10-JOULE 200 kV MINI MARX

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Introduction

A low-energy Marx generator was designed at Los Alamos as a spark gap trigger. Since the initial report[1] the design has been improved and is now manufactured commercially. The Mini Marx has a risetime of less than 2 ns to over 200 kV measured into a 23 Ω load. The power output approaches one gigawatt. The Mini Marx can multichannel field distortion gaps or fire a number of gaps with little gap-to-gap isolation. It has also been used to power a small X-ray tube.

The Mini-Marx shown in Fig. 1 is now manufactured commercially by Veradyne Corp.[2] The Mini Marx was designed for ease of manufacture from the outset. Its commercialization is a good example of technology transfer from a National Laboratory to private industry. The Mini Marx should have an excellent sales future since its output characteristics are better than other more expensive and complicated units on the market.

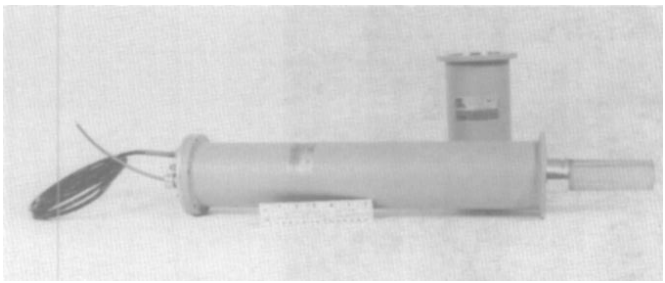

Fig. 1 The assembled Mini Marx with its protective sleeve removed from the output end. The ruler is 6" long.

Construction

The 8-stage Marx uses 2.7 nf of 40-kV ceramic Murata capacitors. They are charged through 1.5-megohm, 2-watt carbon resistors. The capacitors are held by 0.020-inch thick, 1/2-inch wide brass straps. The capacitors and spark gaps are supported by a cast epoxy rail.

The spark gaps are 5/8-inch brass balls spaced 0.1 inch apart held to the epoxy rail by 10-32 screws. Figure 2 shows the grooves which shadow the insulator and prevent surface flashover. The trigger ball is cut down and drilled to accept a Cerama-seal feedthrough as seen in Fig. 2. The epoxy rail is screwed to a 1/4-inch aluminum end plate. Electrical feedthroughs in the plate are commercial rubber compression fittings. The housing is a 4-inch diameter, 1/16-inch wall aluminum tube 20 inches long. A bolt flange with an O-ring seal is welded to one end and mates to the 1/4-inch end plate. A one-piece epoxy insulator and air pressure seal is cast into the tube with a high-voltage feedthrough and output insulator at the opposite end. Figure 3 shows the body and the rail with components attached. The ground connection ring on the output end of the tube is sized to fit standard 2-inch copper copper pipe couplings, and has an O-ring seal for use with insulating oil if desired. The Marx can be mounted by slotting part of a pipe connector and clamping it down on the ground ring with a hose clamp. The design of the output end of the Marx could be altered to incorporate any connector design.

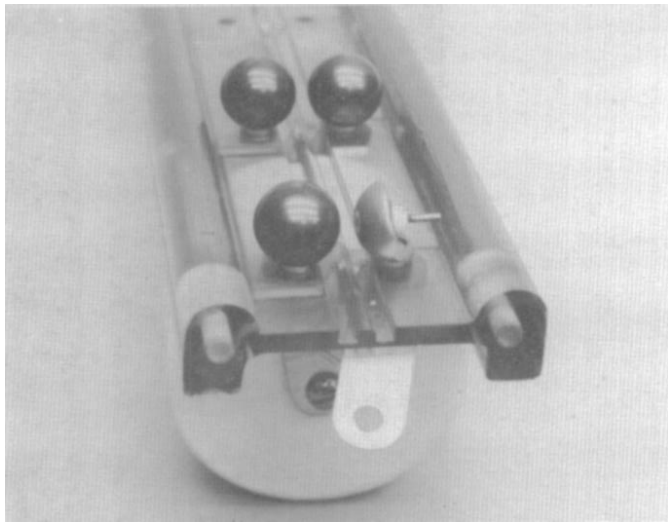

Fig. 2 The rail assembly showing the triggered gap.

