

PROTOTYPE OF A CONSOLE FOR THE ELECTRONIC IGNITION OF PYROTECHNIC FIRE

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Abstract: Fireworks have been universally used for more than 2,000 years to celebrate different types of events. In Mexico, it is an ancestral tradition that manifests itself in colored lights, sounds and smoke, although a latent risk is involved due to the raw material it uses. Technological evolution today is beginning to venture into this area, so much so that electronic matches and firing control consoles have been developed. The costs of this equipment are high and sometimes it is necessary to import it, making it inaccessible to a part of the population that is dedicated to fireworks. This paper presents the development of the prototype of an electronic match firing console. It was carried out with an experimental theoretical methodology, the information on console designs is scarce, because the companies keep it in a confidential situation, they only allow data for marketing; The results obtained show the functionality of the console developed since it was tested in a real situation.

Keywords: Electric match, firing console, fireworks.

INTRODUCTION

Since prehistoric times man has been interested in fire, according to Lancaster mentioned by Calderón (Calderón, 2013), the specific origin of fire for social purposes is unknown, but many authors attribute it to the Egyptians, who threw salts into the fire obtained from the Nile managing to generate smoke and flames in different shades. But it was the Chinese culture that achieved the greatest advance with the discovery of gunpowder, which is said to be accidental since the components to manufacture it are materials used in traditional Chinese cooking (coal as fuel, sulfur and nitrate salt) (Calderón Contreras, Sánchez Meza, Pacheco Salazar, & Martínez Barrera, 2013).

Manochio, quoted by Calderón (Calderón,

2013), comments that in the years 1275 to 1292 Marco Polo and his father lived in China and learned the art of fireworks and took it to Europe, Italy being one of the first to adopt this art. In the fourteenth and sixteenth centuries it was used constantly in religious festivities, without changes in the materials and manufacturing processes (Calderón Contreras et al., 2013).

According to López (2000), fireworks were introduced to Latin America with the Spanish conquest, although he considers that the cultures settled in Mexico had fire management as an important cult (López, 2000). After the Spanish conquest and the arrival of religious orders, they used fireworks to convert the natives of the region, thereby creating an association of fireworks for religious festivities (Carranza, 2000).

Currently, in Mexico there is production of fireworks in 28 states of the Republic where each zone has its own techniques and formulas. As it is considered a high occupational risk activity, the Ministry of National Defense (SEDENA) is the one that monitors and regulates the consumption of raw materials as well as the transportation and marketing of the finished product (Calderón Contreras et al., 2013).

The State of Mexico concentrates the largest number of pyrotechnics distributed in 62 municipalities, producing more than 50% of the national production and it is where there are more accidents related to the matter.

Although fireworks are enjoyed around the world, they are a reason for risks and accidents for both active users and observers, the damages range from being slight to losing their lives in some cases. In the United States annually 12,000 people are treated in emergency departments, in Italy 1 to 8 deaths and 1,000 injuries are reported in the same period, in Great Britain accidents of this nature are rare, in the Netherlands 400

people are reported every year. year of which 80% are men between the ages of 12 and 20 (Abdulwadud & Ozanne-Smith, 1998).

On the other hand, one of the most consuming countries in this sector is the United States, which in 2015 imported 324.8 million dollars, of those 311.7 were products from China (García, 2016).

Today the world and the vision of nations are geared towards change and the implementation of technology and fireworks is no exception. The word pyrotechnics comes from the Greek *piros* = fire and *teche* = technique and since it deals with designing artifacts capable of undergoing chemical reactions, it is considered to be linked to science (de Prada Pérez de Azpeitia, 2013). Poulton et al (1995), comment that pyrotechnics is part of the field of high energy chemistry and the difference between it and explosives is the ratio or rate of energy released as heat, light, sound or movement (Poulton & Kosanke, nineteen ninety five).

According to De Prada (2012), pyrotechnic elements are basically formed by an intimate mixture of a substance that provides oxygen (oxidizing agent) and a fuel (reducing agent). When heat is applied, an electron transfer reaction (oxidation-reduction) occurs. The fuel atoms donate electrons to the oxidant atoms, creating new bonds between atoms and releasing energy (de Prada Pérez de Azpeitia, 2013).

