Exploding Bridge Wire Detonators

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iSAFE
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Exploding bridge wires (EBW) detonators have a small wire imbedded in with ignition material. When sufficient electrical current is passed over the wire, the wire explodes and initiates detonation by the resulting shockwave. As a result, EBW detonators are extremely precise. This project aims to design and create an EBW detonator.

Energy Requirements

Energy requirements are based on the chemical energy needed for exploding standard gold bridge wires: 1.5 mil diameter x 40 mil length. Capacitor size, number of capacitors, and material properties are easily changed for new design criteria. Electrical requirements can be enhanced by testing and improving assumptions such as burst time. To ensure initiation and not ignition, energy needs to increase over smaller amounts of time.

Parameters		Calculations	Per EBW	Total EBW
Radius(in)	0.0015	Volume(m^3)	4.63333E-12	
Length(in)	0.04	Mass(grams)	8.95159E-05	
Density(grams/mol)	19.32	Mols(mols)	4.54488E-07	
Molar Mass(grams/mol)	196.96	Hvap(KJ)	0.000159071	0.000318141
Heat of Vaporization(KJ/mol)	350	Voltage(V)	564.0403142	797.673462
Number of Capacitors(#)	1	Resistance(Ω)	0.004932554	
Capacitance(microfarad)	1	Power(Watts)	159070.738	318141.476
Resistivity(nΩ*meter)	22.14	Current(A)	282.0201571	398.836731
Time Frame(microseconds)	1			
Number of EBW(#)	2			

Table 1: Exploding Bridge Wire Electrical Calculations

Marx Generator

Marx generators take low DC voltage inputs and creates high voltage electrical arcs. In essence, the generator is used as an energy storage element, with applications in pulse charging circuits such as High Power Microwave and the Z machine. They charge capacitors in parallel before suddenly connecting them in series. When the first gap experiences breakdown, the remaining gaps breakdown and stack the voltages. The circuit can replace an expensive capacitor with many smaller and cheaper ones.

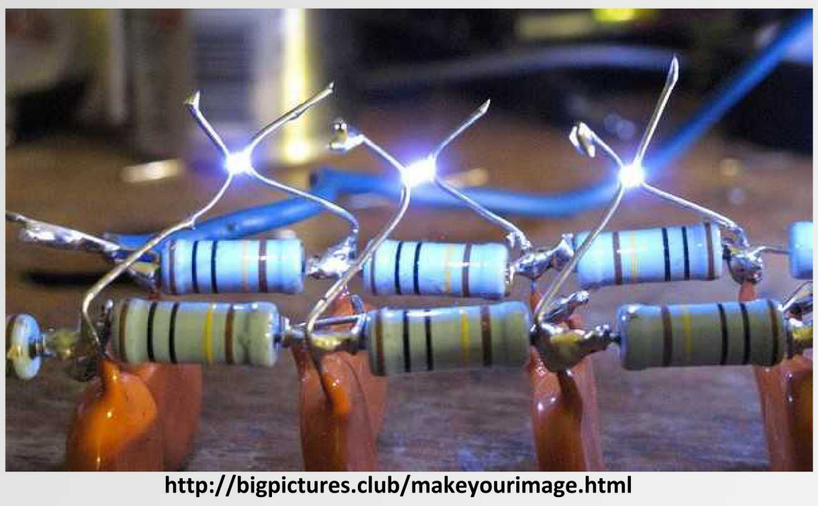

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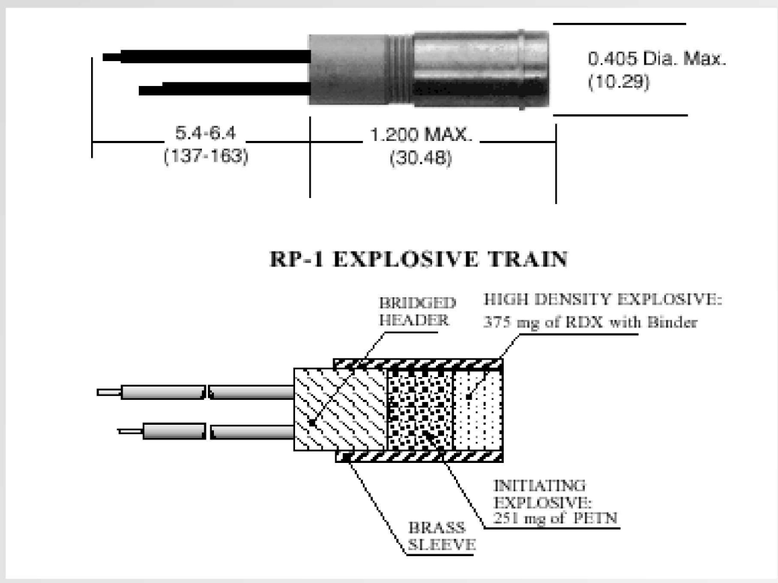
Figure 3: Marx Generator



Teledyne Risi Rp-1

Figure 1: RP-1 Exploding Bridge Wire Detonator

Electrical Design

The explosion of the bridgewire requires current with very fast rise time. Burst action, Gb, is the area underneath the current squared by time. This value is a constant for each bridge wire. Low impedance capacitors allow for smaller burst time and higher burst action.

