PROGRAMMABLE LOGIC IMPLEMENTED TO PYROTECHNIC SWITCHING DEVICE FOR SOUNDING ROCKETS

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Abstract. *The sounding rockets are systems that are able of providing microgravity environment for autonomous scientific experiments accomplishment, with low contractual cost by their users. In order to achieve success in launching missions of those rockets it is necessary that activities foreseen in the pre launching phases and the events forecasted in the flight phase are properly and fully performed. During flight phase, the switching of the pyrotechnic lines is carried out by dedicated modules. In the sounding rocket electrical networks, currently developed by Aeronautical and Space Institute, the modules dedicated to switching of pyrotechnic lines use in their logic circuits components with a limited capacity of function reconfiguration. That limitation jeopardizes mainly time, cost and the involved tests during development of those modules, especially when that is necessity of performing operation and function modifications on those circuits. Another consequence of that limitation is related to rocket launching preparation phase, in which the characteristics imposed by launching mission require modifications that are able to involve the timings for switching of pyrotechnic lines. Within that context, this work presents a proposal for utilization of programmable logic system, in development of sounding rockets on board modules, with goal of minimizing the referenced limitations. The test results with the first prototype version, developed for that module, were satisfactory. Those results indicated that the proposal presented in this work is capable of being executed.*

Keywords*: sounding rockets, electrical networks, programmable logic.*

1. INTRODUCTION

The sounding rockets are systems that are able of providing microgravity environment for autonomous scientific experiments accomplishment, with low contractual cost by their users (AEB, 2006). In order to achieve success in launching missions of those rockets it is necessary that activities foreseen in the pre launching phases and the events forecasted in the flight phase are properly and fully performed (Palmério, 2005). During flight phase, the switching of the pyrotechnic lines is carried out by dedicated modules (Pinheiro, 2005). In the sounding rocket electrical networks, currently developed by Aeronautical and Space Institute, the modules dedicated to switching of pyrotechnic lines use in their logic circuits components with a limited capacity of function reconfiguration. That limitation jeopardizes mainly time, cost and the involved tests during development of those modules, especially when that is necessity of performing operation and function modifications on those circuits. Another consequence of that limitation is related to rocket launching preparation phase, in which the characteristics imposed by launching mission require modifications that are able to involve the timings for switching of pyrotechnic lines.

2. WORK GOALS

The main goal of this work is concentrated in presenting studies concerning to usage of devices based on programmable logic in system architecture of pyrotechnic switching device. That device is included in electrical network of those sounding rockets.

To present more relevant results obtained in tests performed with the first prototype version of pyrotechnic switching device that adopts within its architecture electronic component based on programmable logic.

3. PROPOSED ARCHITECTURE

The main representative components of that proposed architecture for the pyrotechnic switching device based on programmable logic are showed in the Fig. 1.

