METHOD AND APPARATUS FOR COLLECTING IMPACT TEST DATA

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SUMMARY A flexible, powerful and interactive data collection system is described based upon state of the art instrumentation and computer aided digitization and processing. The result is a highly accurate and repeatable system capable of yielding reduced engineering plots within hours after an impact test has been conducted.

INTRODUCTION The accurate acquisition of large volumes of high frequency (2KHZ) impact test data has proven to be a most demanding test environment. Whether the test being conducted involves a full-scale vehicle-barrier interaction to evaluate a hand built prototype which cannot be easily reproduced or a less elaborate impact simulation using a sled fixture, the requirements remain the same; quick, accurate, and reliable acquisition of the test data followed by highly sophisticated data processing and plotting techniques. As an adjunct to these two test classes, a third is added which involves vehicle component and dummy testing. Together, these 3 test classes dictate that a data collection system serve the needs for test durations of between 250 milliseconds and several minutes, from one to 100 channels, and rapid turnaround time of processed data.

Historically, early data acquisition at the Safety R&D Lab involved the recording of test data from transducers directly to oscillographs. This equipment was shared amongst test sites and the time required to relocate such hardware was inordinate. Data processing was limited to time-consuming hand calculations often requiring several weeks to complete. As the nature of crash testing became more extensive, more sophisticated techniques emerged such as dedicated analog electronics to perform some of the specialized calculations on raw data. These low accuracy techniques became archaic as stringent vehicle safety development time schedules were shortened. What evolved was a fixed data acquisition site (data room) yielding a system capable of collecting data from remote test sites for the most generic classes of testing. Concurrently, processing functions were performed by a “number crunching” large scale computer easily programmable from one test to the next.

The business of collecting impact data is rather Straightforward and is by no means unique. However, the most important system feature is that it operates under a multiple user environment with minimal delay associated with running a test. This paper describes the techniques utilized to collect impact test data, digitize it and to some degree the processing techniques used to obtain engineering plots.

DESCRIPTION OF SYSTEM A block diagram of one data channel is depicted in figure 1 and will be described in subsequent sections. For simplicity, the discussion will be divided into three functional groups: acquisition, digitizing and processing. Figure 1 combines digitizing and processing into the processing category.