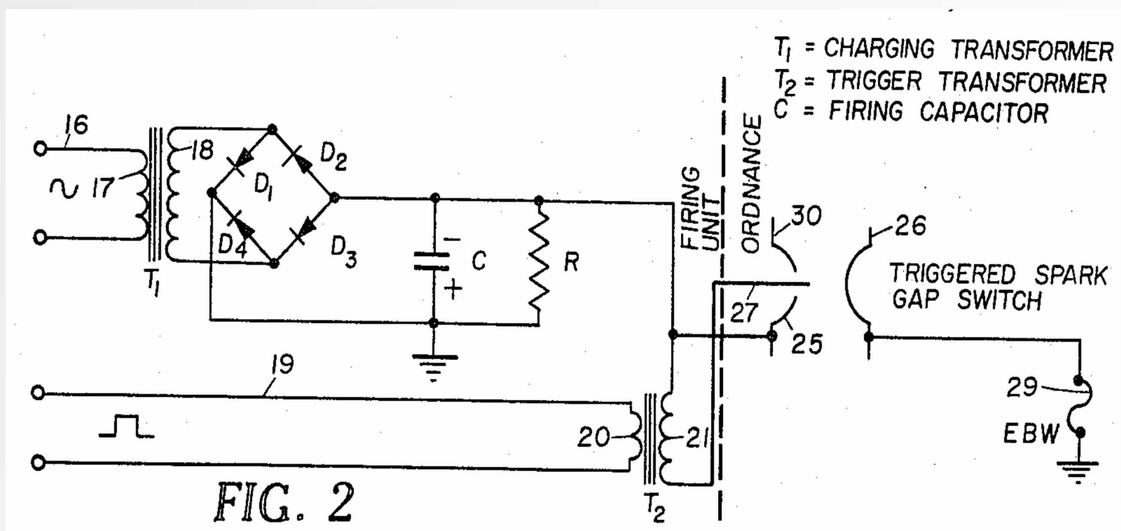


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Figure 2: Exploding Bridge Wire Detonator Electrical Diagram

- Gb = 0.11 A^2 s for standard gold wire
- Because of the statistical nature of EBW detonators, firing requirements are given as mean and standard deviation
- PETN pressed to certain densities require different threshold burst currents