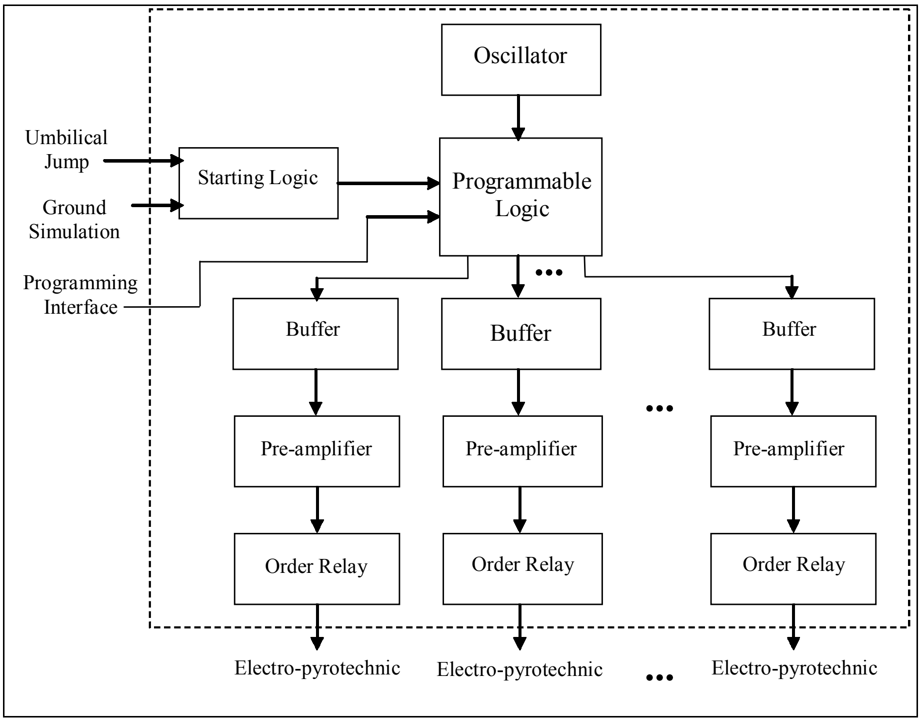

Figure 1. Architecture proposal for the pyrotechnic switching device

The architecture presented on that figure is foreseen a block named by Programmable Logic, that has as main function to generate signals, at low current, related to the pyrotechnic orders. The main function of that block is concentrated in transforming the signal generated by the Oscillator block, it starting from condition defined by the block Starting Logic, in signals related to the programmed events and likely to trigger the Buffer block input lines.

The clearance for the switching device full working is carried out by the block named by Starting Logic. That clearance can be performed by a command that comes from either a control bench or by umbilical harnesses separation. The target of performing clearance by signal that comes from the control bench is related to the necessity of carrying out tests in the switching device circuit in the delay time prior to rocket launching. In the umbilical harnesses separation, that is the action caused by the rocket relative movement in relationship to the launching rail, the target is concentrated in effectively performing pyrotechnic activities related to the rocket flight as established by the mission.

The Buffer block performs the first level of amplification of the currents related to the signals that are in the Programmable Logic outputs with those necessary signals to support the Order Relays block inputs. The Pre-amplifier block performs the second level of amplification of the currents that will be directly applied in the order relays coils, in other words, that block will effectively provide necessary power for acting the order relays coils when requested.

The block assigned by Order Relays are electromechanical devices installed in the electro pyrotechnic line. Those relays have as main function to execute the current circulation between pyrotechnic batteries and the circuits that support the electro pyrotechnic devices. The order relays are monostable with galvanic separation between their contacts and coils, minimizing like this interaction between the power and the command circuit (Visconti, 2005).

A typical example of those signals that interact with switching device circuit is represented in the timing graphic, to four orders, as showed in the Fig. 2.

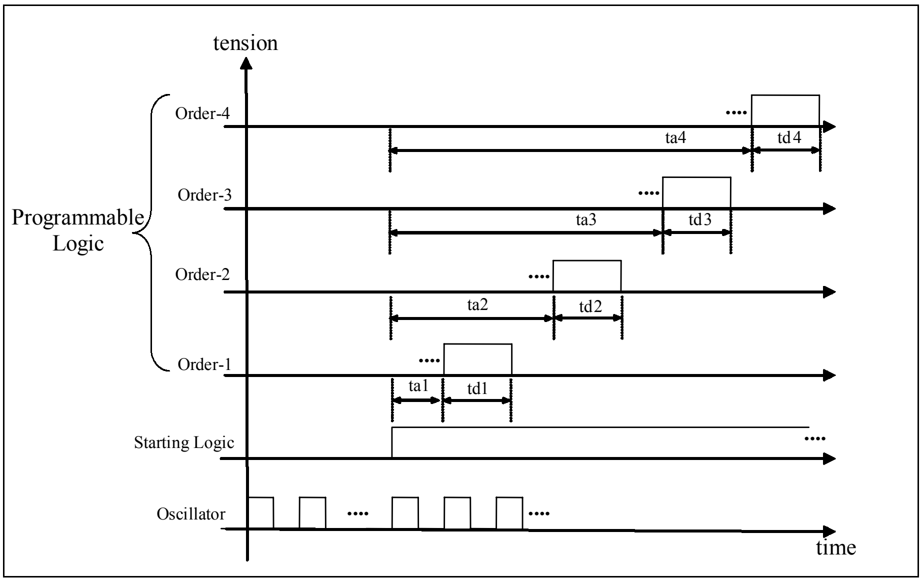

Figure 2. Signals related to the switching device

On that figure can be observed that the block Starting Logic is responsible to start the generation signals process related to the switching device. The actuation of those orders must support pre-defined timings that are related to the type of rocket mission. On that context the circuit shall be able of accepting the activation timings programming (ta1, 2, 3 and 4) and duration (td1, 2, 3 and 4), which are related to the pyrotechnic events.

