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## Electronic Projectile Detonator



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The present invention relates to an electronic projectile detonator according to the preamble of patent claim 1.

Modern electronic detonators currently employ for the energy supply either primary cells or preferably batteries, which are only mechanically/chemically activated through the great accelerations which occur when firing a projectile. This has the advantage that detonators equipped thus do not require maintenance with respect to replacement, for example of an otherwise employed battery-primary cell, since these batteries are entirely passive during their storage and therefore permit long storage times.

In the case of detonators equipped thus, in general the operating sequence of the previously programmed detonator function is started through the activation of the battery, *i.e.* by running up the battery voltage during the mechanical/chemical activation through the launching accelerations.

The activatable batteries employed must therefore be layed out constructionally such that they reliably activate within the entire temperature range even with extremely small propellant charge during the firing. On the other hand, they must withstand mechanical loading through environmental tests (for example 1.5 m drop onto steel plate) and the acceleration during the charging process without activating. Therewith by necessity the constructionally required safety margins between activation and nonactivation grow small. In addition, individual faults in the battery, which are generated by defective battery fabrication or material faults, can reduce these safety reserves further.

According to the above statements it can also not be excluded that such batteries already activate before the shot. Depending on the function and safety layout of the



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detonator, this can possibly lead to dangerous detonator states during the overflight phase.

Specifically in the event of use by the artillery, one's own troops are also overshoot. For that reason the requirements with respect to safety against too early a projectile breakup (overflight safety) are here in general very high. Known numbers for the maximum permitted probability of too early a breakup are between  $10^{-5}$  and  $10^{-6}$ .

On the other hand, due to the above described necessary small constructional gap between function and nonfunction of an acceleration-activatable battery (1.5 m drop: no, smallest charging: yes) function problems must also be anticipated with small charging and can also be observed in practice.

In addition, the production of such special batteries due to today's increasing corporate mergers has become concentrated on increasingly fewer companies such that the supply situation, not least through export restrictions of some countries for such products, is becoming increasingly more difficult. If, however, batteries are available, then, in general, only at prices which are often incompatible with the "low-cost product" detonator.

Other known methods of energy generation during the flight of the projectile are generators which generate electric energy for the electronics, installed in the detonator, either via piezo effect or electrodynamically via projectile acceleration, spin build-up or oncoming airstream. However, such solutions are, for example for an artillery detonator, either due to the low energy yield (piezo) not suitable or even more expensive and more unreliable than a built-in battery and, furthermore, can only be obtained either as a special fabrication as a product of a long and expensive development phase or, with at least similar difficulty, as an acceleration-activatable battery.

Building on this prior art it is therefore the task of the present invention to specify a new projectile detonator, specifically an artillery projectile detonator, which can operate without battery or additional energy generation during the projectile flight.

The solution of this task is accomplished according to the characterizing characteristics of patent claim 1. Advantageous embodiments of the projectile detonator according to the invention can be found in the dependent claims. In the following, the projectile detonator according to the invention will be explained briefly in conjunction with the attached Figure 1.

It is proposed to employ for operating the projectile detonator in the flight phase a capacitor charge during the programming phase, which capacitor has very low leakage current in order to be able to bridge a time in the range of minutes between the programming and the start of the flight phase without significant energy loss.

It is known to transmit programming information during the inductive programming phase via the programming coil 12 internal to the detonator through the transmitting coil 22 of a programming device 23 external to the detonator via the magnetic coupling of the two coils and a modulated magnetic AC field. It is further known to utilize the energy transmitted in the programming process for the supply of the detonator during the programming process and, since after the programming process the energy transmission is interrupted through the programming device 23, to store the information transmitted during the programming process such that it is nonvolatile, for example in an EEPROM in the detonator electronics.

In order to be able to comprehend the inventive concept, first the above stated programming process will be discussed in further detail.