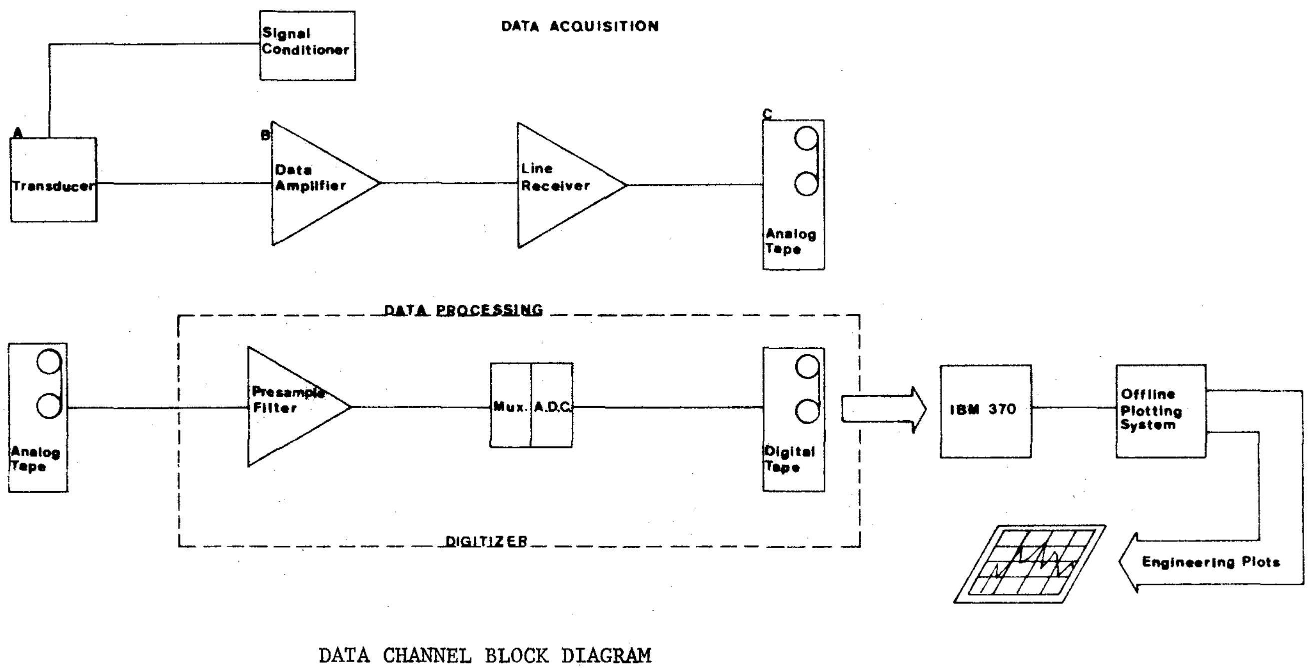


Figure 1

I Acquisition of Data

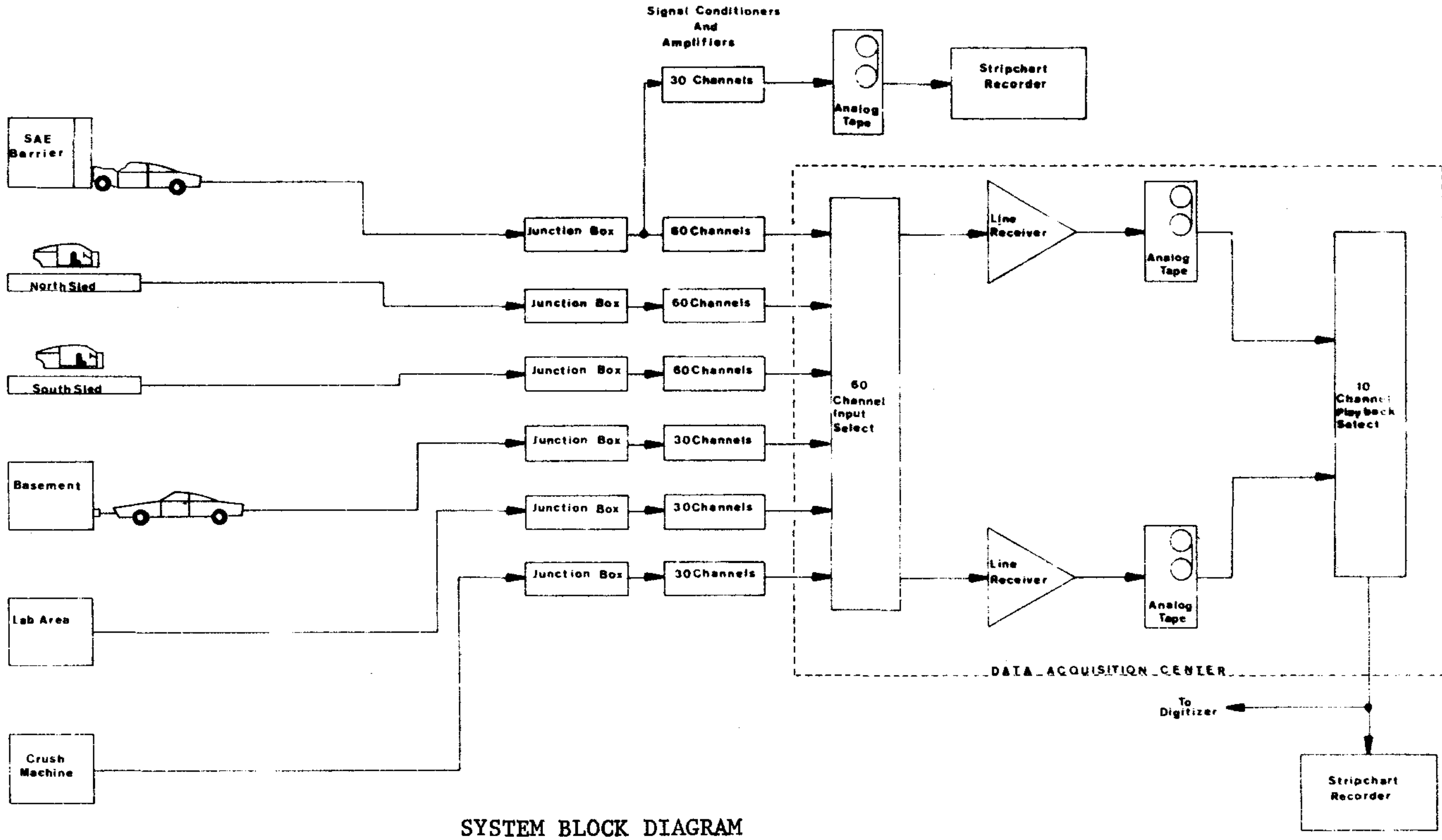
A. Transducers - All impact test data is generated by a transducer, here defined as a device that transforms physical events such as velocity, force, acceleration and displacement into a time-varying analog voltage. Both off the shelf and GM designed units are used.