3.1. Programmable logic block

The foreseen structure for the Programmable Logic block uses mainly circuits with capacity of performing functions related to: frequency divider, counter, movement, comparison and logic, according to the block diagram showed in the Fig. 3.

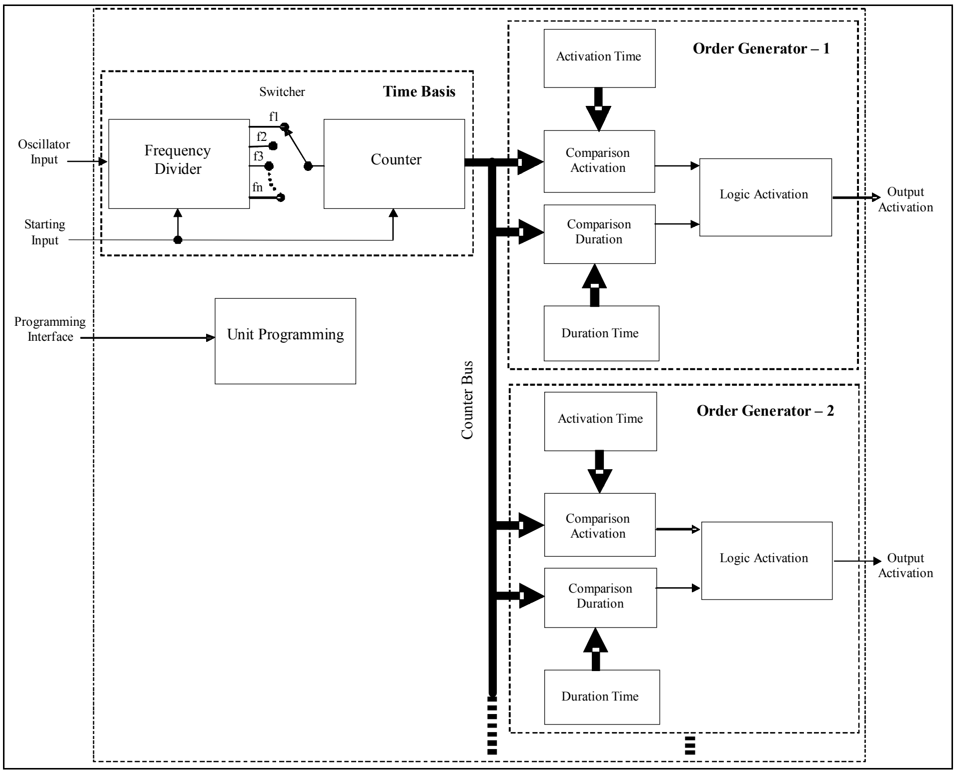

Figure 3. Logic Programmable block structure

On that figure the block named by Time Basis has two main targets in the Programmable Logic block. The first is performed by the Frequency Divider and that is related to the frequency adjustment that can be established by the Oscillator Input, with the time basis that allows all Orders Generators programming. That capacity is necessary to allow that the circuit operates with oscillators of several frequencies and that guarantees minimal time accuracy conditions to activate the events. The second is performed by the Counter and that is related to the accuracy that could be obtained by Comparators (Activation and Duration) contained in the Orders Generators blocks. The mentioned capacity accuracy is achieved by the proper lines quantity determination that will be part of the Counter Bus (Costa, 2005). To determine the number of those lines that is considered the Oscillator Input frequency and accuracy defined by activation of each programmed event.

