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BDX-613-1668 (Rev.)

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DIGITAL ANALYSIS OF
EBW BURST WAVEFORMS

Final Report

J. R. Lembke, Project Leader

Project Team:
A. L. Tindall
C. Latimer

Published January 1978

Prepared for the United States Department of Energy
Under Contract Number EY-76-C-04-0613.

**Kansas City
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Printed in the United States of America

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Price:	Microfiche	\$3.00
	Paper Copy	\$4.00 <i>\$4.00 stat</i>

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DIGITAL ANALYSIS OF EBW BURST WAVEFORMS

BDX-613-1668 (Rev.), UNCLASSIFIED Final Report, Published
January 1978

Prepared by J. R. Lembke, D/812

A dual-channel digitizing capability has been established to digitally record and analyze electrical waveforms associated with exploding bridgewire (EBW) burst. The system is interfaced to a computer for data management and analysis. Programs for calibration and for analysis of voltage and current waveforms have been written. Error sources have been reduced to an acceptable level, and provisions have been made for generation of a waveform data library.

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A prime contractor with the United
States Department of Energy under
Contract Number EY-76-C-04-0613

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SUMMARY

The goal of this project was to digitally record and analyze the electrical waveforms associated with exploding bridgewire (EBW) burst, as a means of improving the characterization of EBW quality.

Two fast transient digitizers were used to record the voltage and current waveforms generated during exploding bridgewire burst. Both digitizers were interfaced to a computer for automatic analysis of waveform characteristics. Programs were developed to align the two data sets in the time domain, and to compute and plot power, action, resistance, and energy as functions of time.

A technique for automatic time calibration and amplitude calibration of the vidicon digitizer was developed, and software was written to apply calibration constants to the recorded data. A capability was added for creation of a data library for storage of burst data and calibration constants.

Measurement accuracy was improved by design of a printed-circuit differential voltage divider, with integral voltage and current probes, to hold the part under test. With this device, error caused by the inductive component of measured burst voltage is negligible.

Future applications of this capability will require provision of a suitable firing unit for each EBW type to be evaluated.

DISCUSSION

SCOPE AND PURPOSE

The goal of this project was to improve the characterization of exploding bridgewire (EBW) quality by making use of information in the waveforms which occur during bridgewire burst. The reported work was accomplished between August 1973 and June 1976 and was funded.

PRIOR WORK

Initial activity on this project has been reported in Reference 1.

ACTIVITY

Waveform Recording System

Burst waveforms are obtained by exploding an EBW element using a capacitive discharge unit (CDU). The block diagram of a typical firing arrangement is shown in Figure 1.

Voltage and current waveforms are recorded by two independent transient digitizers. One of these is a commercial device (Biomation Model 8100) with 10 nanosecond resolution. The other is a vidicon transient digitizer with 1 nanosecond resolution.² Both digitizers are interfaced to a PDP 11/05 minicomputer. A detailed description of the two transient digitizers is contained in an earlier report on this project.¹

Dual Channel Operation

Programs were written to coordinate the operation of the two digitizers so that voltage and current waveforms from a single burst could be recorded simultaneously. Because the digitizers operate at different sample intervals, it was necessary to develop software to align the waveforms at zero time and to interpolate within the slower data set to obtain voltage and current data at identical points in time. The programs also apply calibration factors to convert the measurement data to SI units. A typical set of processed waveforms is plotted in Figures 2 and 3.

After these steps have been performed, it is possible to compute resistance (v/i), action ($\int i^2 dt$), power (vi), and energy ($\int vi dt$) by numerical operation on the voltage and current data.³

Figure 1. Waveform Recording System

Figures 4 through 7 are plots of these functions, computed from the voltage and current data in Figures 2 and 3.

Automatic Calibration

The vidicon digitizer hardware includes a capability for automatic calibration under computer control. Programs were developed to make use of this capability for both amplitude and time calibration.

Calibration of the time axis is performed by digitizing a square wave which has crystal-controlled frequency and locating the positions of zero crossings in the digital data. Because the time between zero crossings is accurately known, a map of time versus digital position can be generated. Intermediate values (between zero crossings) are interpolated by a cubic spline technique.⁴ Once the mapping function has been computed, it can be stored for application to actual waveform measurement data. The entire operation is controlled by the computer.

