A microcomputer software package for shake table testing

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ABSTRACT

A new microcomputer data acquisition and shake table control system has been developed for the Earthquake Engineering Research Laboratory at the University of British Columbia. The new system utilizes an IBM/AT compatible microcomputer for acquiring data and controlling the motion of the shake table. Two Metrabyte DAS20 boards attached to a microcomputer provide 32 channels (Analog to Digital) for data acquisition and 4 channels (Digital to Analog) for control. The software is capable of simultaneously acquiring data at a rate of 500 Hz per channel (16 kHz total), saving this data directly on the hard disk and controlling the shake table. The software, written in C language, was designed to be user friendly. Setting up a multi channel experiment, controlling the shake table, checking the data acquired and saving the data from all the channels in ASCII single column files is achieved through very simple window menus. Special features, such as automatic file naming, automatic parameter setting, translation functions and graphics enable the completion of an experiment within minutes.

INTRODUCTION

Shake table testing is employed extensively to demonstrate the operability of vital equipment during a seismic event, to verify the accuracy of analytical studies and to experimentally qualify and study systems which are not readily amenable to mathematical analysis. Shake tables can be used to investigate the dynamic behaviour of diverse and complex structural and mechanical systems, such as nuclear reactor components, submerged structures, piping networks, bridges, dams, buildings, tanks, transformers and circuit breakers, hospital equipment etc.

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The University of British Columbia (UBC) Earthquake Engineering Research Laboratory offers comprehensive facilities for seismic research and qualification testing. The central feature of the laboratory is an advanced, closed-loop, servo-controlled electro-hydraulic shake table. The shake table is controlled by an electronic feedback control system for simulation of single axis horizontal ground motion. This system is in the process of being upgraded for multi-axis excitation.

Recently, a new data acquisition and control system has been incorporated into the UBC Earthquake Shake Table Facility. This involves a feedback control system, signal conditioning cards and a microcomputer with the addition of two Analog/Digital cards, as shown in Fig. 1.

