LA-UR-15-26000

Title: Data Analysis for Explosive Firesets

Author(s): Barks, Thomas A.

Intended for: Student Poster Session
Report

Issued: 2015-07-30

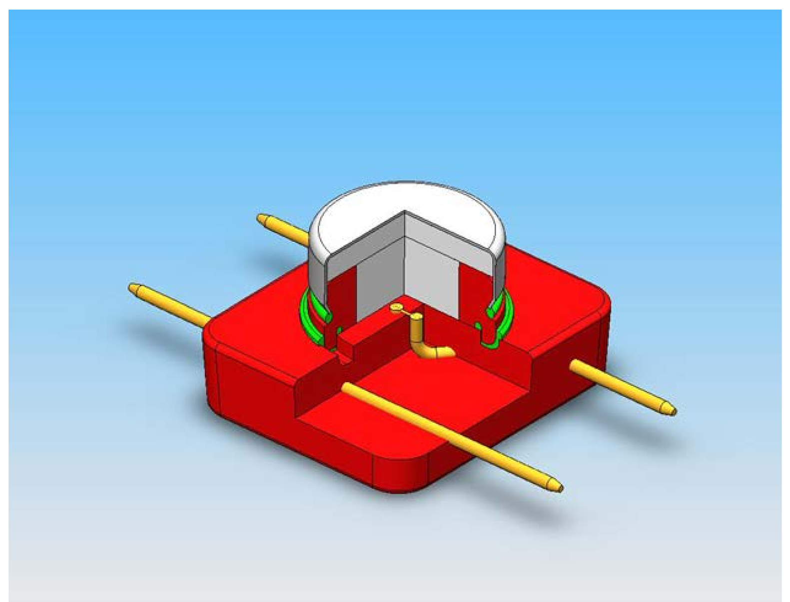
Data Analysis for Explosive Firesets

Thomas Barks, W-6

Weapon Systems Engineering

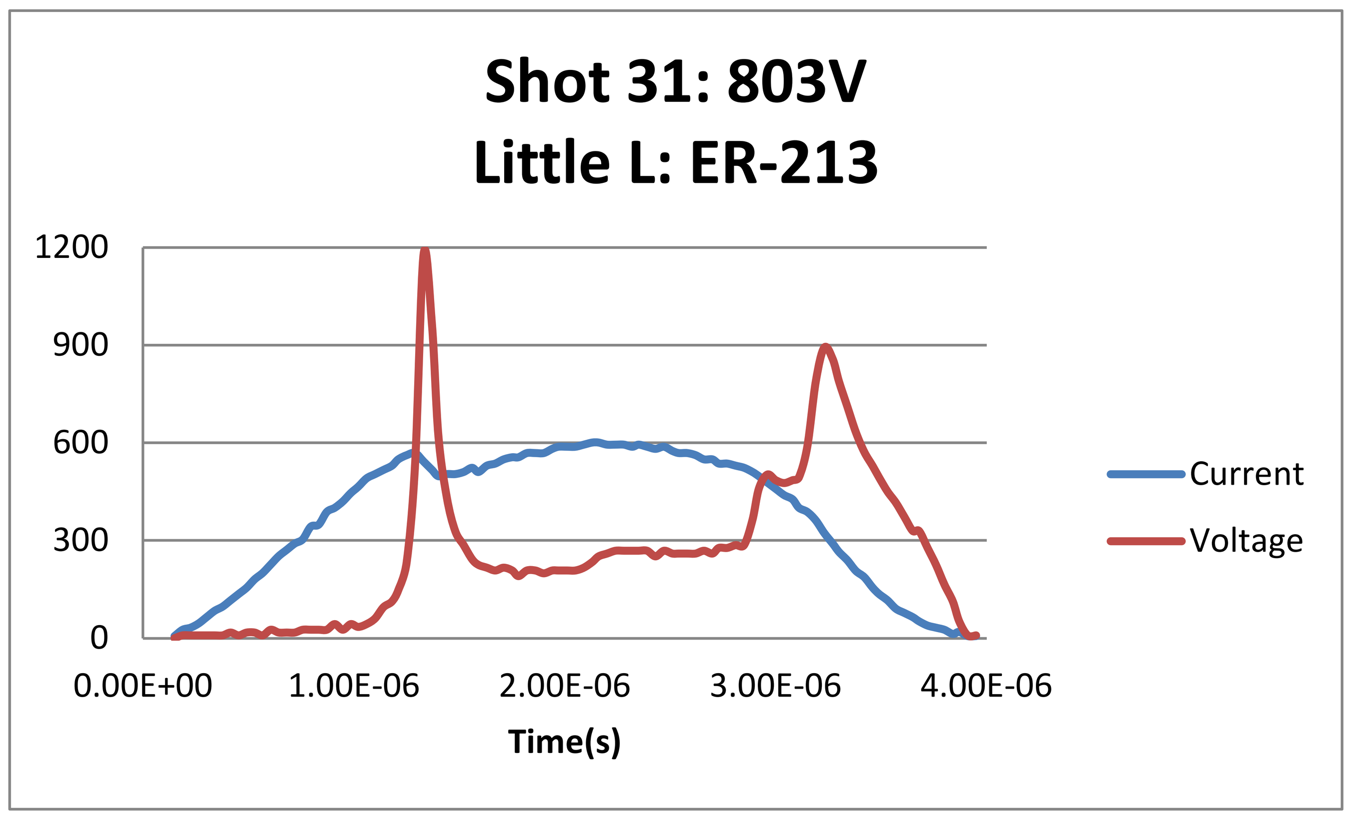
What are EBWs?

