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DATA COMPRESSION FOR TRANSIENT MEASUREMENTS.(U)
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DATA COMPRESSION FOR TRANSIENT MEASUREMENTS (U)

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Introduction

Several years ago an effort to replace obsolete data acquistion instrumentation at Aberdeen Proving Ground's Materiel Testing Directorate was initiated. The thrust of this effort was to develop a networked, distributed acquisition and processing system to provide a higher data integrity, reduce the time frame from experiment to report, and to enhance productivity.

One type of testing that is performed within MTD involves the capture of high speed transient phenomena, such as internal weapon chamber pressure or blast overpressure.

The requirements encountered in the measurement of blast overpressure are particularly strident, and consist of up to 16 data channels, each with a recording rate of 400,000 samples per second, over a recording interval of up to 200 milli-seconds. Each repetition of a set of blast overpressure measurements generates in excess of 1.25 million words of data. This type of experiment is at times performed at approximately five minute intervals, and the amount of data involved can seriously impair the effectiveness of the data acquisition system. Other classes of testing impose data loads that can approach these figures.

To reduce the impact of these large quantities of data, a means of reducing the amount of data while maintaining the level of information has been developed and implemented in APG's Automatic Sampling Rate Digitizer.

Background

Data compression can be defined as the elimination of redundant data samples. Such techniques as the extraction of the mean and standard deviation, the root-mean-square (RMS), or other statistical measures such as histograms are certainly compressive in nature, but for the purposes of this presentation only those processes which allow the reconstruction of the time history of the original signal will be considered.

The concept of data compression is not a recent development, and in fact a family of data compression algorithms have been applied to telemetry data over the past several years. Table 1 is a listing of eight standard compression algorithms (1,4).

ORDER	CORRIDOR	RECORDED SAMPLE	DESCRIPTOR
Zero	Fixed	Nonredundant	ZFN
Zero	Variable	Preceeding	ZVP
Zero	Variable	Adjusted	ZVA
First	Fixed	Nonredundant	FFN
First	Fixed	Preceeding	FFP
First	Fixed	Adjusted	FFA
First	Variable	Preceeding	FVP
First	Variable	Adjusted	FVA

Table 1. Standard Data Compression Algorithms

The simplest of these algorithms is ZFN, demonstrated in Figure 1. In this compression scheme, the first sample is recorded and a programmed delta corridor is established with that value at the midpoint of the corridor. Each subsequent data sample that falls within the delta corridor is rejected until a sample falls outside the corridor. That sample is recorded and the corridor is moved so that it is centered on the nonredundant sample.

The maximum error produced by ZFN processing is equal to one half of the corridor value. Compression ratios (number of sampled data points divided by the number of recorded data points) in the range of 7:1 to 50:1 have been documented.

The other compression algorithms vary in complexity and effectiveness. Table 2 (1,4) indicates the peak error for the standard algorithms. Also included in this table is an indication of the range of compression ratios for some of the algorithms from an experiment using both simulated and real data.

Algorithm	Peak Error	Compression Ratio Range	
		Simulated Data	Real Data
ZFN	+-1/2 Delta	11:1	7:1-50:1
ZFP	+-1/2 Delta		
ZVA	+-1/2 Delta	19:1	10:1-65:1
FFN	+-Full Scale		
FFP	+-Delta		
FFA	+-Delta		
FVP	+-1/2 Delta	10:1	6:1-40:1
FVA	+-Delta	9:1	7:1-45:1

Table 2. Comparison of Errors and Compression Ratios

ASRD Compression Algorithm

All of the standard compression algorithms are asynchronous in nature, and as such each recorded data sample must be accompanied by the time of occurance. This effectively reduces by one-half or one-third the savings gained by data compression. In addition these schemes are primarily designed for application to stationary data.

