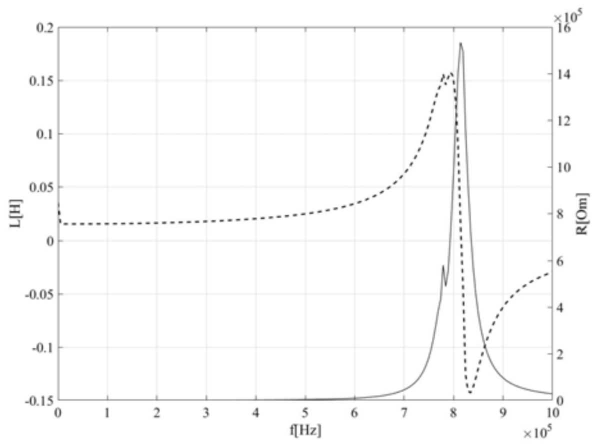


Fig. 8 The results of the measurement of inductance and resistance of the secondary winding as a function of frequency (secondary winding shorted,“-“ – resistance, “- -“ – inductance)

As the energy storage in built HV trigger four parallel connected electrolytic capacitors of total capacity 4000μF were used. Thus, the main capacity of this system (C1 - Fig. 2) was charged to voltage Uzas = 45 V, which allowed to accumulate energy equal to 4,05 J. The use of large value of main capacitance ensured that during the entire triggering cycle, the main power supply voltage does not decrease by more than 0,5 Volts.

**Laboratory tests**

The measurement results of current and voltage at specific measurement points of the HV triggering system, which schematic was shown in Figure 2, are presented below.

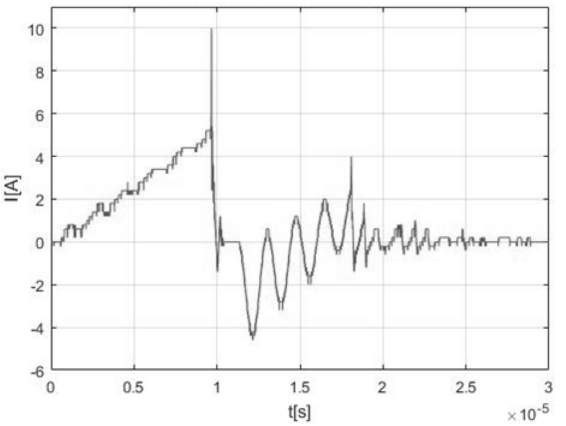


Fig. 9. Current waveform (Izas) as a function of time in the main execution circuit of the HV release system – no brake down on the spark gap

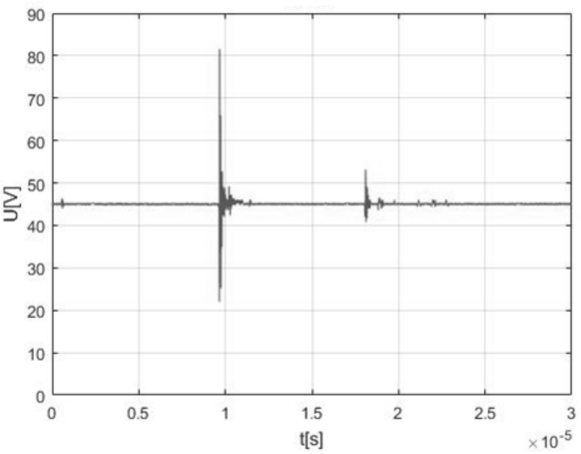


Fig. 10. Voltage waveform (Uzas) on the main capacitor of the HV trigger unit as a function of time – no spark on the spark gap

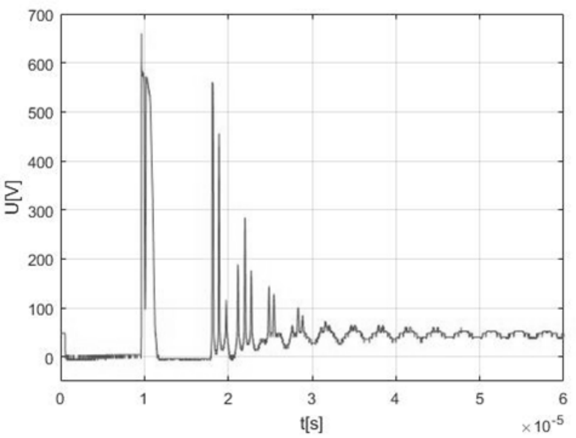


Fig. 11 Voltage waveform (Uds) on the transistor (drain-source) at the output of the HV triggering system as a function of time – no brake down on the spark gap