There are a number of different detonators that can be used to initiate an explosive, but one of the older yet still commonly used today is the exploding bridgewire(EBW) detonator. The EBW was invented at the Los Alamos National Lab during the Manhattan Project and has been used since despite the introduction of new detonators. An EBW has two very small wires, usually made of gold, that allow current to come in and go out. Inside the EBW, connecting the two wires is an even smaller wire that is barely visible to the human eye. When current is sent into the EBW, the connecting bridgewire is heated very rapidly, causing the wire to quickly change phases from solid to liquid to gas. Within nanoseconds, the wire effectively bursts and creates a plasma arc that can initiate a low density explosive, like powdered sugar, which initiates a higher density explosive, like a candy wafer, which is capable of initiating a booster and finally the main explosive.



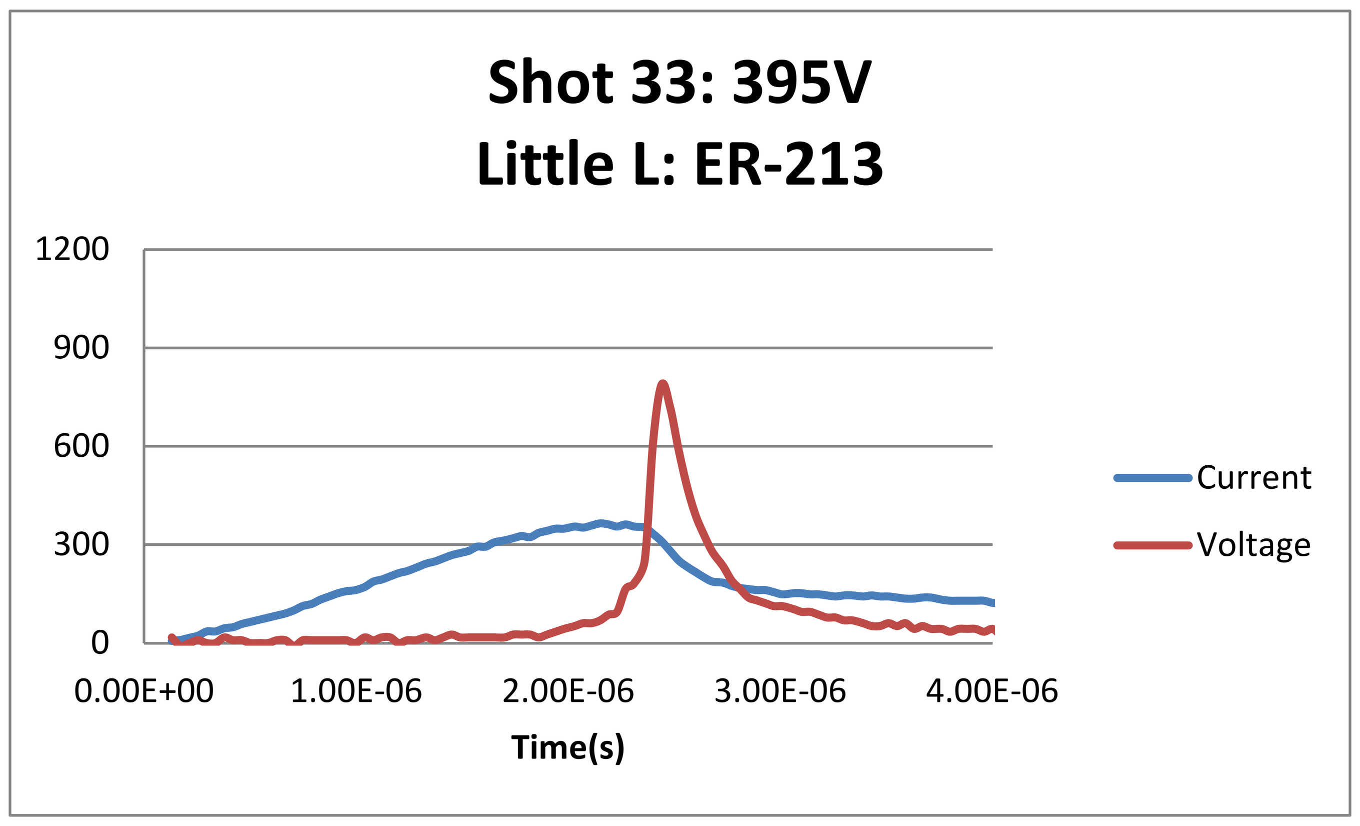
What is a Fireset?

