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Miniaturization of Stun Gun Voltage Amplifier Circuit

Introduction

Despite the ubiquity of stun guns in the self-defense weapons market, relatively few advancements on this technology have been made ever since it was introduced to the market. Stun guns today are bulky and burdensome to carry along for the average person. It is thus the goal of this design project to design a miniature stun gun that can fit on a ring and yet not have its shock abilities compromised. This technical review paper focuses on the recent advancements in the miniaturization of the power electronic components used in electroshock weapons.

State of the art of stun guns

Commercial stun guns today are cheap, costing around $20 on average as one can attest by searching on Amazon. Firms typically emphasize the output voltage and additional utilities over the size of their products. Many commercial stun gun producers purposefully inflate the voltage ratings of their products in order to evoke a sense of security in their customers. [1] For example, the popular pocket-sized stun gun Streetwise™ Sting Ring Rechargeable Stun Gun Black 18M claims to be able to unleash 18,000,000 volts of electricity, which is physically impossible as 30 kV is the maximum voltage that can be applied between stun gun contacts spaced one centimeter apart. [1,2] Other popular stun gun producers advertise additional features that come with the stun gun. For instance, the number 1 best-selling stun gun on Amazon Vipertek VTS-989 comes with a rechargeable LED flashlight and spiked electrodes that can pierce clothes and skin. [3] While there is a demand for small and carriable stun guns, the smallest commercially available stun guns are still inches long in their dimensions (e.g., Sting Ring dimensions: 3" x 2.28" x 1") and therefore not wearable on the average person's hands. [2]

Circuitry of stun gun

Stun guns contain an amplifier circuit that boosts the voltage of a commercial DC battery to high voltages that are capable of producing electric arcs at the output electrodes. In a typical amplifier circuit today, the DC battery is coupled to a power inverter that converts the DC voltage signal to an AC signal. The AC signal is then fed into a series of step-up transformers that amplifies the signal to high AC voltages. The AC voltage signal from the transformers is then fed into a voltage multiplier circuit consisting of diodes and capacitors that further amplifies the signal. The capacitors then release charges to the electrodes, which generates an electric arc. [4]

Transformer miniaturization

The transformer plays a central role in the amplifier circuit. Typical high voltage transformers used in electroshock weapons are, however, centimeters in dimensions, which presents a great difficulty in miniaturization of the physical device. Thus, in order to minimize the dimensions of the stun gun, one would have to first device a method to reduce the dimensions of the transformers. Fortunately, there has been an abundance of research being conducted on micro-transformers. In a 2016 conference paper, Khan et al. demonstrated the possibility of fabricating a micron-scale planar transformer with a single metal layer. The structure they created consists of two metal wires that are interwounded side by side in a spiral configuration. [5] Since then, other micro-transformer geometries have been proposed. In a 2020 journal article, Dinulovic et al. demonstrated the possibly of fabricating a solenoidal transformer with a CoFeB core on a silicon substrate using only sputtering physical vapor deposition and chemical vapor deposition processes. The device they fabricated has a dimension of 1.6 mm x 0.8 mm and a breakdown voltage of 1250 V, which is below what a typical transformer used in electroshock weapons would have. [6] While the designs may not be intended for use in high voltage devices, they nonetheless provide valuable insight on miniaturizing transformers in general.

Battery miniaturization

Conventional stun guns are powered by alkaline batteries that are bulky and heavy. Thus, in order to miniaturize the dimensions of the stun gun, one must reduce the dimensions of the battery. However, like transformers, it is often the case that smaller batteries provide less power. Hence, it suffices to find a battery that provides high energy density. In recent years, solid state batteries have shown to satisfy this requirement. The typical solid-state batteries today are not suitable for high voltage applications. However, Zhang et al. recently discovered a method to fabricate an all-solid-state lithium-ion battery that exhibits a high anodic limit over 6 V by using a dual-halogen solid electrolyte. [7] While the device the showed limited stability, it nonetheless still serves as a great indication of the potential application of solid state batteries to high voltage devices.

References

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