In the ASRD a compression algorithm somewhat related to ZFN is implemented. Instead of establishing a delta corridor, however, the absolute value of the rate of change (first derivative) of the signal is calculated, and based upon this value data samples are recorded at power of two multiples of the basic sampling interval of 1.25 microseconds (2). The equation governing the recording interval is:

$$I = 1.25 \times 2^{(15 - RC)} \text{ microseconds} \qquad (1.)$$

Where

$$RC = 7 + \log_2 \left(\sum_{J=1}^{N} |\Delta_j| / M \right) - \log_2 (80/fmax) \qquad (2.)$$

In addition to the establishment of recording intervals in accordance with equation 1 the ASRD algorithm is modified by the establishment of minimum recording rates, dependent on the signal bandwidth, and by the use of recording rate hysteresis. Recording rate hysteresis implies that the recording rate is maintained at an elevated level for a programmed length of time after the required rate, as determined by equation 2, decreases. Both of these features reduce the compression ratio, but serve to enhance the fidelity of the reconstructed signal.

Table 3 is a compilation of the parameters used in the ASRD. These parameters are chosen to generate summations with values ranging from 0 to 255. The function for RC is designed to cause the recording of at least 10 samples per cycle of any full scale signal within the programmed bandwidth.

f MAX (KHz)	DIVISOR	SUMMATION INTERVAL	DECREASE DELAY (MICROSEC)	MINIMUM RECORDING RATE (SAMPLES PER SEC)
80	1	4	200	6,250
70	2	9	200	6,250
60	2	11	200	6,250
50	2	13	200	6,250
40	1	8	300	6,250
30	2	21	300	6,250
20	1	16	500	3,125
10	1	32	900	1,562.5

Table 3. ASRD Compression Parameters

Hardware Implementaion

A block diagram of the data acquisition systems of which the ASRD is a part is shown in Figure 2 (3). This system consists of assorted computer peripherals, an event interface which allows the recording of external timing events, and signal conditioning and digitizer for 16 independent data channels.

The ASRD is shown in block diagram form in Figure 3. Control information is communicated to each ASRD from the computer via the control bus, and data are transferred to the computer via the data bus. Each ASRD has in addition an internal data and control bus. Each channel has a resident microprocessor to oversee bus communications with the computer and to control the various elements within the ASRD, as shown in Table 4.

Trigger Mode	Internal/External Slope/Absolute Value
Threshold Level	+ - Full Scale
Memory Partitions	Separation of memory into pre- and post- trigger areas on any 1K boundary
Start Delay	Length of Time (0 to 4096 msec) after channel trigger before data recording begins
Stop Delay	Length of time (0 to 4096 msec) after the enable goes away before data recording ceases
Rate Calculation	Sum interval, division factor, decrease delay and "RC" from Table 2 and equation 1

Table 4. ASRD Programmable Parameters

The rate calculation circuitry, which implements the compression algorithm, is shown in block diagram form in Figures 4 and 5. Its operation proceeds in the following manner:

a. Sample to sample differences are determined.

b. The absolute values of the differences, delta, are calculated.

c. Alternately, the complement of the variable length buffer and the new delta are added to the running sum of deltas.

d. The sum is shifted right (division by a power 2).

e. This value is used as an address into a random access memory in which are stored the values calculated using equation 2.

f. If the value in the addressed location is larger than the current value, the data recording rate is immediately increased, but if it is smaller the rate is not decreased until an interval defined by the decrease delay has passed.

The implementation of the compression algorithm as a functional look-up table allows other data recording schemes to be programmed. Any functional relationship between recording interval and the absolute value of the signal's first derivative could be used. In actual practice this unit is at times programmed to record data at a constant rate.

To enable a reconstruction of the time history of the data, a four bit rate code is appended to the digitized signal amplitude. In addition, when the recording rate is increased the contents of the skipped sample counter is recorded, as is the IRIG time value at the instant the channel triggers. Each of these types of data has a unique identifier added to make up a 16 bit word.

Application

Before the construction of the first ASRD extensive computer modeling was performed (2). The results of this simulation exercise indicated that compression ratios as large as 41:1 could be attained while maintaining sufficient reconstructed signal fidelity.