Pyrotechnic artifacts or devices require an element to fire them, commonly a fuse is used. Currently, with technological advances, more efficient devices have been generated, such as the electric match, which serves as a lighter for said devices. It consists of two wire conductors connected at one end by a fine wire called a jumper, which is covered with a conductive composition (Gilliam, 2009).

A commercial electric match consists of a substrate electrically insulated with copper

covered with foil, which at the end of the junction of two conductors is soldered with a nichrome wire, see Figure 1 (Son, Hiskey, Naud, Busse, & Asay, 2002). Commonly manufacturers use the head of the match on average .01 in., .46 in length, .15 in width and .9 in thick and 40 mgr of mass composition at the tip, 1.6 ohms of resistance, 6 amperes of current and the trip time in 29.9 ms (B.J. Kosanke & K.L. Kosanke, 2001a; B.J. Kosanke & K. L. Kosanke, 2001).

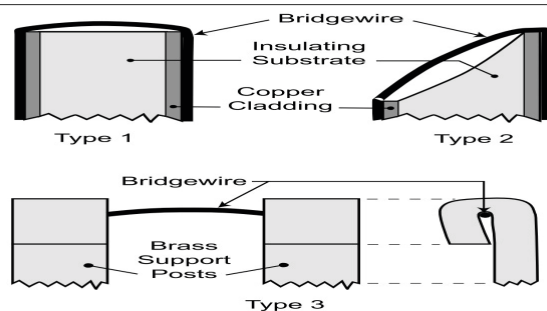


Figure 1. Types of electric matches.

Source: (B.J. Kosanke & K.L. Kosanke, 2001b)

According to Kosanke (Kosanke 2001), there are three types of electric matches, type 1, 2 and 3 cone is seen in Figure 1. In type 1, the jumper wires are soldered to the copper of the coating, in type 2 a final part of the match point is removed before installing the bridge, in type 3 the bridge is supported by two support posts (B.J. Kosanke & K.L. Kosanke, 2001a). In Figure 2, a commercial electric match is shown.



Figure 2. commercial electric match.

The electric match can be modeled as an electrical resistor, as illustrated in Figure 3.

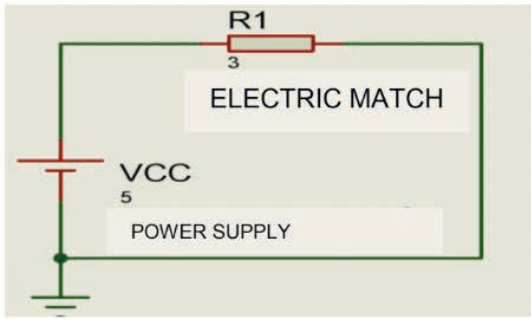


Figure 3. Electric model of the electric match and firing circuit.

Source: Own

With the help of Ohm's law, the desired current to burn the electric match can be calculated, as presented in equation 1. The current can be direct or alternating, but it must be at the levels set by the manufacturer, which, as already mentioned is about 0.6 to 1.2 amps.

$$I = \frac{V_{cc}}{R1} \quad \text{ec. 1}$$

Where:

I = Current in Amps

VCC= Voltage in Volts

R1 = Resistance in Ohms

Currently there are semiconductor devices called semiconductor bridges (SCB) that are replacing the aforementioned wires as electric matches. In this regard, Pradnya presents a characterization of an SCB-type igniter, commenting that it is widely used in the civil and military area due to its speed of action of the order of microseconds, low firing energy, and safety of not igniting over its characterization current approximately. of 990 ma (Pradnya, s., & Muuthurajan, 2016).

Classical fireworks firing systems consist of electrical or mechanical switches and electrical cables (called firing cables), their handling is simple, efficient and relatively safe; however, it is limited in the effects it can produce (Costin & Francillon, 2014).

A fireworks firing system is made up of a

control or main module and a firing or power module, both communicated via cable or wirelessly (Costin & Francillon, 2014).

Equipment from various brands is offered on the market, such as Kingdom, which is a wireless firing system, allows from 1 to 20 sequential activations with a 12-volt rechargeable battery, activations can be made via the computer to the rhythm of the music, this requires a computer a transmitter and several receivers and can be expanded.