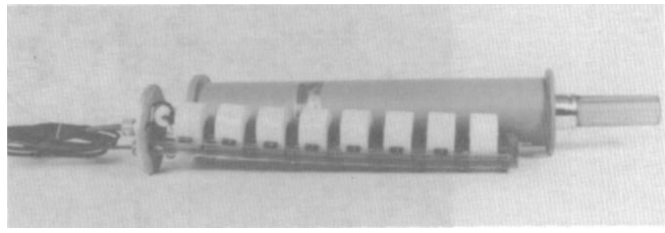

Fig. 3 The rail assembly with all the components mounted, shown removed from the housing.

Improvements

Since the original design was finished, two improvements have been made in the cast epoxy components, and a capacitor has been added to the circuit.

The epoxy used in the rail tended to creep so the rail would sag with time. This caused no functional problems since the rail is constrained by the housing in use. however it was difficult to assemble a badly sagged rail, and some shipping damage indicated the desirability of a stronger rail. As shown in Fig. 4, the present rails are strengthened by casting two 1/4-inch diameter G-10 (fiberglass-epoxy) rods longitudinally into the rail assembly. These reinforcements prevent sag and help resist breakage from mechanical shock.

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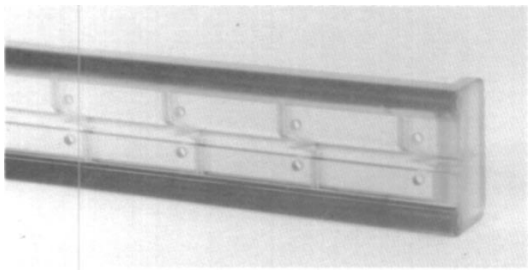

Fig. 4 The rail showing the reinforcing rods cast into the epoxy.

The second problem was caused by shrinkage of the cast epoxy insulator in the neck of the aluminum housing. This shrinkage, which occurred as the epoxy cured, caused localized stress at the junction of the housing and the output insulator. This made the insulator prone to fracture at this point, and may have also reduced its dielectric strength. To cure this problem, the mold was redesigned to eliminate the shoulder of epoxy which overhung the neck of the housing as shown in Figs. 5 and 6. This allows the epoxy to shrink back into the neck during the cure, thus reducing stresses in the insulator. this makes the insulator stronger both mechanically and electrically.

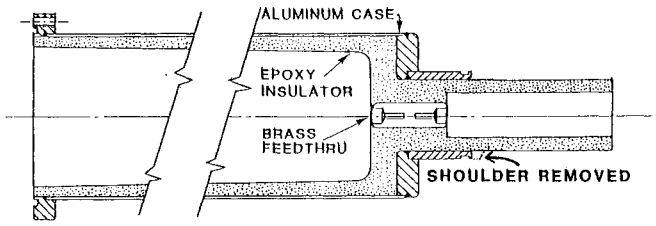

Fig. 5 Section through the housing showing the place where the shoulder was removed.

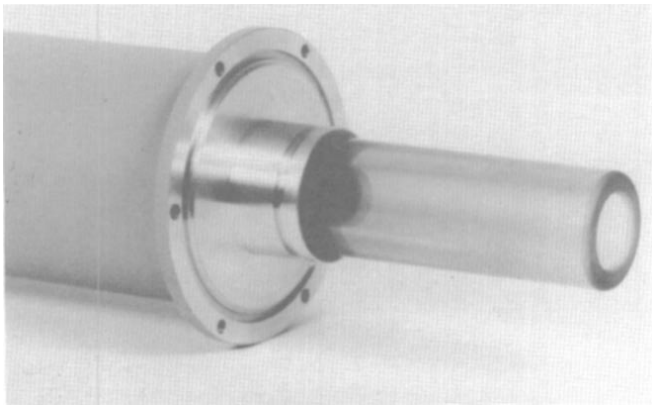

Fig. 6 Photograph of the output insulator of the Marx.

The last improvement involved the addition of a capacitor across the first gap to give the arc enough time to extinguish after the Marx fires. It was discovered that at high charge currents the charge resistors would supply enough voltage to sustain the arc in the first gap thereby preventing the Marx from recharging. As shown in Fig. 7 a 570 pF turn-off capacitor was added across the gap to solve this problem. This capacitor keeps the voltage on the gap low, long enough for the arc to extinguish.