After construction of the ASRD's testing was performed to verify its proper functioning (3). Shown in Figure 6 is a single cycle of a triangle wave generated by a function generator and digitized by the ASRD. Instead of connecting the data points with line segments only the points are shown. This figure shows the initial low rate increasing by a factor of 32, thus allowing the transient waveform to be accurately digitized. Notice also that the recording rate increase occurs before the onset of the transient. This figure also demonstrates the effect of recording rate hysterises, where by the recording rate is maintained at its elevated level through the decrease delay interval.

A comparison test was carried out in which data were simultaneously recorded on analog magnetic tape and digitized and recorded by an ASRD. The results of this comparison showed good agreement between the two systems, and during these actual field tests compression ratios of 20:1 were achieved.

In other tests, data were digitized using two ASRD channels: one programmed with the data compression algorithm while the other was programmed to digitize at an elevated, fixed rate. The plots are shown in Figures 7 and 8. These figures demonstrate the reconstructed signal fidelity.

Conclusion

Experimenters can be very protective of data collected during their experiments and often resist any effort to eliminate redundant data samples. The inclusion of nonintelligence bearing data, however, can impose unacceptable burdens on data acquisition and processing systems, and can thus slow the testing process and inhibit productivity. The compression algorithm described here provides a modest compression ratio while maintaining the fidelity of the reconstructed signal. The use of these techniques decreases the requirements for both dedicated off-board data memory and processor memory, for test site mass storage, and for archival storage.

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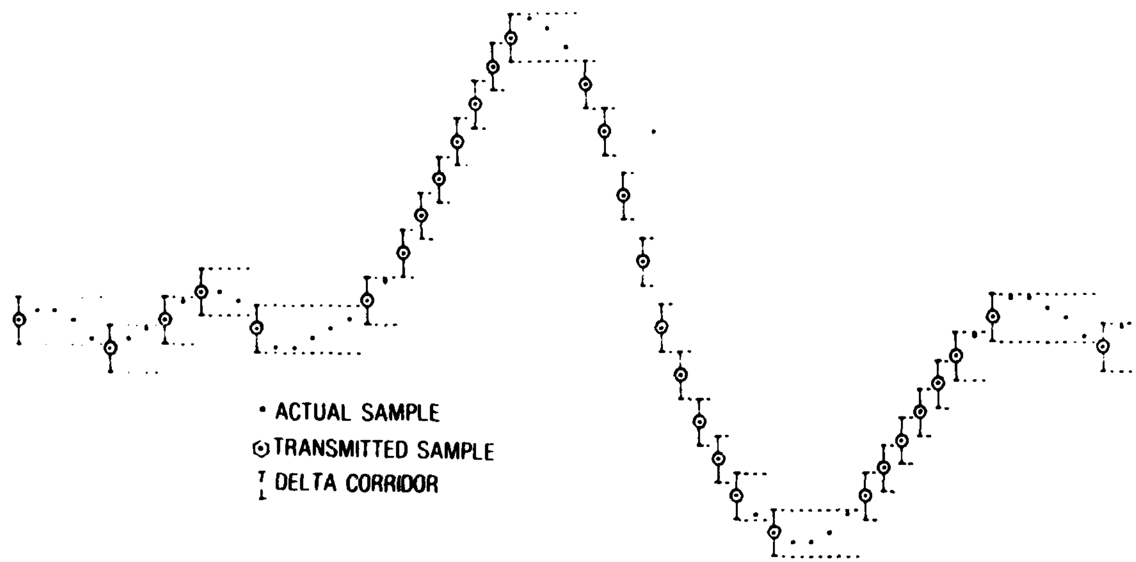


FIGURE 1 ZERO ORDER: FIXED CORRIDOR: NON—REDUNDANT SAMPLE TRANSMITTED (ZFN)