UBC SHAKE TABLE CONTROL SYSTEM

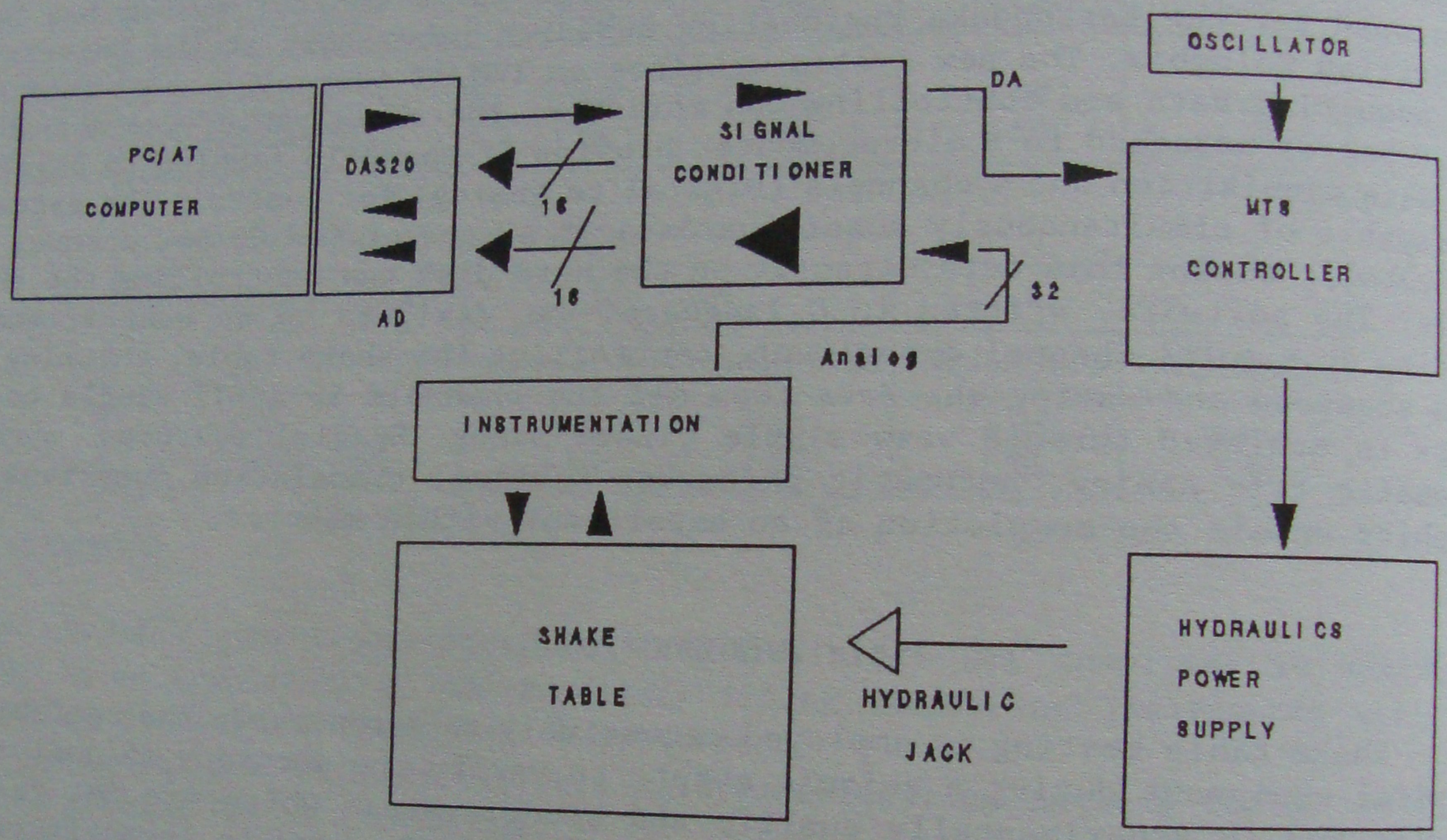

Figure 1 - Block diagram of the control system

The UBC microcomputer system was designed to deal with up to 32 channels having sampling rates of up to 500 Hertz per channel (16 kHz total) and to have the ability to simultaneously control the shake table and transfer the acquired data directly to the computer's hard disk. In addition, special features were added to help the user in defining active channels, defining names of result files and in obtaining result data that are in physical units and in ASCII formatted files ready to be imported to any data analysis software package.

GENERAL DESCRIPTION OF THE SYSTEM

The Shake Table

The shake table, located in the Earthquake Engineering Research Laboratory at the University of British Columbia, is a 3m x 3m cellular aluminium construction weighing 20 kN. The table is driven by an uniaxial 135 kN hydraulic actuator, can support a payload of 155 kN and is mounted on four vertical posts with swivel end bearings located in an isolated concrete pit foundation. In normal operation the shake table can achieve a maximum acceleration of 2.5 g, a maximum velocity of 130 cm/s and maximum displacements of ±7.5 cm.

The MTS Control system

The movement of the hydraulic actuator is controlled by a MTS (MTS Systems Corporation) system which consists of a MTS 443 Controller with the addition of control and selector cards. Control of the servo loop is accomplished with a displacement transducer.

The Signal Conditioner Cards

The signal from each recording instrument goes through an analog filter and an amplifier before reaching the AD board in the computer. This achieves two functions; it serves mainly as a signal conditioner but also protects the microcomputer system. The filters are low pass filters with settings from 2.5 to 100 Hz. The amplifiers allow amplification by factors of 0.5 to 10. Further amplification is also obtainable from the amplifier in the DAS20 analog/digital board.

Table I Microcomputer System Specifications

Number of channels	up to 32 channels.
Sampling rate	from 1/3600 to 500 Hz.
DA output rate	from 1/3600 to 500 Hz.
Data acquired	up to 5 Mbyte (can be expanded).
Duration of a test	from one second to 27 hours.

The Microcomputer System

Table 1 contains a condensed specification list of the microcomputer system. A 10 mHz IBM AT compatible computer (an AST product) with the addition of two Metrabyte DAS20 analog/digital converters are used for controlling the shake table as well as acquiring all the data from the instruments. The software is written mostly in the C language; only the drivers of the DAS20 boards are written in assembly. The software was developed under Microsoft's C Compiler and Assembler. The user interface is fully menu driven using windows for the display of each menu. The program accepts standard earthquake files in ASCII format, or any ASCII formatted single column file, as a DA control file (this file controls the shake table). The program offers only basic post-analysis options; excellent data analysis programs exist on the market and can be used more efficiently than home written packages. The physical measurement of each instrument is produced

in a single column ASCII file. The program can display the maximum value (and the time it occurred) for each channel. The user can also view a graph of up to eight channels at a time on the screen. These features are given mainly to allow the user a quick view of the data recently acquired. A comments file contains a summary of all the parameter settings of the experiment together with the user's comments. In the CALIB menu it is possible to display the value of each channel in real time. This feature enables the user to calibrate the instrumentation and also to read the initial offsets of the instruments before the experiment. Finally, the user may save the settings of the experiment in a file which can be reloaded later.