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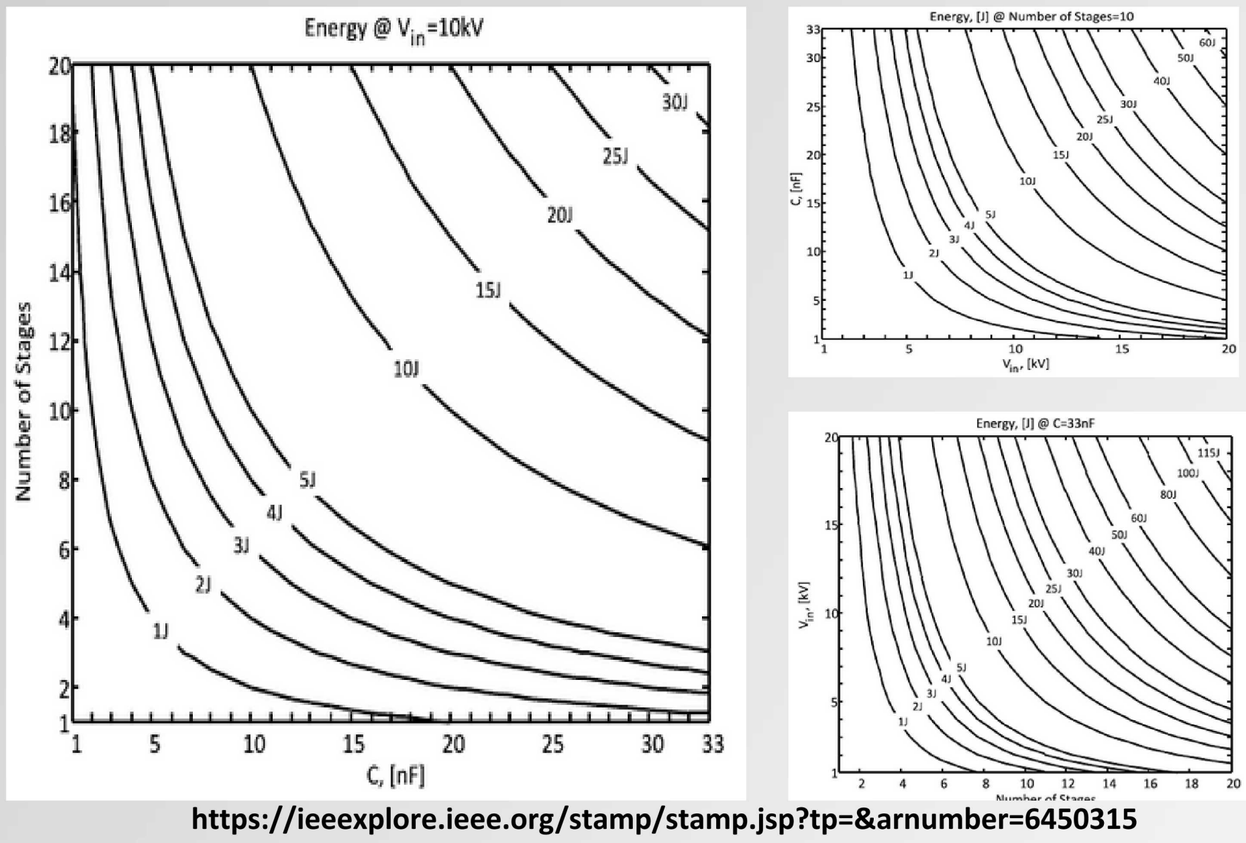
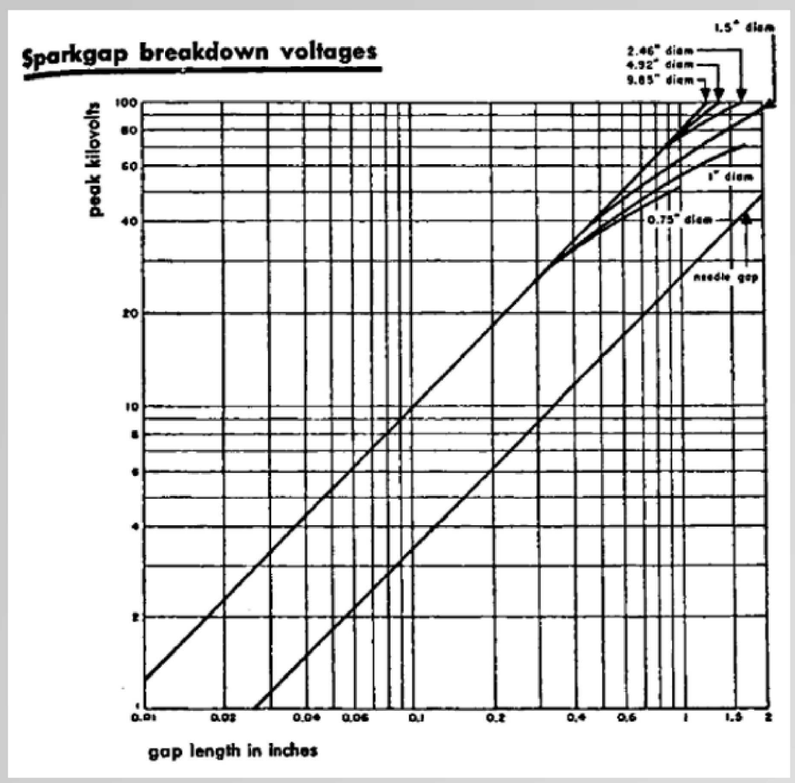
Cockcroft-Walton Generator

A high voltage source is needed to charge the capacitors. Cockcroft-Walton circuits generate high DC voltages from low AC inputs. This circuit can be extended to any number of stages. The no-load output voltage is twice the peak input voltage multiplied by the number of stages N or equivalently the peak-to-peak input voltage times the number of stages.



https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6450315

Figure 4: Marx Generator Testing Results



https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20000053468.pdf

Figure 5: Spark Gap Testing Results

- Marx generators can be configured based on 4 parameters: number of stages, capacitance, energy, and voltage
- Sparkgap breakdown voltage are characterized by peak kilovolts, gap length, and gap diameter. Pressure and temperature can also multiply the results from 0.26 at 127 mmHg and -40 deg C to 1.69 at 1524 mmHg and 60 deg C.