In the NATO STANAG 4369 with the associated AOP22 switching proposals for the external circuitry of the inductive programming interface are proposed, which in this

way or in similar form are realized in every detonator which must fulfill the demand for compatibility. This external circuitry is roughly indicated also in Figure 1 through the elements 22, 12, 14, 4, 15 and 2. Upon closer inspection of only these few elements, it is apparent that the AC voltage induced in coil 12 through the programming coil 22 is one-way rectified across diode 14, and through the programming interface 15, the voltage regulator 2 is loaded with connected load. In addition, this voltage is limited with respect to amplitude by a Zener diode 4 in order to protect the components of elements 2 and 15 against overvoltage. Through the one-way rectification through the diode 14, however, only the positive halfwave of the AC voltage, present at the junction point of the components 12, 14, 13 and 18, is loaded such that the positive halfwave at this point virtually never exceeds the Zener voltage of the Zener diode 4 plus the forward voltage of diode 14.

If first the diodes 13 and 18 of Figure 1 are considered not to be present, at the output of coil 12 the negative halfwaves can assume a voltage amplitude of 50 to 60 V. The energy inherent in these halfwaves, is not used up to this point. If, into the circuit of the Figure 1, the high-blocking diodes 13 and 18 are inserted again, through the one-way rectification of the negative halfwaves of the output of coil 12, the supply capacitor 1 for the detonator electronics and the supply capacitor 19 for the detonation stage is charged. The very high-ohmic resistors 6 and 20 connected in parallel with the capacitors serve for the defined discharge of the capacitors in the event of a discharge that has not occurred of the detonator and virtually do not load the charging process. This means that both capacitors are charged to a DC voltage of up to an amplitude between -50 and -60 V.

If the capacitance and the voltage of the capacitor 1 are defined as  $C_1$  and  $U_1$  and as  $C_{19}$  or  $U_{19}$  as the corresponding values of capacitor 19, then, after the programming for the supply of the voltage regulator 17 and of the detonator electronics 3, the energy  $0.5 C_1 U_1^2$  is available and for the supply of the detonation stage the energy  $0.5 C_{19} U_{19}^2$ .

Since the voltage enters as the square into the amplitude of the energy stored during the programming process in the capacitors, but the constructional size and the price of the capacitors increases only proportional to product  $C U$ , by utilizing the high negative halfwaves of the programming process, energy can be cost-effectively stored in the detonator on small space.

The flight phase is subsequently preferably initiated very simply through a (for the blocking phase during the programming and the time before the shot) switch 5 which can be very simply layed out high-ohmically, which connects the inverting switching voltage regulator 17 with the capacitor 1. The switch 5 is actuated through the, in general, specially developed fusible device 9 and hardened against environmental effects highly reliably upon the occurrence of the environmental forces typical for a shot through an actuation element 10 such that an unintentional closing of switch 5 before the shot proper can virtually only occur with the minute probabilities of  $10^{-7}$  to  $10^{-8}$  customary with those occurring with mechanical safety devices. If the detonator is not programmed, it is even entirely energy-free, which makes it even safer compared to detonators with built-in batteries.

If the switch 5 is constructionally layed out such that after the occurrence of the typical projectile acceleration it closes and, for example, also remains closed through mechanical latching even during the entire flight phase, the electronic self-holding latching, shown in dotted lines in Figure 1, becomes superfluous. If this cannot be ensured, the self-holding latching 11 ensures that during the occurrence of a voltage at point Z, input X is electrically connected with output Y, and also remains connected as long as the voltage regulator 17 operates.

Detection of the two operating modes programming/flight takes place via the two inputs  $U_p$  and F of the detonator electronics. If at  $U_p$  voltage is present and not at F, the switch 5 is still open and the electronics detects upon occurrence of UV the presence of programming and processes the corresponding programming sequences

at port  $U_p$ . However, if switch 5 is closed, at input F voltage is present (and at input  $U_p$  no programming sequence) and the electronics works down its programmed flight program.

The switching voltage regulator 17 must have high efficiency as well as a very large input voltage range in order to avoid unnecessary energy losses. It is therefore preferably specifically developed for these or similar applications and, due to the smaller and therefore current-saving structures, integrated into an ASIC.

The storage capacitors 1 and 19, also for reasons of low losses, must preferably be foil or ceramic capacitors with minimum leakage current, since its charge must be available in the flight phase as much as possible unchanged even after 10 to 20 minutes after the programming.