Since an experiment could produce more than 32 files, a special feature allows automatic file naming. The user defines a name for the binary result file. The program will use this name to automatically create names for the 32 result ASCII files, the statistics file and the comments file. In addition, the next time the experiment is run the program automatically modifies the name of the previous binary file. Therefore, the user can run any number of experiments (up to 100) while having to define only one name. In addition, there is no danger of overwriting a previous file.

The source earthquake files are received in an ASCII format. To use these files an ASCII to binary translation is necessary. In addition the user may wish to create his own "earthquake" file or to use a waveform created in a data analysis package. The BUILD menu allows these features.

SOFTWARE MENUS DESCRIPTION

Menu Display

Figure 2 illustrates a typical screen menu display. The main menu always appears at the top of the screen; this menu allows the user to choose one of the many available functions. These functions are displayed by overlapping windows as shown for the BUILD option in fig 2.

A typical experiment may involve the following steps :

1) Choose the OUTPUT menu to modify any of the parameter fields (Earthquake file name, DA rate, DA duration etc.).

2) Choose the INPUT menu to select the active channels and to change the sampling parameters (AD rate, AD duration, etc.).

3) Choose the CALIB menu to calibrate the instrumentation and to read the initial value of each channel.

4) Choose the RUN menu to proceed with the experiment. At the end of the experiment the user may change the name of the AD binary file which contains the raw data of the experiment.

5) Choose the RESULT menu to obtain the physical data in ASCII files. The user may display the results for a quick check.