The blocks named by Order Generator 1 and 2 have the target of generating command signals related to the programmed events, within the activation and duration timings foreseen to that rocket mission. Within that context the Order Generator is compound by the following blocks: Activation Time, Activation Comparator, Duration Time, Duration Comparator and Activation Logic.

The Activation Time block has the function of allowing that the operator to perform the programming of the initial time for the pyrotechnic event activation. Analogously the Duration Time block allows to the operator to perform the programming of the event duration final time.

The Activation Comparator uses the value restored in the Activation Time block to perform comparisons successively with the values reached by the Counter Bus, until to identify the specified activation condition and this way in the following moment to send signal related to that condition to the Activation Logic block. Analogously it happens with the Duration Comparator block to identify the condition to finalize the activation.

The Activation Logic block uses the signals sent by Activation and Duration Comparator to compound logic operation that is able of generating likely command signal to the pyrotechnic event.

3.2. Prototype

The choice of a device able of performing the Programmable logic function considered systemic aspects related to: i) hardware implementation feasibility, ii) functions available in the components library, iii) possibility of programming in Integrated Development Environment (IDE), iv) components availability in the national market. Within that context it was opted by utilization of MAX 7000 system and the programming environment MAX+plus®II from Altera enterprise (Altera, 1999). The Fig. 4 presents a view of the first prototype version developed to the switching device circuit with architecture based on programmable logic.

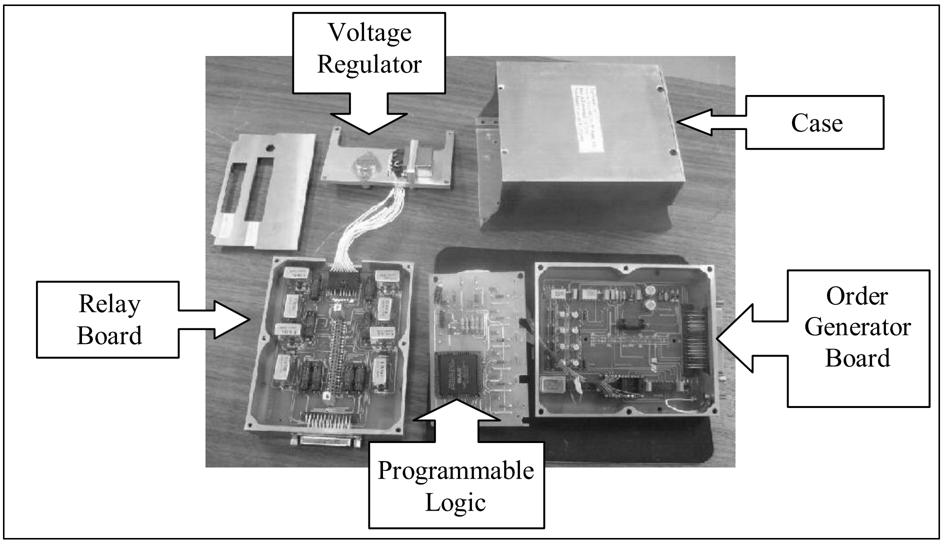

Figure 4. Prototype developed view

4. PRACTICAL TESTS AND RESULTS

The practical tests performed with the architecture proposed on this work were accomplished in three main steps. At the first step was elaborated two timing diagrams related to the tests performed during the development of the switching device circuit and with the timings utilized by a sounding rocket during its flight. The second step was concentrated in determining the equipment set that is able of complying with the requirements necessary to the test, in programming of parameters related to the pyrotechnic switching devices events and in the tests accomplishment. The third step presents the results obtained on those tests.

The Fig. 5 presents the timing diagram that the pyrotechnic switching devices shall present in their outputs, during the accomplishment of the first practical test step, to mirror similar conditions to that applied in the development of a circuit that does not utilize the architecture that is proposed in this work.

The wave form expected on that figure shall be repeated by the switching device, submitted to the test, to verify the capacity of that device in activating pyrotechnic orders in a cyclic manner and for a long period of time.