A fireset is the device that sends current to the detonator, in this case an EBW, which then sets off the explosive. To send this current, a capacitor is charged inside the fireset and is then discharged into the detonator. Because of the very small time interval, the way the fireset is set up, and the quickly changing states of the bridgewire, voltage and current behave according to the graph below.



As the graph shows, current and voltage both rise and fall, but in response to different things. If there were no burst, then the current graph would be a smooth parabolic rise and fall, but because of the burst, there is a slight deflection. This deflection is especially noticeable if the bridgewire does in fact burst. If not given enough initial voltage to charge the capacitor or if a large sized wire is used for the bridgewire, there may not be enough current to create a burst. Opposed to the current, the voltage has a very steep rise and then fall. The peak of this rise is when the bridgewire will burst if it bursts at all. If the bridgewire does burst, then there are often odd voltage readings after the initial peak.

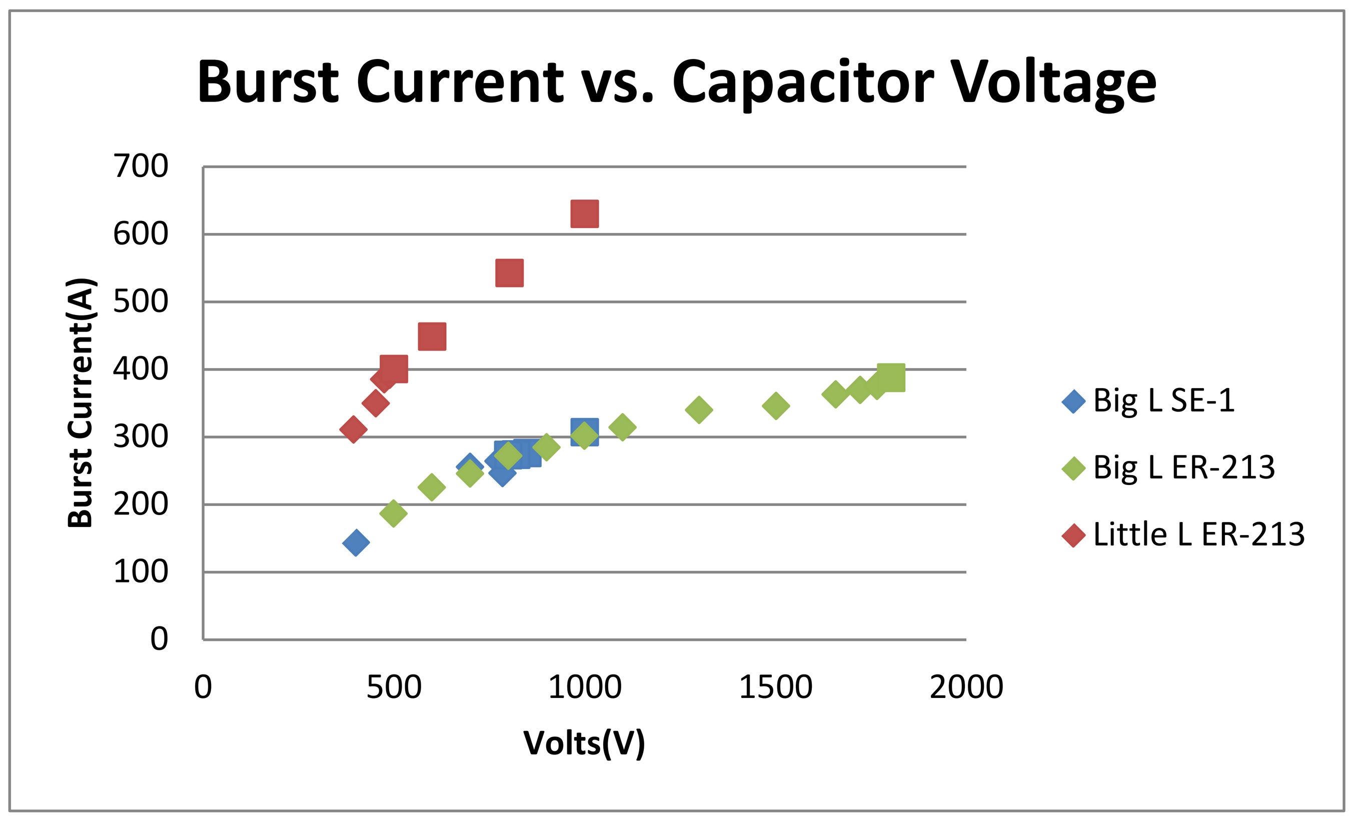
Under ideal circumstances, the voltage peak occurs when the current is rising. This will give the best chance for the bridgewire to burst. When not enough initial voltage is used, the peak voltage will sometimes be when the current is falling, often resulting in a no go, no burst.