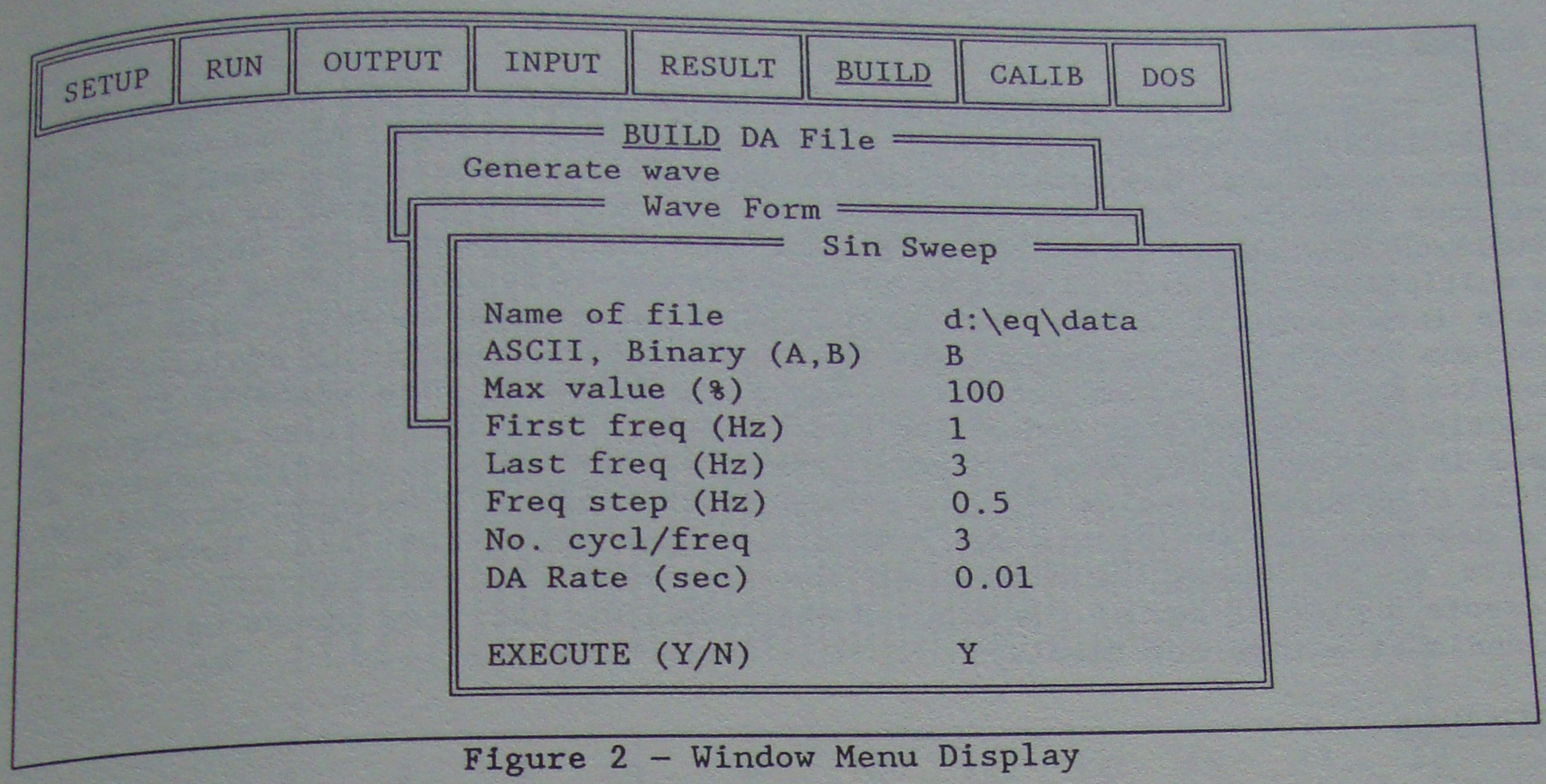

Figure 2 - Window Menu Display

6) Choose the DOS menu to exit, or the RUN menu to start another experiment, or the SETUP menu to reload the parameters with a previously defined experiment.

SETUP Menu

This menu allows the user to choose a setup file which contains the parameters of a previously defined experiment.

RUN Menu

This menu gives a check list for starting the hydraulics system and prompts the user to press the start/stop switch. The bottom of the screen contains the main settings of the experiment for a last check. At the completion of the experiment the user may choose a name for the binary file. This file contains all the raw data of all the active channels.

OUTPUT Menu

The user may choose a DA file for controlling the shake table. Then the DA output rate and the duration of the output are selected. An additional feature allows the user to select a portion of the DA file for output.

INPUT Menu

The user selects any subset of the 32 available AD sampling channels. The sampling rate (AD Rate) and duration for sampling are selected. An additional feature allows the sampling to be delayed relative to the DA output (or vice versa). The user may also set the programmable gain for each of the 32 channels separately.

RESULT Menu

This menu contains several sub-menus namely : SET SCALE/CHANNEL, STATISTICS, TRANSFER DATA TO ASCII, COMMENTS and DISPLAY DATA. At the completion of a test the user may decide to run another test or to view the results of the current test. To obtain the results of the test the first step is to use the SET SCALE/CHANNEL option to set the scales for each channel separately. This includes a multiplication factor as well as an addition factor for translating the sampled data into physical units. The STATISTICS menu creates an ASCII file of the maximum values for each channel and the time of these results. In addition these results are displayed on the screen for a quick review. The TRANSFER TO ASCII function allows the creation of the final result files. These files can later be used in any available data analysis package. The COMMENTS function creates an ASCII file which contains all the parameter settings of the test. In addition, the user may add any of his own comments to the end of the file. There are no limits to the amount or format of the comments. The DISPLAY DATA function presents a plot of any of the sampled channels. The user may choose up to eight channels at a time for display.

BUILD Menu

This menu contains some utilities to create DA binary output files for controlling the shake table. Functions are available to generate a waveform, translate a standard earthquake ASCII file to a binary DA file, translate a single column ASCII file to a DA binary file or to translate a binary DA file into a single column ASCII file.

The waveform generation function allows the user to generate a ramp waveform (i.e. a linear increasing or decreasing function) or a sine sweep function. The parameters (amplitude, DA Rate, duration etc.) are set interactively by the user. For the sine sweep function, the first and last frequencies and number of cycles per frequency must be defined. For clarity, an example of a sine sweep wave is presented together with measurements of the reaction of a model structure to this waveform.
First frequency = 2 Hertz
Last frequency = 5 Hertz
Frequency step = .5 Hertz
Number of cycles per frequency = 10
DA Rate = .005 second.

Figure 3 presents the waveform created by the BUILD menu which will be transmitted to the hydraulics control system as a DA output file - an acceleration file in this case. Figure 4 shows the acceleration measured by an accelerometer attached to a model structure, having a fundamental natural frequency of about 4Hz, which was mounted on the shake table.