B. Signal Conditioners and Amplifiers - Each data channel has its own signal conditioner and amplifier. The signal conditioner provides DC excitation for each transducer and also the ability to remove any offset voltage from the transducer. The low-level signal from the transducer, typically 20 millivolts rms, is fed into a variable gain differential amplifier. This device maintains a high common-mode rejection characteristic and contains a highly selective low pass filter whose band width is controllable from a front panel switch. The output of the data amplifier is routed through several hundred feet of shielded cable to the data acquisition center.

C. Tape Recorders - The data lines entering the central acquisition site emanuate from various test areas in the laboratory. Since sufficient capacity is not available to handle all tests simultaneously, input selection electronics is called upon to select one of the test areaal data lines as can be seen in figure 2. The selected data lines are stripped of common-mode noise voltages by the unity gain line receivers. The data is then recorded on analog magnetic tape at a speed of 60 inches per second. Tape allows data to be stored indefinitely and also facilitates time expansion when played back at 3 3/4 inches per second. This reduces the frequency response requirements of data analysis equipment. In addition, magnetic tape data storage, coupled with digital computer data reduction allows cross-plotting of data, either with data of the same test or another test.

From figure 2, one can see that a variable number of tape decks are available for recording test run information. This provides the flexibility for collecting data from one up to 96 channels. All data is recorded using frequency modulation techniques to minimize tape drop-out problems and provide DC to 10 KHZ response characteristics. It is this potential far wide frequency response on many channels that has led us to use hard-wiring and FM magnetic tape recording as opposed to telemetry techniques. When failure does occur only one channel of information is affected and not the entire set of data.

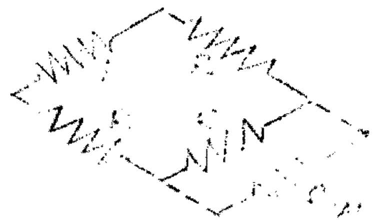
At this point, an example of how test data is collected from a test site is in order. Before any test data can be recorded, it is essential that all data from transducers be calibrated. Calibration involves relating the analog data, in volts, to a reference voltage assigned some engineering unit. For instance, for a load cell transducer, 500 millivolts might be equivalent to 260 pounds of force. Since all transducers used are electrically equivalent to a Wheatstone bridge, a voltage is said to be equivalent to some physical event and can be simulated by shunting a known resistor across one arm of the bridge (see figure 3a). The test technician knows what the approximate full-scale engineering unit output will be and thus can select the calibration resistor to simulate this fullscale output for each transducer. When all shunt cal values have been programmed, he informs the data room operator that he wishes to record calibration signals. When the operator can respond, he pushes a button to manually select the data lines from that area. The analog tape is started and the test technician pushes a button causing each cal resistor to be simultaneously applied to one arm of the respective bridge for a fixed interval. At the end of this period the cal resistors are removed and then applied to the opposite arm of each respective bridge so as to produce a signal with a minus, zero and plus, full scale amplitude deflection. The net result is the calibration signal shown in figure 3b., During the record process, the signals are scanned in real time by a computer to detect any gross failures. After the cal signals are recorded, the data room operator may then select any other area for recording. Shortly