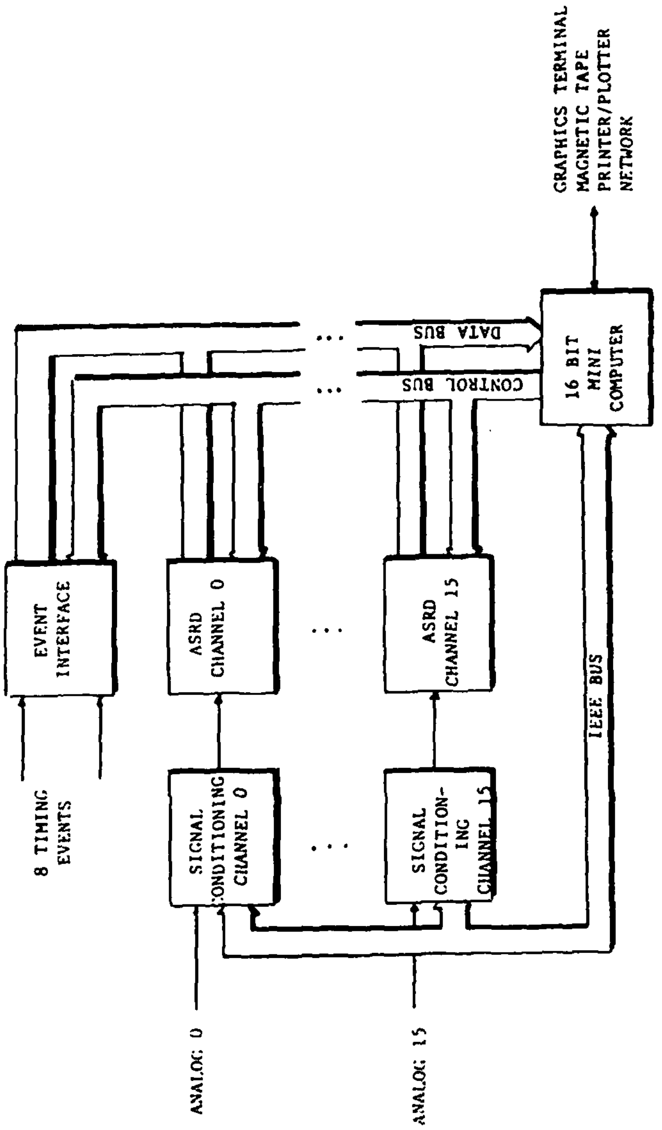


FIGURE 2 BALLISTIC TEST SITE TERMINAL BLOCK DIAGRAM