Triggered Spark Gap

Trigatrons have three electrodes. During normal operation, the voltage between the main electrodes is slightly lower than the breakdown voltage, dependent on their distance. To activate the device, a high voltage pulse is delivered to the triggering electrode. This pulse ionizes the medium between it and one of the main electrodes, creating a spark. Then, the spark leads to the rapid electrical breakdown of the main gap, culminating in a low resistance electric arc between the main electrodes.

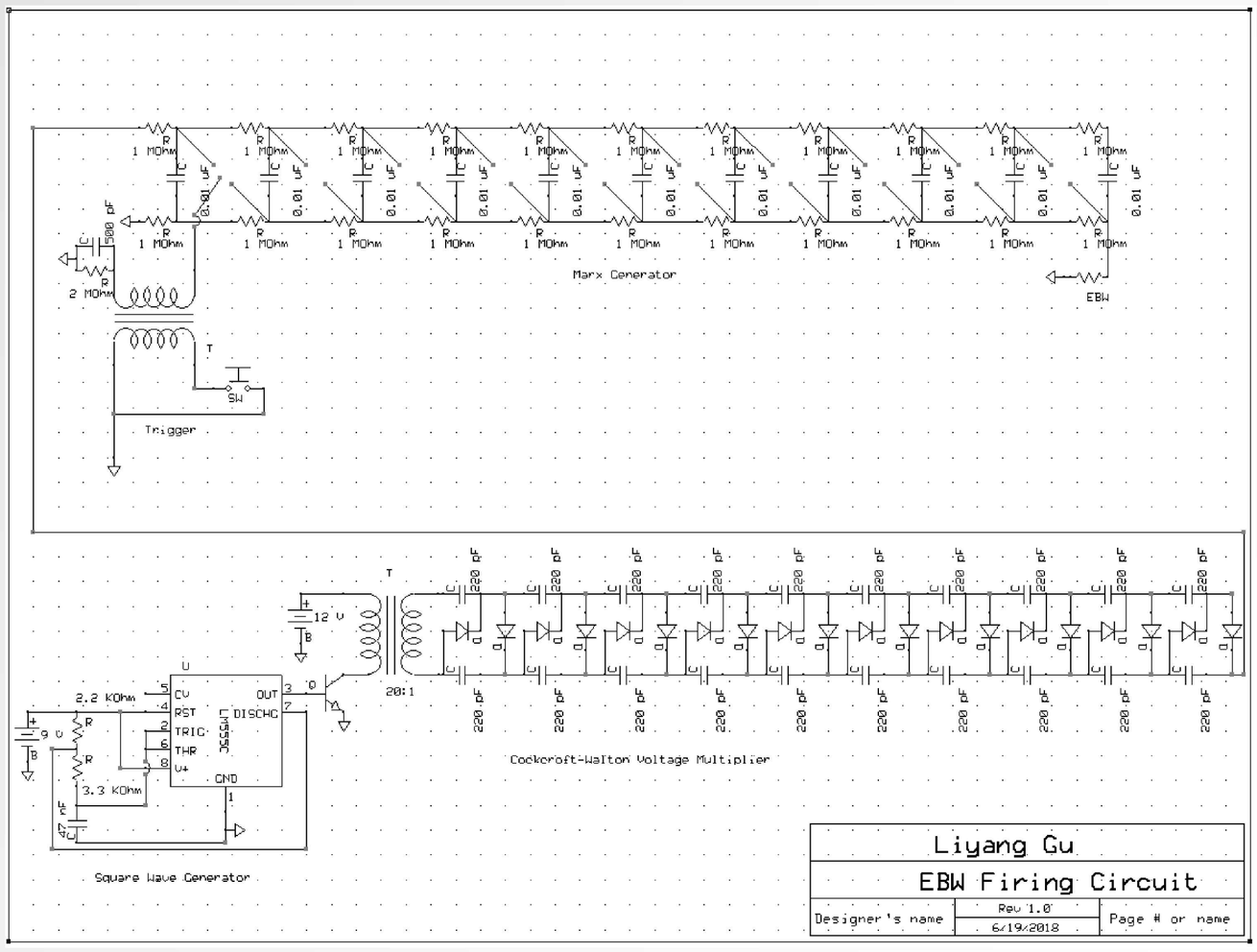


Figure 6: Firing Circuit Diagram

Further Work

In depth statistical work has been performed on the major circuit components. Other components can affect the operation of EBW detonators. Cables increase current rise time. Multiple EBW detonators in parallel will be limited by current and multiple in series will be limited by voltage. Exploding bridge wires require more designing than hot wire initiators, but their accuracy, safety, and reliability are huge advantages.

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