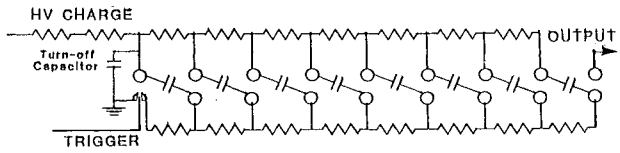

Fig. 7 Schematic diagram of the Marx showing the added turn-off capacitor.

Design Features

The Marx was designed for low inductance to achieve short risetimes and low source impedance. The wide brass connecting straps, short path lengths, and close-fitting coaxial ground return provided by the case are important features of this design. The inductance of the capacitors is the limiting inductance. The close-fitting case provides a high stage-to-ground capacitance. This prevents the inter-stage stray capacitance from causing following stages to rise in voltage during erection of the Marx, which would cause long erection times and unreliable triggering.

The reliable triggering of the micro-Marx is also aided by the air pressure which insulates and suppresses corona as well as pressurizing the spark gaps. Corona in any spark gap system causes ionization and electrical noise, thus higher pressure is required to hold off the charge voltage which makes triggering difficult or impossible. Pressurizing the entire micro-Marx suppresses corona and avoids messy and complex insulation systems.

The Mini Marx has proven quite trouble free in use, but it was designed to be easy to work on. Removal of six screws allows the rail assembly with all the components attached to be removed from the body. The output of the Marx does not need to be disturbed, and there is no oil to spill.

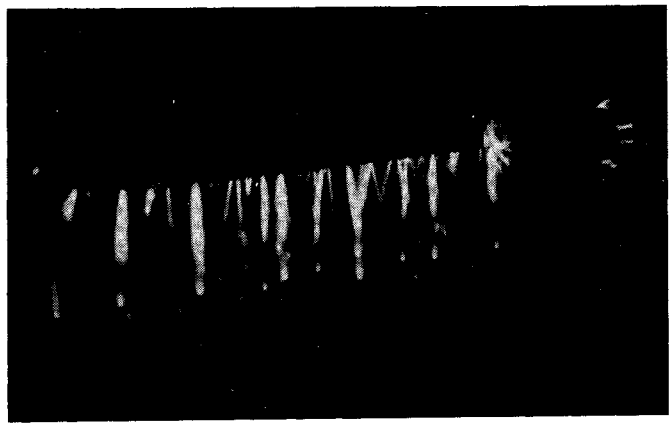

Fig. 8 One shot of the Mini Marx with an 18-inch-long wire three inches above a ground plane plugged into the output. The output insulator is visible on the right.

Electrical Characteristics

The output of the Mini Marx has been measured at over 200 kV into a 23 Ω load with a sub 2 ns risetime. One demonstration of the fast and high voltage is provided by suspending a wire connected to the Marx output about three inches above a ground plane. The result of a single shot is shown in Fig. 8. The multiple channels tell the story.

The Mini Marx is triggered by low energy 10 to 40 kV pulses. The most common system at Los Alamos uses a 10-kV Krytron pulser feeding a 4:1 ferrite step-up transformer. This produces a 40 ns risetime trigger pulse which gives a total system jitter of less than 5 ns. A faster trigger will give less jitter, but where this is not a consideration, slower lower voltage triggers provide reliable firing of the Marx. The Marx shows good immunity to triggering on various noise transients. A closely coupled trigger transformer helps this immunity. The coaxial high voltage change line and high value charging resistors contribute to this also.

The Marx will fire at about 1 pps with the 1.5 megohm charging resistors supplied. The rep. rate has been increased to about 10 pps by lowering the value of the charging resistors, and flowing air through the unit with the fittings provided.

Employment History

The Mini Marx has been used in a number of experiments at Los Alamos. In general, when a system is hard to trigger, especially when multi-channel operation is required, or when more precise timing than can be obtained with other units is needed, the experimenters come borrow a Mini Marx and are never heard from again.

The units in use at Los Alamos have fired tens of thousands of shots and have proven quite trouble free. It is hoped that commercial experience will be as successful.

REFERENCES

1. D. Platts, Proceedings of the Third IEEE International Pulsed Power Conference, Albuquerque, NM, 1981, p.485.

2. Veradyne Corp., 330 N. Victory Blvd., Burbank, CA 91502, (213) 849-6003.

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