Figure 2. Voltage Waveform, Measured

Figure 3. Current Waveform, Measured

Figure 4. Resistance (v/i), Computed From Data in Figures 2 and 3

Figure 5. Action ($\int i^2 dt$), Computed From Data in Figure 3

Figure 6. Power (v_i), Computed From Data in Figures 2 and 3

Figure 7. Energy ($\int v_i dt$), Computed Integral of Figure 6

For amplitude calibration, five different dc voltage levels are generated in response to computer commands, and each of the voltage levels is digitized. The levels are automatically selected to cover the amplitude range of the digitizer as it is configured during the calibration. Multiple regression is used to compute a "calibration response surface" which is the best fit to the level measurements over the entire measurement field. The result is a set of coefficients which allow rapid computation of the voltage corresponding to any digitized coordinate pair (amplitude versus time).

The coefficients are stored and are recalled later for transformation of actual waveform data.

Reduction of Voltage Error

A primary source of measurement error is the inclusion in the voltage waveform of components other than EBW voltage. Figure 1 indicates that voltage components from the current viewing resistor (CVR) and from stray circuit inductance will be included in the measured voltage waveform. These voltage components must be minimized if EBW resistance, power, and energy are to be computed.

A possible approach to this problem is to develop programs to correct the measured data by computing and subtracting the error components. CVR voltage is known from the measured current waveform, and can be eliminated easily. Voltage due to stray inductance is of the form $V = L (di/dt)$, and its computation would require numerical differentiation of the measured current waveform. (Direct measurement of di/dt is possible, but would require an additional digitizer channel.) After several attempts with various techniques, it was concluded that numerical differentiation is too unstable for this application. Small errors due to the digitizing process are magnified during differentiation to produce results which are unusable. Numerical smoothing and filtering techniques were attempted, but produced arbitrary results.

Since numerical correction for inductive effects was not practical, it was extremely important to minimize the inductive component in the measured waveforms. For this purpose, a differential voltage divider was developed which combines the functions of mounting the EBW, of providing voltage and current contacts to the EBW, and of providing two identical voltage divider circuits whose differential outputs are matched to the 50-ohm input impedance of the transient digitizer. The electrical configuration is shown in Figure 8.

The divider consists of an etched circuit board, 25 by 75 mm, with provision for mounting the resistor network and coaxial connectors

Figure 8. Recording System With Differential Voltage Divider for EBW Voltage

for attachment to the CDU and digitizer. A pattern of etched contacts (Figure 9) provides four-point electrical connection to the EBW. The element is placed face down on the contacts and held in place with a resilient pressure pad. Only the very small inductance of the EBW element (typically less than 2 nH) is included in the voltage measurement.

Results of measurements made with this differential divider indicate that the recorded inductive voltage component is acceptably small in comparison with the resistive voltage component across the EBW. Inductive effects are noticeable only very early in the waveforms, when di/dt is large and the EBW is still relatively cool. This is especially evident in the resistance waveform (Figure 4) which shows a false peak in the first 100 ns. The effect on computed power and energy (Figures 6 and 7) is negligible. (Action is not affected, because it is a function only of current.)

Figure 9. Etched Contact Pattern of Differential Voltage Divider

Data Library

A waveform data library was established to facilitate comparisons between various data sets and to develop a basis for discriminating between acceptable and unacceptable firing data. The library is stored in digital form on magnetic media (disc and tape).

To implement the library, the computer programs were divided functionally into two units. The first unit coordinates operation of the digitizers during EBW burst and stores the raw (uncalibrated) voltage and current waveforms. This unit also performs automatic calibration when required, and stores the calibration data. The storage files are cross-referenced, so that each data file contains a pointer to its associated calibration file.

The second program unit retrieves any data file specified for analysis. It also accesses the indicated calibration file, and transforms the raw data into calibrated data. Finally, the data is processed to establish a common time reference between voltage and current and to produce related waveforms, such as power and action. Graphical output can be produced at this time, and numerical results such as "action at time of voltage maximum" are printed.

This approach was used to provide flexibility in use of the library. When improved computational methods are developed, or additional types of analyses are required, the stored raw data will not become obsolete because it can be reprocessed with new analysis programs.

ACCOMPLISHMENTS

A capability was established for dual-channel digitizing of EBW voltage and current burst waveforms. The two digitizers employed were interfaced to a computer, and programs for control of the data recording process were written. Automatic calibration of the vidicon digitizer was achieved, and measurement error was further reduced by implementation of a differential voltage measurement technique.

A system of programs was developed to permit permanent storage of raw waveform data and calibration coefficients, and for subsequent retrieval and processing of stored data. Functions such as energy and action can be computed, and all waveforms can be plotted for visual analysis.

FUTURE WORK

This project has established the capability for EBW waveform analysis. Appropriate firing units will be required for application of this technique to specific EBW designs.

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