Pirodigit, an Italian company, also builds shooting consoles like the Master 1920, which has the same functions mentioned above.

In the United States there is Cobra Firing Systems, which provides firing equipment with functions similar to those already mentioned. Likewise, Cienfuegos is in South America and in Mexico there is Pirotecnia Internacional with similar systems.

It can be seen that there are companies dedicated to the generation of fireworks firing equipment that only provide general marketing information, the rest is confidential.

So it can be said that the information on how the equipment is built is scarce, so this project aims to provide more detailed information to people interested in the subject. In this work the prototype of an electronic ignition control console for fireworks is described.

DEVELOPMENT

METHOD DESCRIPTION

For the development of the shooting console, the following methodology was carried out:

- Documentary investigation
- Obtaining parameters and approach to the design
- Shooting console design proposal
- Simulation and construction of the console

- Tests and results
- Conclusions

IMPLEMENTATION

The project was divided into a control box and a power box, where the entire process for the activation of the matches is carried out.

The number of firing channels is proposed to be 16, which is enough to activate a complete castle or activate different bombs, flares or some other type of pyrotechnic device.

For user safety, as mentioned above, the project must be in 2 sections, the power part that must be away from the controller. This way the team's shots can be made at a sufficient distance.

In the control box, the activation decision process of the 16 shots is carried out, in addition to the display of the active channel.

The power box is where the switching of the electrical energy that will activate the electric matches is executed, for the outputs of the 16 channels whose connection will be through terminal blocks.

Control box design parameters:

- 16 buttons, one to trigger each channel
- General ignition switch
- Launch button or switch
- Safety switch against wrong launches
- Active channel display
- Rechargeable battery

Power box:

- 16 output terminal blocks for connecting cables to electric matches.
- General ignition switch
- Power source safety switch
- 2 rechargeable batteries

The firing box will be used in manual mode, where the pyrotechnic craftsman will be able to burn different fireworks in the

sequence that he himself decides, pressing each channel button and activating it with the security button.

The connection between the control and power stage was made with opto-coupling to isolate both sections. Figure 4 shows this action with the 4N28 integrated.

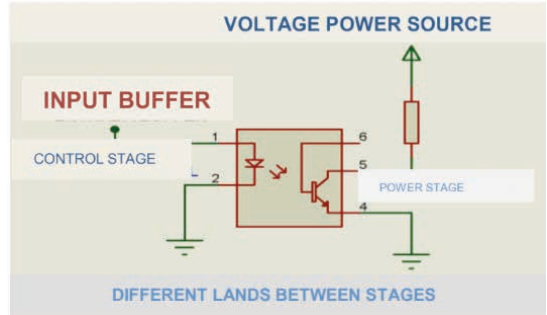


Figure 4. Opto-coupling circuit, between the control and power stage.

Source: Own

The brain of the console is a Microchip™ 16F877 microcontroller, as can be seen in Figure 5. Port A is assigned to a hexadecimal keyboard that allows selecting the activation number of the electric match, ports B and C eight bits connect to 16 4N28 optocouplers which activate the gates of 16 transistors that close the switch of a relay each, and thus generate a spark with the electric match.

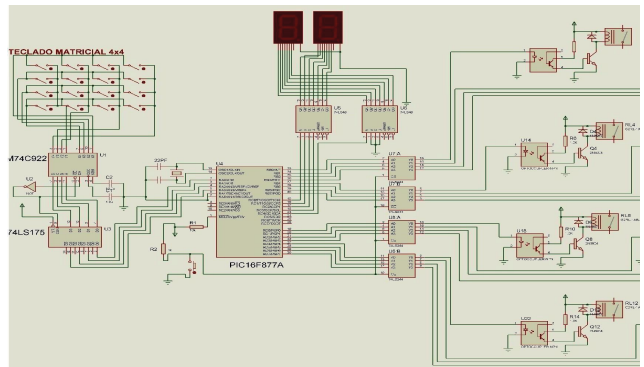


Figure 5. Connection of the Microcontroller and the power stage.

Source: Own

The programming was done in assembler

in MPLAB, which is the official software for this type of microcontrollers. The functions that were programmed were to take data from the keyboard, view them on the display and control the firing of the electric matches.