CALIB Menu

This menu displays, in real time, the sampled data of all the selected channels. This menu serves two purposes. First, the user may use this menu to calibrate the instrumentation. Secondly, the data displayed on the screen can be used in the RESULT menu to translate the sampled data into physical units.

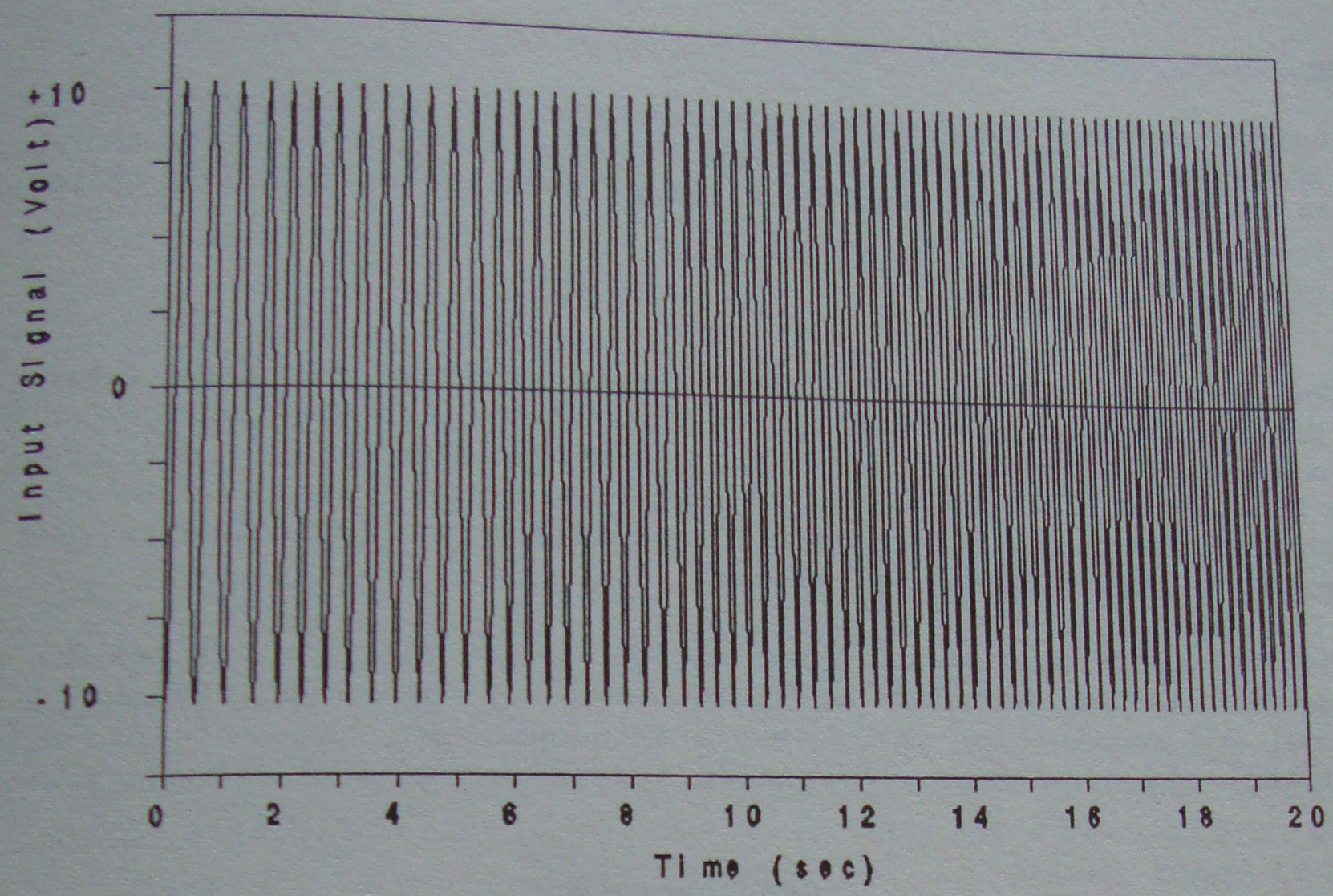

Figure 3 – Acceleration sine sweep file.