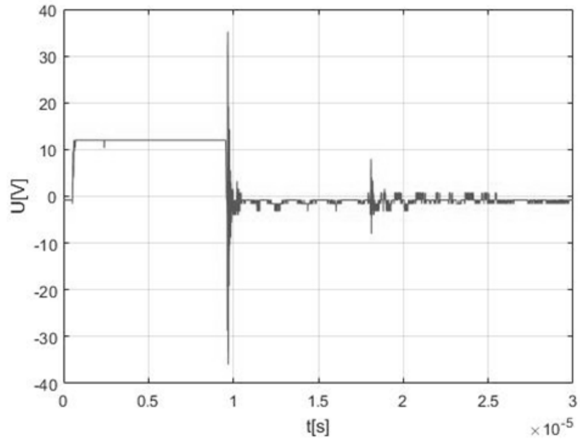


Fig. 12 The voltage waveform at the gate of the transistor (Ugs) as a function of time – no brake down on the spark gap

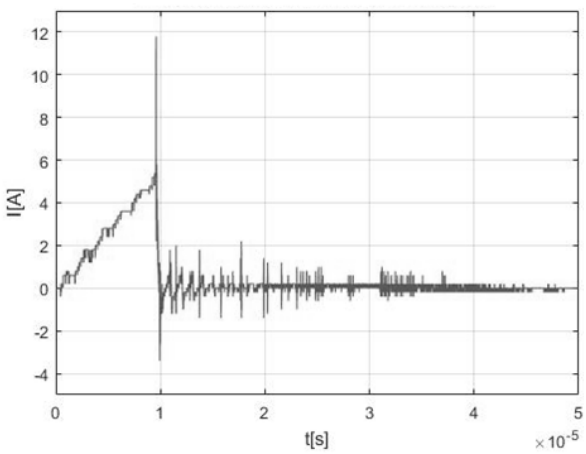


Fig. 13. The current waveform (Izas) as a function of time in the main execution circuit of the HV triggering system - brake down on the spark gap

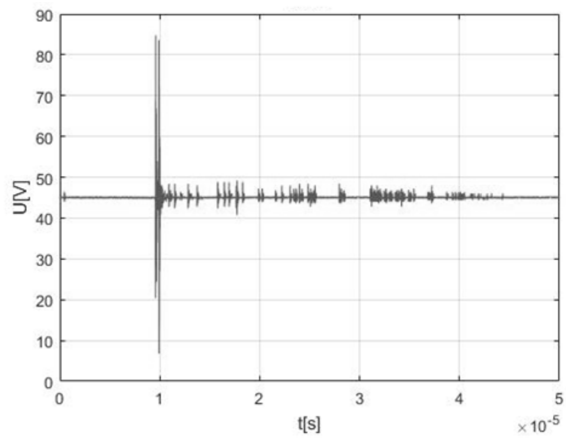


Fig. 14. The voltage waveform on the main capacitor of the HV triggering system (Uzas) as a function of time - brake down on the spark gap

Figure 17 shows the voltage waveform at the output of the HV trigger for the case of there was no brake down on the spark gap, whereas in Figure 18 when the full discharge occurred.