The function of the equipment as a firing console is shown in the flowchart of Figure 6.

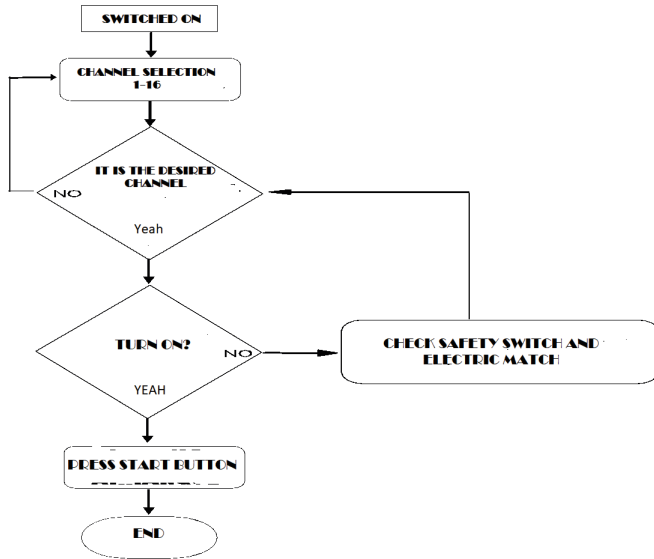


Figure 6. Trigger Console Flow Chart.

Source: Own

A printed circuit was made for the control box, another for the isolation stage of the optocouplers and one more for the power stage as shown in Figures 7, 8 and 9.

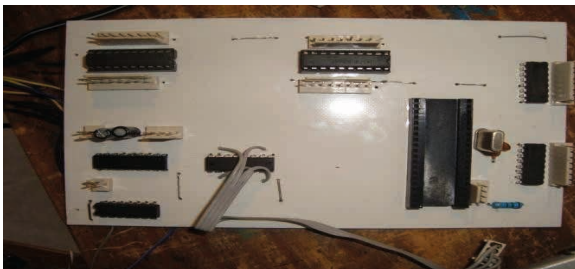


Figure 7. Control stage printed circuit.

Source: Own

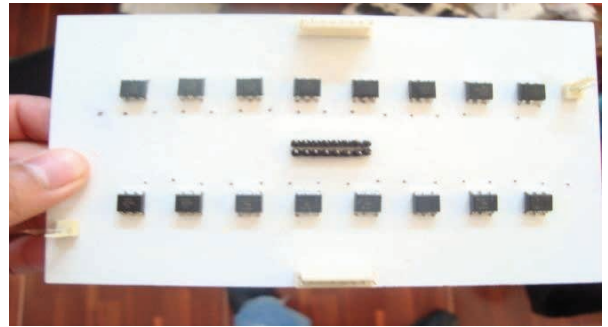


Figure 8. Card with 16 integrated 4N28 optocouplers.

Source: Own



Figure 9. Card of the power stage with the relays.

Source: Own

The system is powered as follows: a 12-volt lead-acid rechargeable battery for the control box, a LM7805 voltage regulator was used that allows polarizing or powering the integrated circuits. For the power stage, two 6 volt batteries were connected in series.

The batteries are rechargeable and for this a single-phase inverter with solar cells was used, which allows the system to be autonomous and independent of the main electrical power outlet, it was also used to provide the firing power of the electric matches. The inverter is shown in Figure 10.



Figure 10. Single-phase inverter powered by solar cells.

Source: own

The main characteristics of the single-phase inverter are: 12 Volt input voltage, 110 Volt and 60 Hz output voltage, 75W power, an alternating current output socket, power indicator and short circuit protection. A block diagram of its connection is shown in Figure 11.

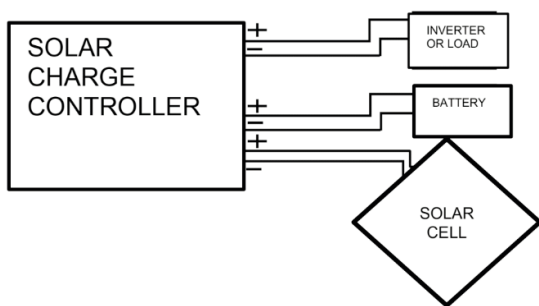


Figure 11. Single phase inverter connection.