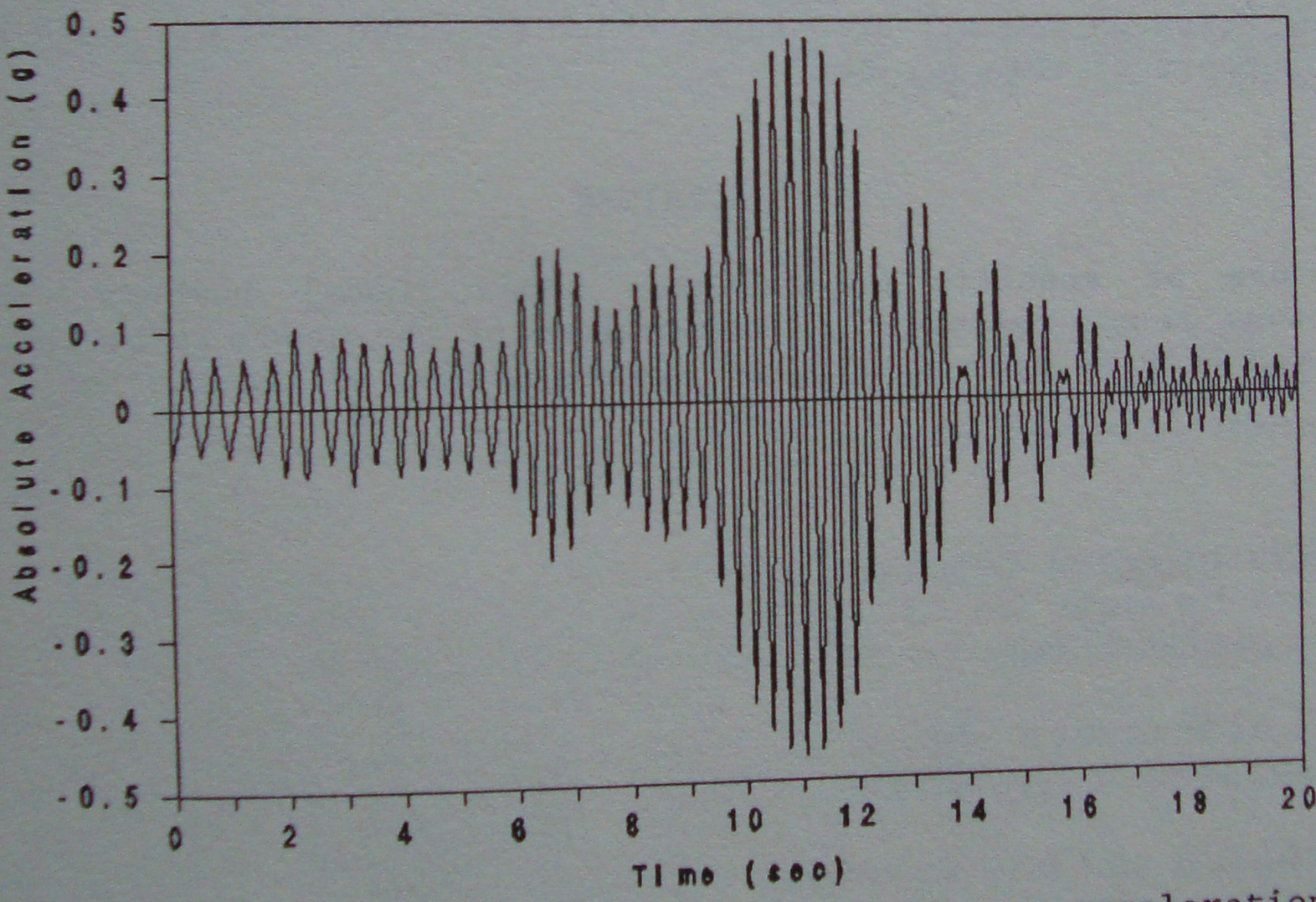

Figure 4 – Acceleration of a model structure under an acceleration sine sweep DA file.

DOS Menu

Before exiting the program, the user may save all the parameter settings of the experiment. The user gives a name for the file that contains the settings. There is no limit on the number of files allowed (other than DOS limitations).

CONCLUSION

The data acquisition and control system developed for shake table testing in the Earthquake Engineering Research Laboratory at the University of British Columbia meets all the specifications required for running a seismic experiment. Because it was developed and designed in-house, the software enables the user to set up an experiment for multi channel acquisition, view the results, and obtain ASCII result files within a few minutes.

The UBC software package does not depend on any special feature of the microcomputer; it can therefore be installed on any IBM compatible machine. Since the control and acquisition parameters are independent, the software can also be utilized strictly as a data acquisition system for general dynamic testing.

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