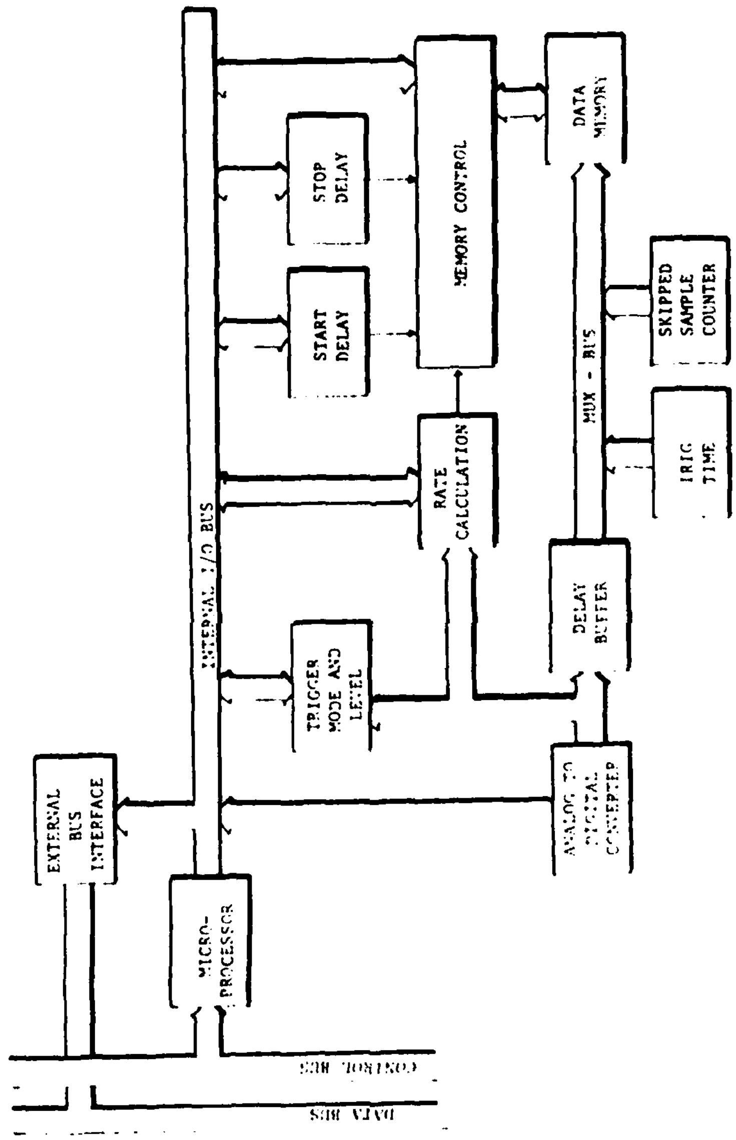
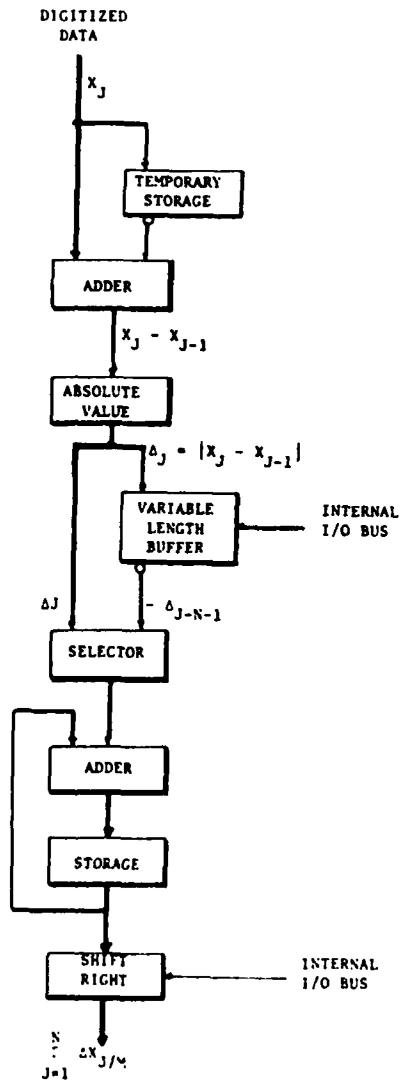