Source: Own.

For the final product, special cases built by specialized people were made, where the cards and the respective switches were mounted, as shown in Figure 12.



Figure 12. Trigger console, control box left side, power box right side.

Source: Own.

TESTS AND RESULTS

The test of each of the printed plates was carried out, in addition to analyzing their individual functions for their subsequent connection.

To ensure the operation of the main board, each and every one of the conduction lines that communicate to the integrated circuits of the project were verified, in addition to measuring and soldering the components again, rectifying their function in the most exhaustive way.

One of the ways in which its operation was analyzed was to measure with a multimeter the high and low voltages (0's, zeros and 1's) of the digital outputs of each of the circuits that make up the project.

The signals that were analyzed by means of the oscilloscope were those mentioned below.

Digital output signal from the microcontroller to the buffer, which is a well-defined pulse; it was verified that it does not contain any bounce that could alter the digital value. This same type of signal is the one that can be observed at the output of each of the digital circuits, as shown in Figure 13.

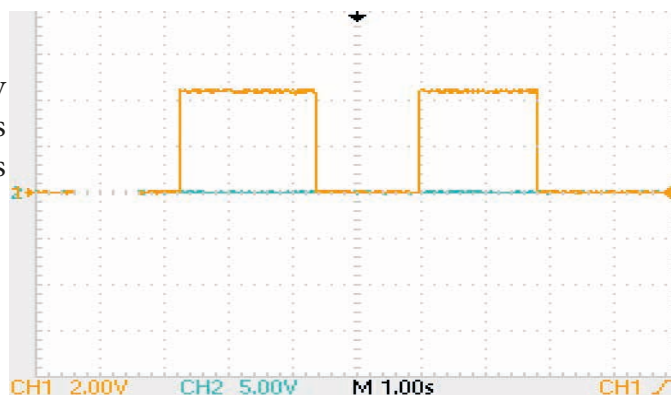


Figure 13. Monitoring of the digital output of the microcontroller to the power channels.

Source: Own

The output signal of the inverter, a voltage inverter is responsible for converting direct

current (DC) to alternating current (AC), for this particular case it is required to convert from 12 Volts DC to 127 Volts AC. The inverter used is not one with a completely sinusoidal signal, it is a quasi-square signal. This means that the resulting waveform is square or stepped, but meets the condition of being alternating. As seen in Figure 14.

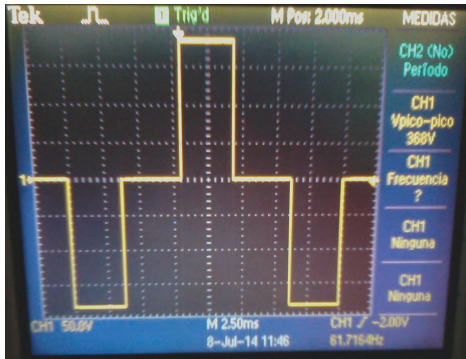


Figure 14. Single phase inverter output.

Source: Own

The physical detonation tests were carried out with people dedicated to the craft of fireworks from the State of Mexico, especially with Mr. Juan López García who participated with ideas and suggestions for the same project.

The cable that joins the control box and the power box was 20 m long, this means that the operator remains at a prudent distance to avoid or reduce the risks associated with burning fireworks.

CONCLUSIONS

An electric match firing console was designed and built, which operates manually to light fireworks with its operation manual.

The tests carried out were applied both to the control and power cards and to the function of the finished console.

Specialists in pyrotechnics from the State of Mexico participated in the field tests, they provided the electric matches, the practices were without spectators. There was no incident

in the execution, the console did not fail to detonate the gunpowder contained correctly in the 16 channels.

The control and power box cases were made by specialists and own for the project, the material used is robust against humidity, falls, etc.

The design of both the hardware and the software of the ignition system can allow its mass production. The final cost of the project, including the cases, was 5,034 pesos, national currency.

Among the possible improvements is wireless ignition, random shots, using sound as a trigger element and programming sequences.

The realization of this console required an electrical schematic diagram, for its construction, this can serve as a guide to make a repair or subsequent maintenance.

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