In both registrations (Fig. 17 and Fig. 18), the thin waveform is a signal from the operator panel given to the trigger. The wide waveform is the voltage registered at the trigger output

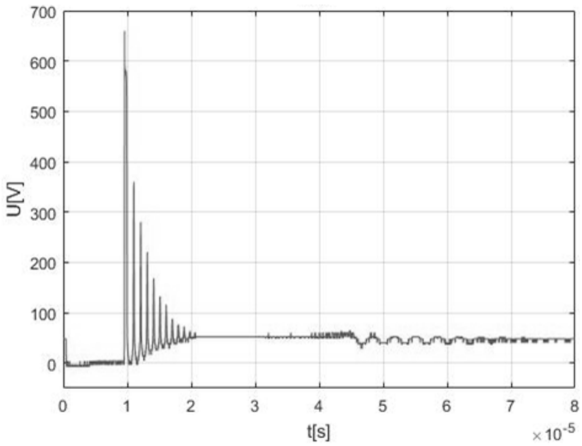


Fig. 15 The transistor voltage (drain-source) (Uds) in the HV triggering unit as a function of time – brake down on the spark gap

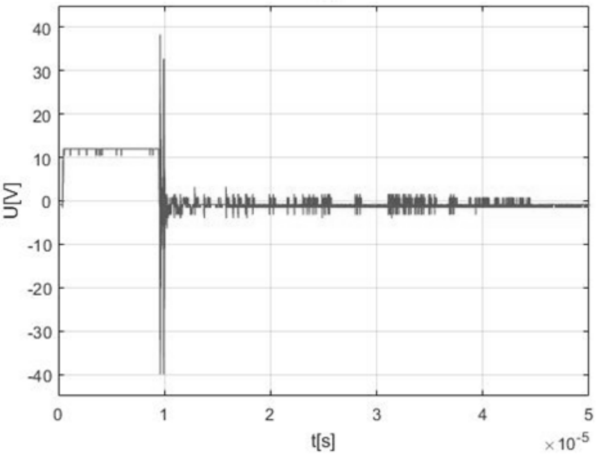


Fig. 16 The voltage waveform on the gate of the transistor (Ugs) as a function of time - brake down on the spark gap

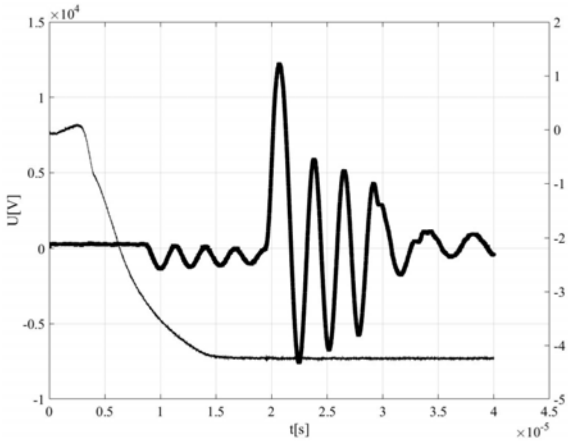


Fig. 18. Voltage waveform at the HV trigger output (Uwy) – brake down on the spark gap

**Summary**

The HV triggering system presented in the article has been tested in laboratory conditions. The measurements carried out confirmed the validity of construction assumptions by determining the electrical parameters of this device. As shown, the device has many advantages:

- short self time – 15 μs (Fig. 17-18),
- relatively high discharge energy,
- high voltage level (several kilovolts) at the output of the device (Fig. 17),
- galvanic separation from the trigger system (optical signal control)
- compact housing,
- independent power source.

All the above-mentioned features allow for the universal use of this device in high-voltage applications.

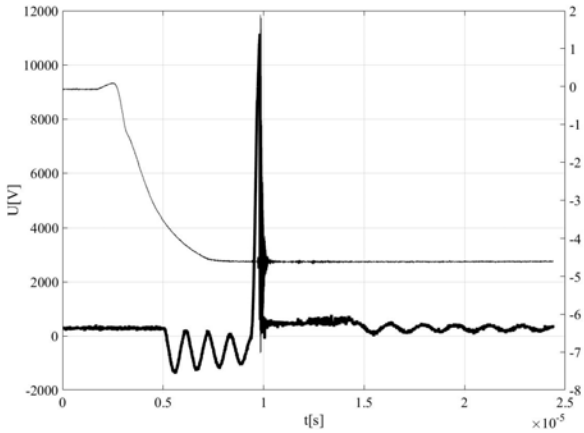


Fig. 18 The voltage sequence at the HV trigger output (Uwy) - complete discharge

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