FIGURE 3 AUTOMATIC SAMPLING RATE DIGITIZER BLOCK DIAGRAM

FIGURE 4 RECORD RATE DETERMINATION — PART 1



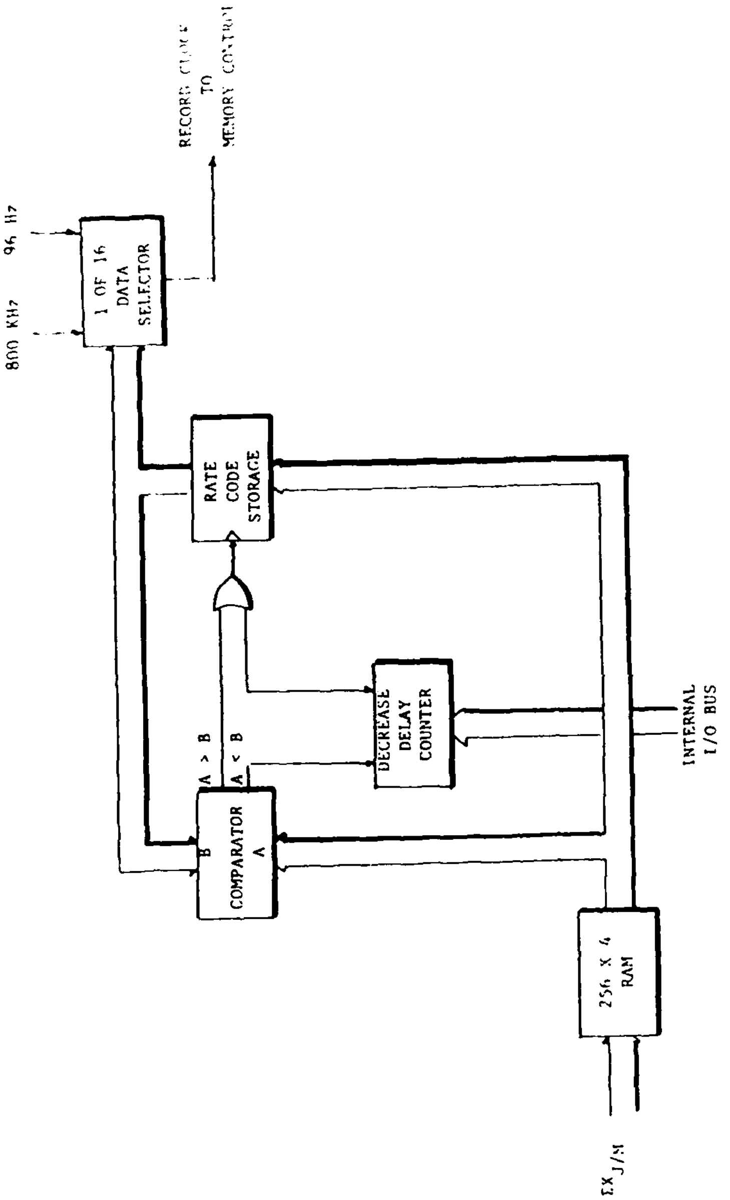


FIGURE 5 RECORD RATE DETERMINATION— PART 2