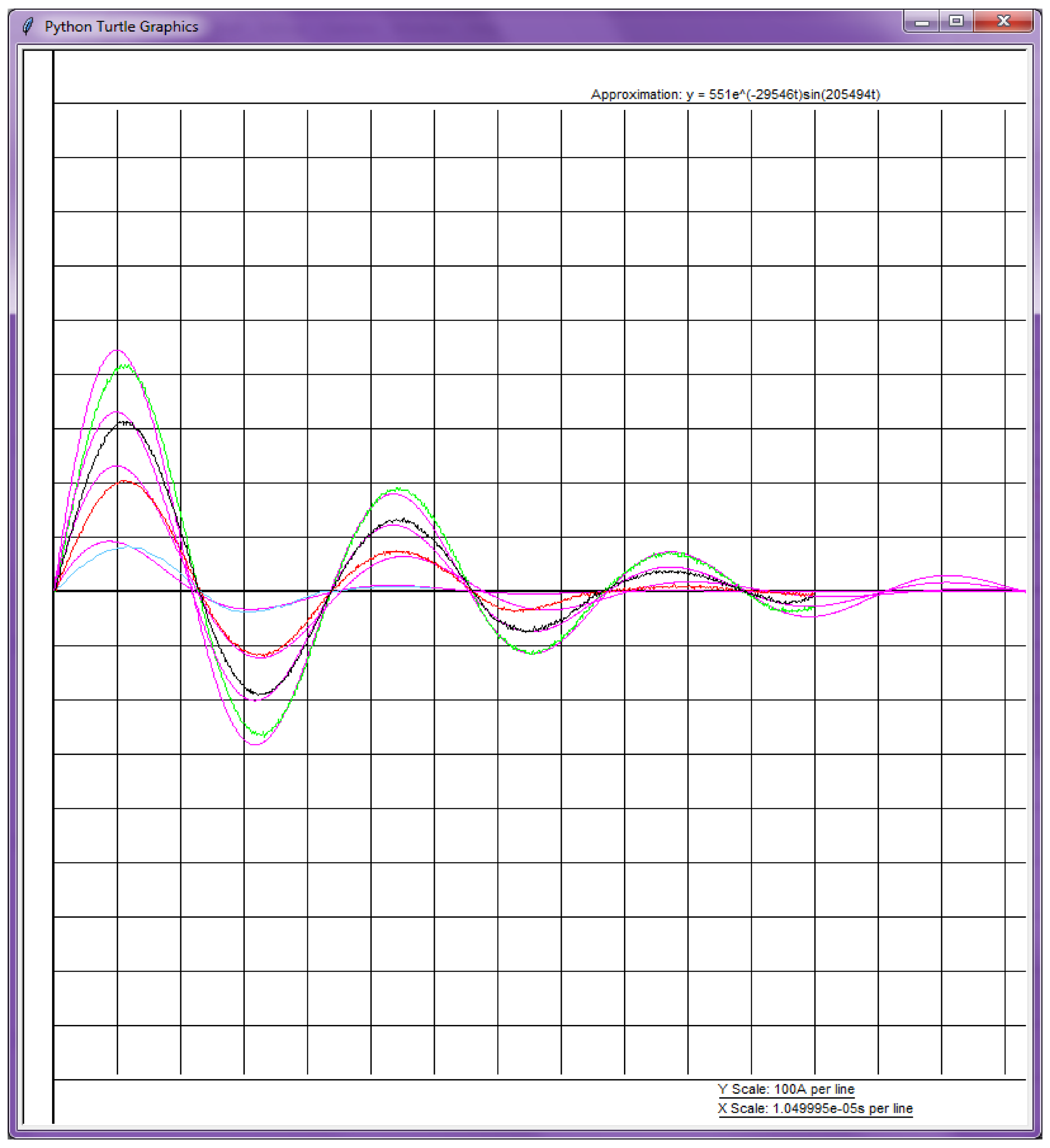
What am I Doing?

I analyzed the data from various detonators at different initial voltages to find the RLC values (resistance, inductance, capacitance) of the fireset. The data I was given contained a current and voltage for each time value taken on nanosecond intervals. From this, I was able to make plots of several variables to try and find which if any of variables correlated with a burst or a go. These results will allow us to fully understand what is required to achieve a burst in the bridgewire so that we can know what is safe or what will never cause detonation. We may also be able to predict the outcome of using the same fireset with different detonators or with different sizes or materials of bridgewire.

The results of some of my data analysis are shown below. Diamonds indicate a no go, squares are a go.