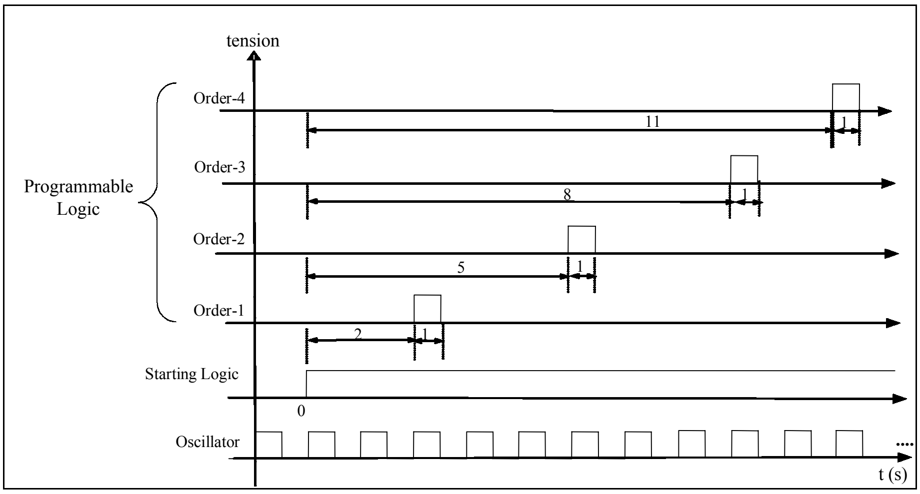

Figure 5. Foreseen signals at the first step of the tests

At the second step of the practical tests the goal is concentrated in evaluating the switching device proposed in this work to apply the pyrotechnic orders during a typical flight of sounding rockets. Within that context, that device shall present in their outputs signals look like those showed in the Fig. 6.

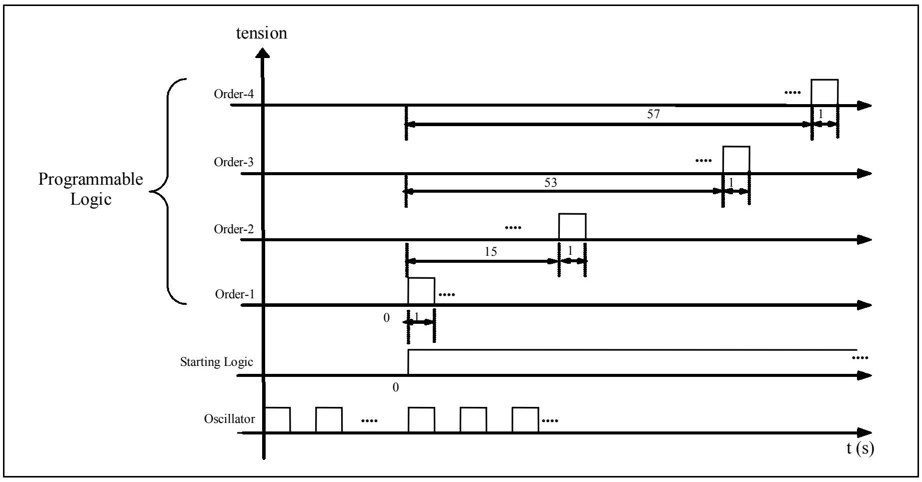

Figure 6. Foreseen signals at the second step of the tests

The connection diagram presented in the Fig. 7 represents the equipment set elaborated to accomplish the practical tests with the pyrotechnic switching device proposed in this work.

That connection diagram the block named by Command Module performs switching of the safety relay installed inside the pyrotechnic switching device and it simulates the umbilical harnesses separation (Umbilical Jump). During the accomplishment of the practical tests the safety relay was positioned to the armed state and that state mirrors a utilized condition for the rocket flight. The state named by safety, for the mentioned relay, that is related to the phases of preparation and tests for the rocket launching.

The block named by sources represents the four types of electrical power sources, in directed current, necessary to support the switching device operation. That block provides lines with the following voltages: i) +28Vdc for functional feeding, ii) +28Vdc and –28 Vdc to simulate power that comes from the Control Bench, iii) +15Vdc related with the pyrotechnic batteries.