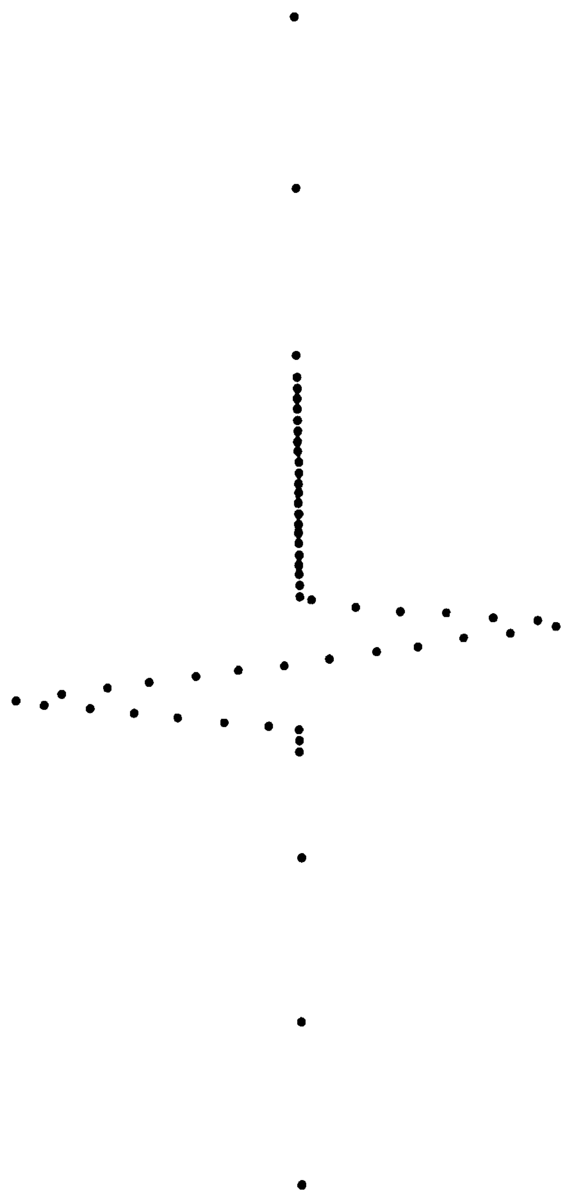


FIGURE 6. TRIANGLE WAVE DIGITIZED BY ASRD

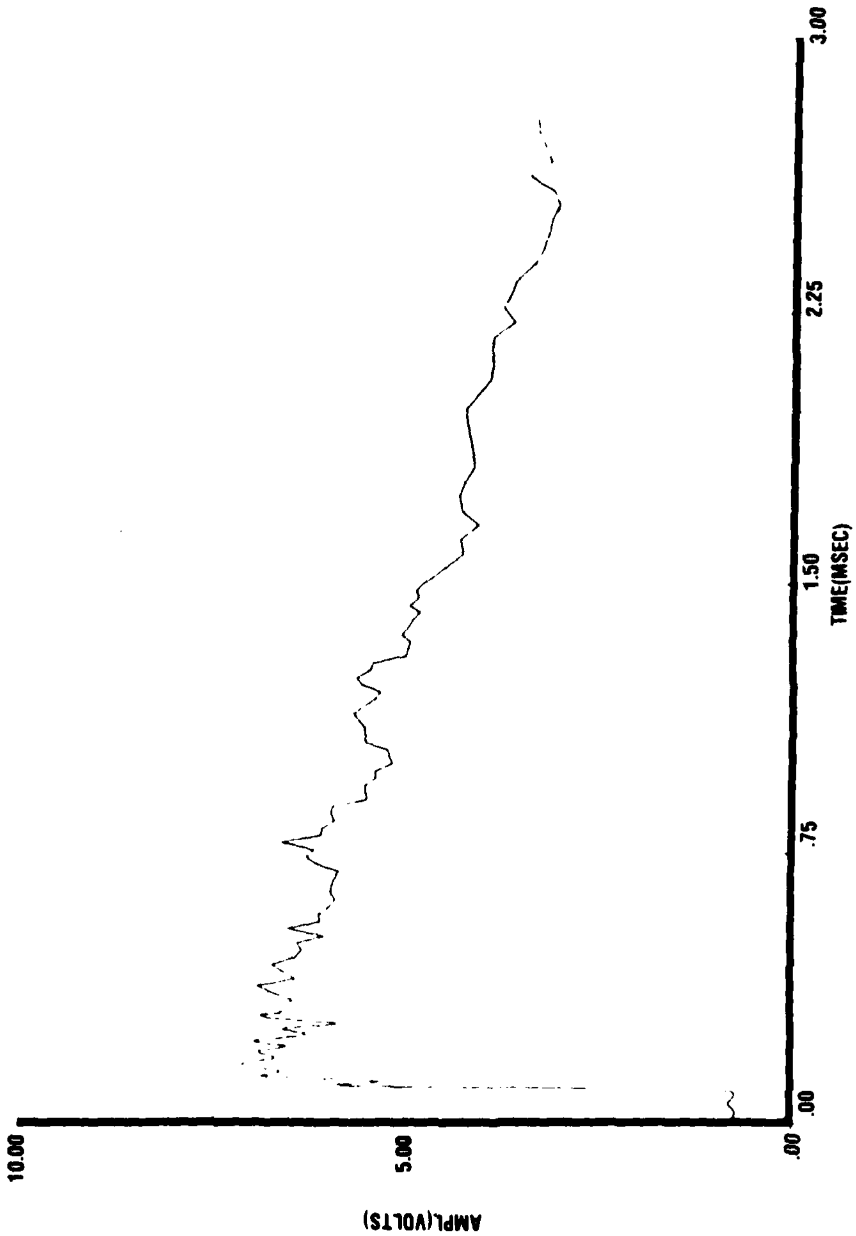


FIGURE 7 BLAST OVERPRESSURE RECORD WITH VARIABLE SAMPLING RATE