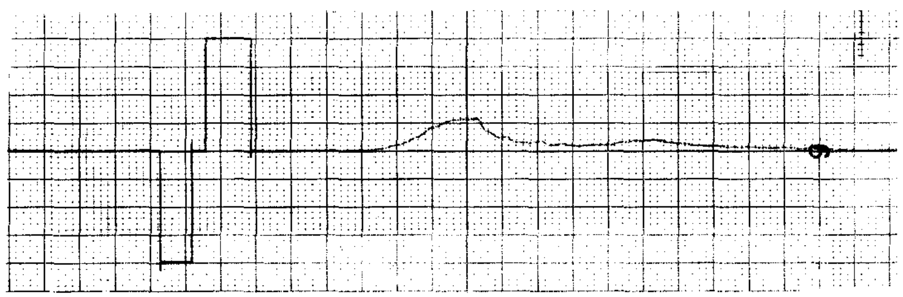
SYSTEM BLOCK DIAGRAM

Figure 2

thereafter, the test is conducted and a similar procedure of manually selecting an area occurs. With both cals and data recorded, the operator may now choose to digitize this information or record a test from another area.



3a Wheatstore bridge with Rcal shunting one arm of the bridge to produce an equivalent full-scale output.



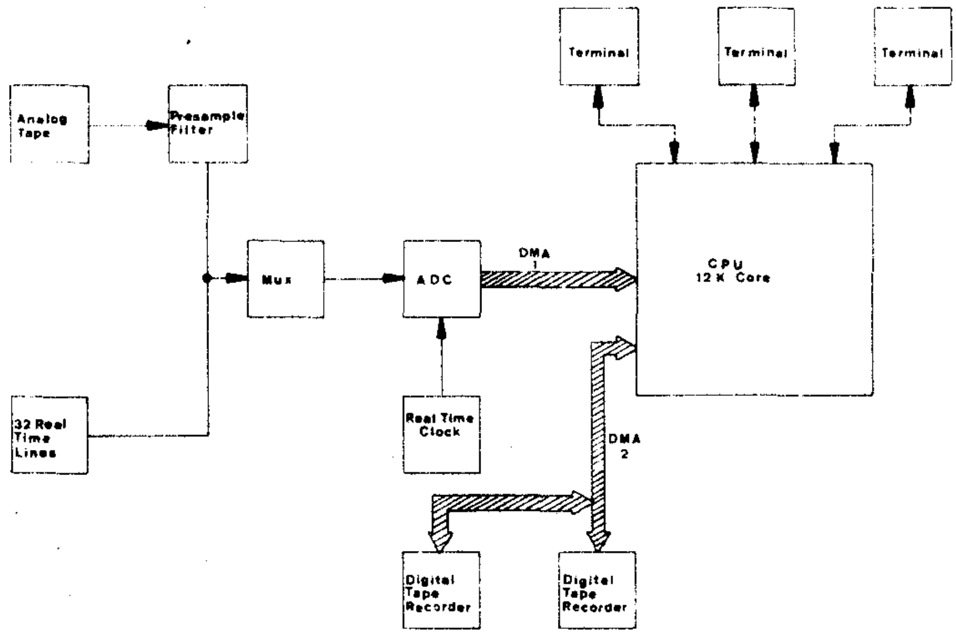
3b. A calibration signal with minus, zero and plus amplitude variations followed by acceleration data.