The block named Integrated Development Environment (IDE) represents the environment used to: i) configuration of the function and signals from the switching device, ii) programming of activation and duration timings of the pyrotechnic events.

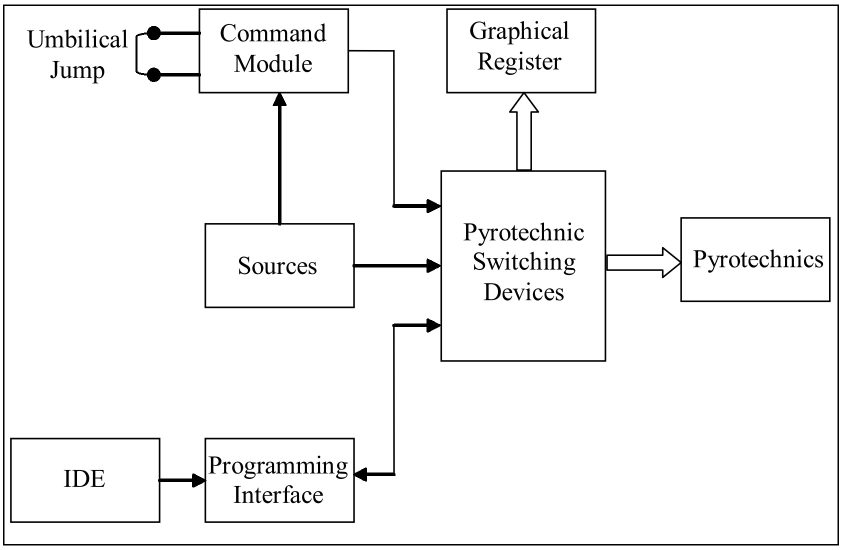

Figure 7. Connection diagram for the practical tests

It starting from the connection diagram presented in the Fig. 7, it was performed the assembly of the equipment set and physical means necessary to perform and record the tests results. A view of that assembly is presented in the Fig. 8.

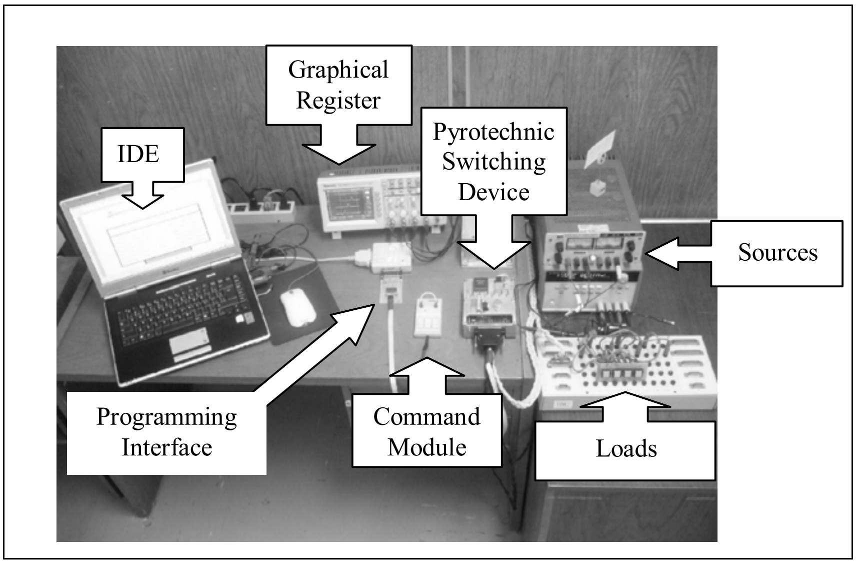

Figure 8. Vista do conjunto utilizado nos ensaios

On that equipment set were utilized two types of practical tests. The first was concentrated in the verification of the system capacity in generating pyrotechnics orders in a cyclic and repeatable mode with the goal of evaluating the robustness during a long period of time.

In the second was verified the system flexibility concerning to the capacity of supporting modification of the programming times. Within that context was used as example the pyrotechnic orders activation timings foreseen for the two stages rocket flight.