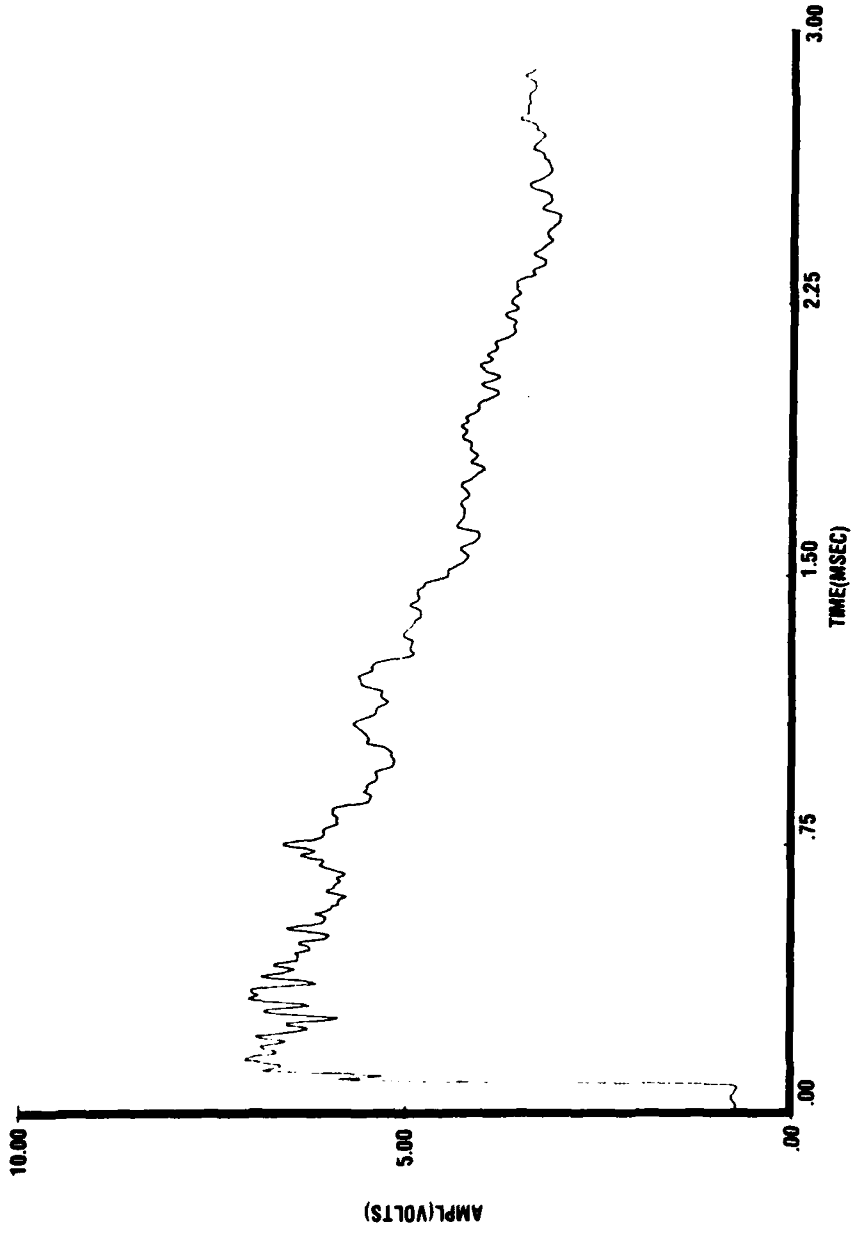


FIGURE 8 BLAST OVERPRESSURE RECORD WITH FIXED SAMPLING RATE

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