II Digitizing of Data

The data that is recorded on magnetic tape can be analyzed in two ways. First, the data is played back onto a strip chart recorder along with calibration steps. This gives the engineer a preliminary look at his data and provides a way to detect defective channels. See figure 3b. The second method available to the central operator is the data conversion system or digitizer. This process usually takes place simultaneously with the strip chart recording method. Before describing the digitizing process in detail a brief description of the system configuration is needed.

A. Hardware - A block diagram of the system is given in figure 4. The system centers around a Varian 620L minicomputer which utilizes a 16 bit word length and 1.8 µsec machine cycle time. The memory consists of 12 K words and is expandable to 32 K words. Other features of the CPU include:

1. An accurate crystal clock operated under program control. The clock provides the sampling time base and is programmable from 500 usec to a user defined upper limit.



A/D CONVERSION HARDWARE

Figure 4

2. Hardware integer multiply-divide allowing either of these two functions to be performed in less than 15 µsec.
3. Two channels of direct memory access (DMA). These channels are used for transferring data directly from the A/D converter to core and from core directly to magnetic tape. Using these devices, data transfer rates can occur at up to 200 K words/sec.
4. The A/D converter and multiplexer provide the interface for up to 32 input lines to the computer. The 12 bit plus sign converter (± 10V full-scale) allows digitizing at rates up to 50 K words/sec.
5. An I/O bus which enables connection of peripheral devices through plug-in interface cards. A total of 16 priority level interrupts are available for peripherals.
6. Power-fail detection hardware provides an orderly shutdown in case power is lost. When power again returns, the machine continues to run from the point of interruption.

The presample or anti-aliasing filters prevent errors of commission. These programmable filters have an equivalent bandwidth of 1600 hz for normal data reduction. The cut-off characteristic of this filter is arranged so that frequencies above 1600 hz are reduced before the sampling process is performed.

The peripherals used in the system consist of two magnetic tape units and three terminal units. One tape unit is dedicated to storing digitized test data while the other tape maintains a current library of all system programs. The three terminal units serve as the interface between user and machine. Two of the terminals are CRT units manufactured by ITT and operate at 300 baud; the other unit (ASR 33) serves as both a line printer and terminal.

EXAMPLE

Digitizing a Test - To generate a tape containing digitized test data requires a minimum of operator-computer interaction. By simply typing a two character command phrase requesting digitizing, the computer will sequentially interrogate the operator so that it may initiate itself properly. The operator must supply a unique test number, the number of channels the machine must digitize, and the sampling rate. The number of channels that may be digitized by the computer is dependent on the sampling rate, A/D and magnetic tape throughput rate, and to some extent on machine speed. We have designed our system so that a maximum of 10 channels may be digitized from analog tape. When a multichannel test must be digitized, the 10 channel blocks are broken into passes. If it is desired to digitize a 28 channel test, then the 32 track analog tape must be played back three times, i.e., the data is said to consist of three passes of 10, 10 and 8 channels respectively. In addition calibration signals for the respective channels are also digitized prior to each pass of data. Thus, for our example an operator would digitize this test as shown in Table 1.

Table 1

Type of Data	Pass Number	Number of Channels
CALS	1	10
DATA	1	10
CALS	2	10
DATA	2	10
CALS	3	8
DATA	3	8

A sampling rate of 10 samples/cycle is based on studies of determining reconstruction errors associated with different sampling rates. The 3db signal bandwidth of 1600 hz is reduced to an equivalent 100 hz through tape playback speed reduction. As a result data is sampled at 10 samples/cycle x 100 cycles or 1 KHZ per data channel. If the spectral characteristics of the data are below 1600 hz, then the operator may reduce the sampling frequency needed by the A/D equipment. The advantage is less digital tape is required to digitize such a test.

B. System Software - The software used by the system is categorized as either an application program or a supervisory routine. The application programs, written in BASIC and assembly language allow users to digitize data, load, compile, debug and edit programs while on line. The supervisory programs, written in assembly language, provide the scheduling of tasks, execution of programs and the allocation of I/O resources. All programs were developed at the GM Safety Research Laboratory.