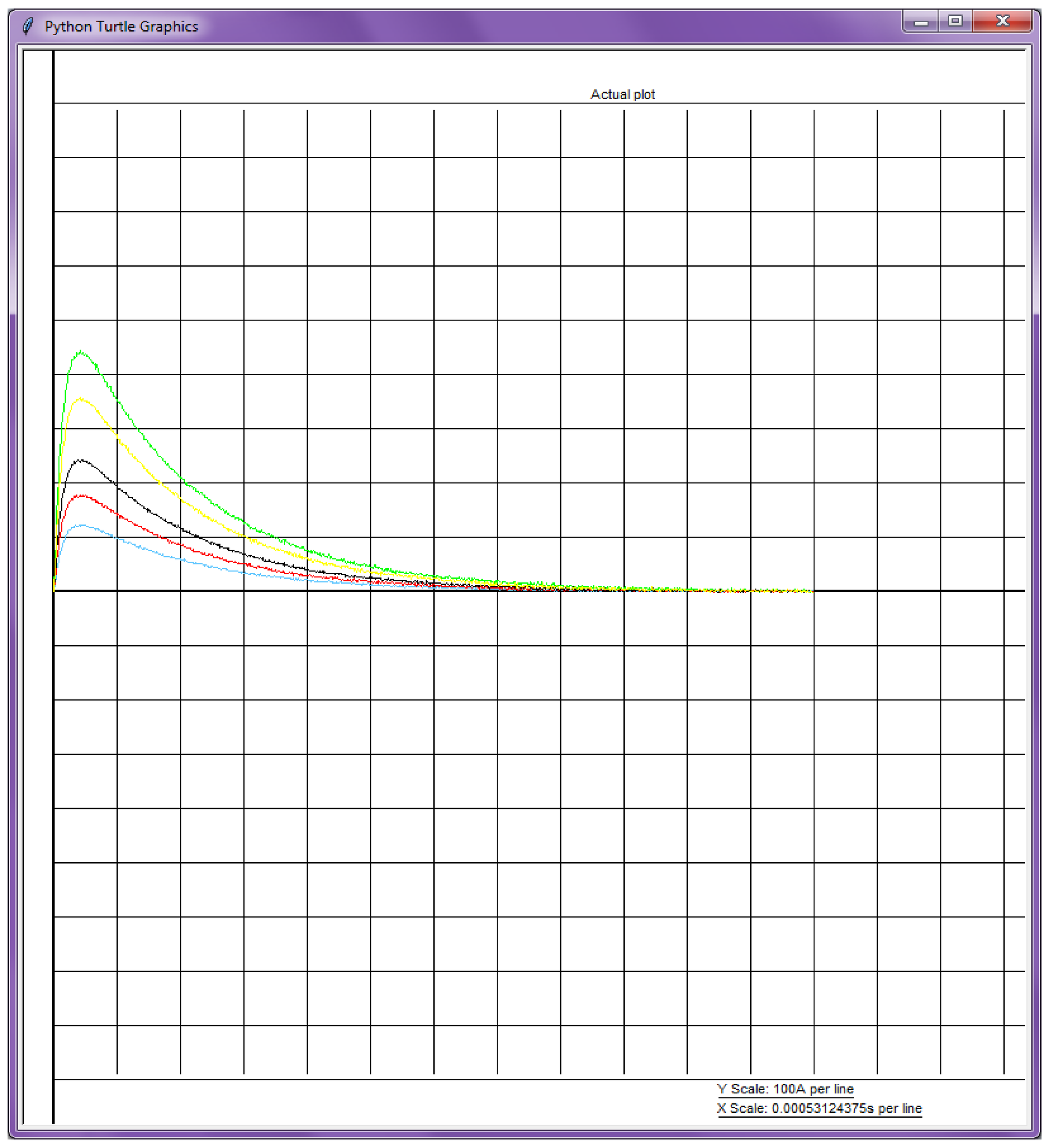


This plot shows burst current (the amount of current at the voltage peak) versus capacitor voltage (the initial voltage the capacitor was charged to before sending the current into the detonator). As the capacitor is charged with higher and higher voltage, the current at burst is increased. In this plot, there are two EBWs with differing bridgewire sizes, SE-1 and ER-213, and two different outputs, big inductance and little inductance. From the graph you can see that the big inductance shots have a fairly linear increase and the little inductance shots have a different linear increase. What is interesting in this plot is the point at which the shots transition from no go to go. With the same detonator, ER-213, the burst current at the transition from no go to go is roughly the same for both big and little inductance at about 400 Amps. Normally, to find the transition capacitor voltage, guesses are made to narrow in on what goes and what does not. With this finding, there is a target burst current for that specific detonator that can be used to narrow down on the transition faster. Besides just knowing if our voltage is too high or too low, we now have an idea of how far off the voltage is from the transition.



In addition to the previous plot, I also developed an algorithm to create an equation to approximate the current data (current versus time). These ringdowns do not have a burst, they just oscillate, and their peaks decay exponentially. From the derived equation, the RLC values of the fireset can be calculated. The above graph shows four different ringdowns of four different capacitor voltages for one detonator.

What's Next?



This next graph shows a different experiment that does not ringdown like the others. It peaks and the dies off. Because of this, I must develop a new method to solve for the RLC values. I will also try to improve what I have done by trying to find the same answers without needing as much data. An example of this is removing features such as the voltage probe which measures the change in voltage throughout the burst. If this probe is removed, then the deflection in the current can possibly be used to know when the burst occurred instead of using the voltage peak.

Through these experiments, we can make detonators safer and more efficient as well as develop a deeper understanding of how they work.

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National Nuclear Security Administration