The result obtained in the first practical test performed with the pyrotechnic switching device, based on programmable logic, is presented in the Fig. 9.

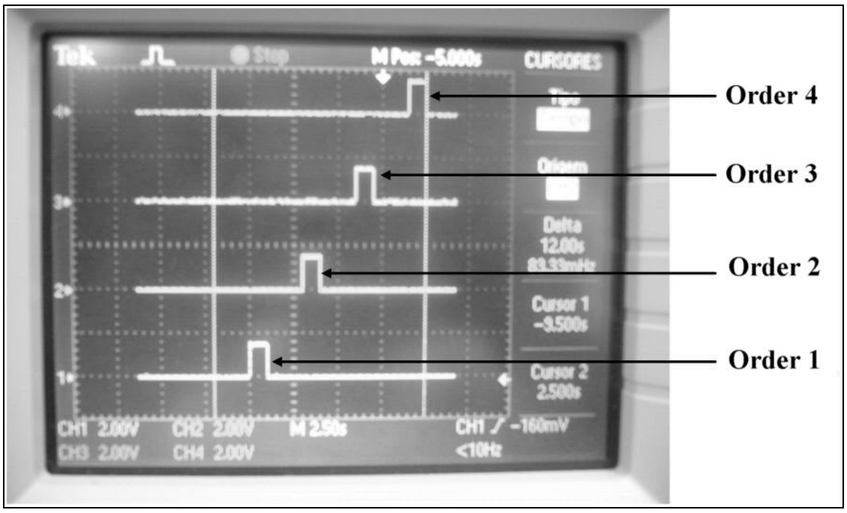

Figure 9. Results obtained in the first practical test

That figure shows that the switching device proposed in this work is able of generating pyrotechnic orders in a cyclic and repeatable mode and supporting the pre-established standards.

The Fig. 10 presents the results obtained in the second type of practical test. That result is complying with the timings of pyrotechnic orders activation utilized in a sounding rocket flight.

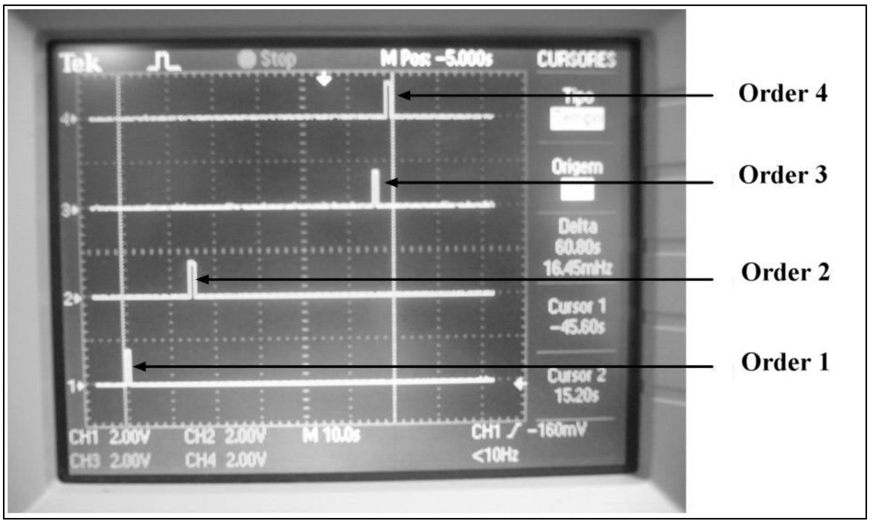

Figure 10. Results obtained in the second practical test

5. CONCLUSION

The satisfactory results obtained in the practical tests accomplishment with the developed prototype revealed that the adoption of a component based on programmable logic in the system architecture of pyrotechnic switching device, present nowadays in sounding rockets, it allows remote programming of the pyrotechnic events, it allows its function modification, inclusion of new signals in the operation logic and to cause low implementation impact in the current configuration used for those modules.

The flexibility observed in the functions and signals configuration with the usage of programmable logic component shall allow the inclusion of new sensors that become possible to increase the ground safety and improvement of the in flight rocket performance.

6. REFERENCES

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