The supply capacitor 19 for the detonation stage 16 is, as already described, charged parallel to the supply capacitor 1 during the programming phase. This configuration is necessary since the capacitor 1 during the supply of the detonator electronics 3 is being discharged and for that reason a satisfactory detonation voltage amplitude with a possible joint supply of the detonation stage 16 from capacitor 1 could not be ensured.

Shortly before the detonation of the detonation stage 16 through the detonation trigger signal at output T of the detonator electronics 3, via the signal S of the detonator electronics 3 and a suitable electronic switch 24, the capacitor 19 is connected with the detonation stage 16 and the latter is only supplied with energy at this late point in time. Thereby, in spite of early charging of capacitor 19 in the programming phase a high overflight safety of the detonator is attained.

The configuration according to Figure 1 has a further advantage. During the programming through the detonator electronics 3, apart from the programming input

$U_p$ , the input F is also queried. If the switch is open, *i.e.* if the fusible device is in safety position, no voltage is present at F and the programming can be carried out as intended. However, if during the programming process switch 5 is closed, *i.e.* if the fusible device is primed, the voltage of the capacitor 1 charging during the programming, after conversion by the voltage regulator 17, is impressed on input F of the detonator electronics. The programming function is suppressed with the simultaneous detection of this voltage in connection with a programming sequence at  $U_p$ . Since the programming in general takes place bidirectionally, in this case this dangerous state of the fusible device can also be reported back to the programming equipment, and thus to the operator, and consequently provide references for further handling of the detonator.

Thereby requirement 4.6.6 of the detonator safety standard MIL-STD 1316 D can be elegantly fulfilled, which requires an external checking capability of the safety state of the fusible device before installing the detonator into the ammunition. This checking can thereby be carried out via an already present interface, the programming interface, and thus requires no additional expensive measures such as viewing window or break-throughs on the detonator housing.

## Patent Claims

1. Device for the electric energy supply of projectile detonators without battery or additional energy generation in the projectile flight, characterized in that for operating the projectile detonator in the flight phase a supply capacitor (1), charged during an inductive programming phase, is disposed, which has very low leakage current, in order to bridge a time in the range of minutes between the programming and the start of the flight phase without significant energy loss, wherein for charging the supply capacitor (1) the halfwaves, not utilized during the programming and not under load, of the programming AC voltage are utilized.
2. Device as claimed in claim 1, characterized by a switch (5) actuated through a mechanical fusible device (9), which supplies the charge of the supply capacitor (1) to a voltage regulator (17) with large input voltage range and high efficiency.
3. Device as claimed in claim 2, characterized in that the voltage regulator (17) inverts its input voltage.
4. Device as claimed in claims 1 to 3, characterized in that the switch (5) actuated by the fusible device (9) is bridged by a self-holding latching circuit (11).
5. Device as claimed in one of claims 1 to 4, characterized in that parallel to the supply capacitor (1) is disposed a detonator capacitor (19) for driving a detonation stage (16).

6. Device as claimed in claim 5, characterized in that the charge of the detonator capacitor (19) is placed onto the detonation stage (16) via an electronic switch (24) actuated by the detonator electronics (3).
7. Device as claimed in one of claims 2 to 6, characterized in that the output of the voltage regulator (17) for the flight phase is queried by the detonator electronics (3) even during the programming of the detonator at a terminal (F) and the programming function is deactivated, if the switch (5) at the input of this voltage regulator (17) does not have the correct switch position.
8. Device as claimed in claim 7, characterized in that the incorrect switch position is indicated to the operator via a report-back channel of the programming function.
9. Device as claimed in claim 1 or one of the following claims, characterized in that the programming AC voltage is switched across a diode (14) poled in a first direction to a programming interface (15) and a programming voltage regulator (2), and that the supply capacitor (1) and the detonator capacitor (19) is charged across diodes (13, 18) poled oppositely, from the programming AC voltage.
10. Device as claimed in claim 9, characterized in that high-ohmic resistors (6, 20) are connected in parallel with the supply capacitor (1) and the detonator capacitor (19).