Initially, the software was written so as to allow only the central acquisition operator access to the machine. As component and dummy certification testing grew in volume, the central acquisition area became saturated to the point that testing was being severely delayed to digitize previous tests. The result was that a remote recorder was installed at this test site to eliminate the saturated condition. To achieve the remote digitizing requirement both hardware and software were modified. The software evolved into a multi-user time sharing system. Switching data lines from the central or the remote area into the computer was accomplished by hardware changes. The net result is that a second terminal was installed at the remote site so that digitizing and program execution could occur from either location. It should be emphasized, however, that digitizing is not shared in the general sense of the term. An operator cannot digitize his test data until an earlier user has completed his digitization process. Response time is somewhat hampered by sluggish loading of programs from magnetic tape which remain in core until execution is completed. In addition, the inherent delay associated with waiting for required peripherals such as the A/D converter can cause slow response.

Data Processing - Processing the data from the digital magnetic tape is accomplished by hand-carrying the tape to an IBM 370/145. A collection of programs written in Fortran processes and interprets the crash test data. The processing is controlled by commmand phrases followed by keywords contained on punched cards. The phrases are used by the system to call up the proper module for a particular operation while the keywords supply specific information to be used by the module. The output of the program consists of plot files of the processed data, complete with labelling. Aside from the basic cards needed to initiate and end execution of the processing program, there are three types of processing cards:

1. Test description cards
2. Signal description cards
3. Processing command cards

Test Description Cards - These cards convey information involving a unique test number, division to be charged, test class date and test title.

Signal Description Cards - These cards give information about each input channel concerning polarity, calibration factors and measurement units. The digitized data has no engineering units associated with it; the data is in the form of A/D converter units. To assign meaningful engineeringunits to the data, a bipolar calibration signal is provided prior to the data (see figure 3b). An engineering value such as ± 500 lbs. can be assigned to each calibration step and the data can be scaled from this value. This scaling process is performed on all channels specified in the signal description cards.

Data Plotting - The processed information is plotted by a Varian 620L-100 minicomputer and STATOS electrostatic plotter system. Under 370 control, the files are transmitted via a high speed data link to the mini where the data is sorted, buffered on magnetic tape and plotted. The speed of the system can be reflected in a ten second period required to plot an 8 1/2 x 11 impact test plot. Grid lines, labelling and all other identification are provided by software control.

The Varian mini was chosen on the basis of cost, availability and compatibility with existing equipment. The machine is basically a faster version of the data acquisition mini and hence many of the interface cards from one unit can be swapped with cards from the other unit. The timesharing supervisory software was modified to run in this new machine. The software that coordinated the high speed transfers between the 370 and the mini as well as the programs needed to perform the sorting were developed by Varian Data Machines. All other programs were developed by the Safety Research Laboratory.

CONCLUSIONS AND RECOMMENDATIONS The large measure of success of the system is attributable to several key design factors. For one, eac channel contains its own signal conditioner and amplifier thus minimizi crosstalk between data channels. Shielding and grounding techniques we empirically determined to optimize signal to noise ratio at each site. Perhaps the most significant feature is the high degree of flexibility built into the system. With the numerous configurations available, the equipment can be adapted to almost any test requirement. As an additional consideration, some backup capability exists for almost every link in the data collection-processing path. For instance, digitizing can be handled by the IBM 370 and the electrostatic plotter is backed up by an earlier generation plotting system.

Several errors associated with this system are attributable to the analog tape machines and human interactions required to properly identify and calibrate instruments for a test. As a result of recent advances in inexpensive A/D converter modules and the declining price of semiconductor memories, the lab has long range plans for doing all digitizing in real time. The required sampling rate for this technique would be in the order of 2 MHZ. By using a parallel A/D converter technique and utilizing a medium scale buffer memory, the real-time digitizing can be made feasible. The human errors associated tihe test set-up can be reduced significantly through computer control and monitoring of test technician job functions.