Computerized Data Acquisition System for a Vibrating Reed Mechanical Spectrometer

INTRODUCTION

A large number of current experimental techniques still entail the acquisition of copious amounts of analog data which must subsequently be analyzed to extract the desired information. The availability of low-cost microcomputer systems has opened numerous opportunities for increased experimental speed and precision through the automation of existing instrumentation. In the cases where the output capacities of older equipment is not directly compatible with digital logic voltage levels, inexpensive solutions can usually be found by application of simple electronic principles.

The vibrating reed experiment makes use of the flexural wave resonance of a viscoelastic cantilever to obtain the dynamic mechanical parameters characterizing a polymeric material. The sample undergoes forced vibration due to an applied sinusoidal excitation near its resonance frequency. The loss tangent, tan δ, as a measure of the energy dissipated by the material due to its nonelastic (viscous) component, is obtained for a range of temperatures. The vibrating reed apparatus was described in detail by Nolle.[1] The theoretical basis of the experiment was treated by Horio and Onogi.[2]

The experimental data collected at each temperature consists of an array of driving frequencies and the corresponding amplitudes of reed vibration. The resonance frequency, which yields a maximum in vibration amplitude (V_{max}), as well as the frequencies at half-width ($V_{max}/2$) must be extracted from the array. The dynamic mechanical parameters describing the material can be calculated using these values.

HARDWARE

The Rockwell Aim-65 is a computer based on the 6502 (8-bit) microprocessor. The standard AIM-65 components are listed in Table I. The 6502 can address an additional 40K bytes of random access memory (RAM), read only memory (ROM) or I/O, thus allowing for easy system expansion. The basic system was expanded to 16K of RAM through the addition of a motherboard. The equipment used in the vibrating reed interface is described in Table II.

Where necessary, the analog data available for input was first converted to direct current (dc), amplified, and then digitized. Digitization denotes the breaking up of the analog value into n segments. A 12-bit ($n = 12$) analog to digital converter (ADC) of the successive approximation type

TABLE I
AIM-65 Complete Standard Package of Hardware and Software

Hardware
Full-size keyboard
20 column thermal printer
20 character display
2 cassette interfaces
1 20 mA loop teletype interface
1 6522 versatile interface adapter (VIA)
16 individually configurable I/O lines
4 handshake (control) lines
1 16-bit timer/counter
1 16-bit timer
Software
8K-byte monitor/editor (ROM)
8K-byte Microsoft® BASIC (ROM)
4K-byte assembler (ROM)
4K-byte read/write (R/W) memory

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TABLE II
Equipment Used in the Vibrating Reed Interface

Component	Manufacturer	Cost (Can. $)
AIM-65 computer with 4K RAM, 4K assembler and 8K BASIC options	Rockwell International Corp. Microelectronic Devices P.O. Box 3669, Anaheim, CA	800
Little Buffered Mother 4-slot motherboard with 4K RAM	Seawell Marketing Inc. 315 N.W. 85th Seattle, WA 98117	275
16/8K memory board used as 8K board	Seawell Marketing Inc.	225
ADC363KD, 16-channel, 12-bit ADC	Analog Devices, Ltd. P.O. Box 280 Norwood, MA 02062	350
AD536A, rms-to-dc converter	Analog Devices, Ltd.	50
TL081, operational amplifier	Texas Instruments	1
Cassette recorder, TC-215	Sony Corp.	120
Power supply for AIM-65/motherboard	Sorensen Products, Raytheon Co. Richards Ave. South Norwalk, CT	150
Power supply for ADC circuitry	Analog Devices, Ltd.	130

was used. This type of ADC has a conversion time which is independent of the input voltage and converts at high speed. A 12-bit conversion is performed in 25 μs with a maximum error of $\pm$ 0.012%. A block diagram of the AIM-65/vibrating reed assembly is shown in Figure 1.

The data are input to the computer through a parallel interface to memory-addressed I/O ports. These ports are located on the 6522 VIA described in Table I. A schematic of the interface is shown in Figure 2.

SOFTWARE

The AIM-65 user software comprises 20K bytes of ROM distributed in the following manner. An 8K monitor controls the AIM-65 operation and allows memory examination, register display, program editing and debugging among other functions. An assembler, residing in 4K bytes, allows programming in machine code with the use of mnemonics. The remaining 8K of ROM are occupied by the Microsoft® version of BASIC operating as an interpreter language.

The specific software developed in this laboratory consists of a BASIC master program, which makes use of a machine language subroutine to control the ADC and acquire data points. The software is summarized in Table III. Although BASIC is slower than the assembler, their combination yields an excellent compromise in which the user benefits from the clarity and simplicity of the former while retaining necessary speed through use of the latter language. The software incorporates several

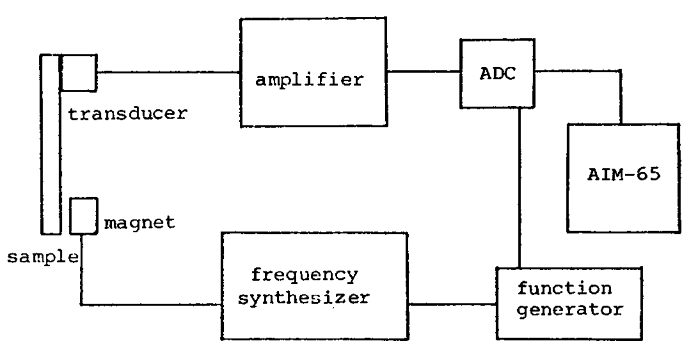

Fig. 1. Block diagram of AIM-65/vibrating reed assembly (power supplies not shown).

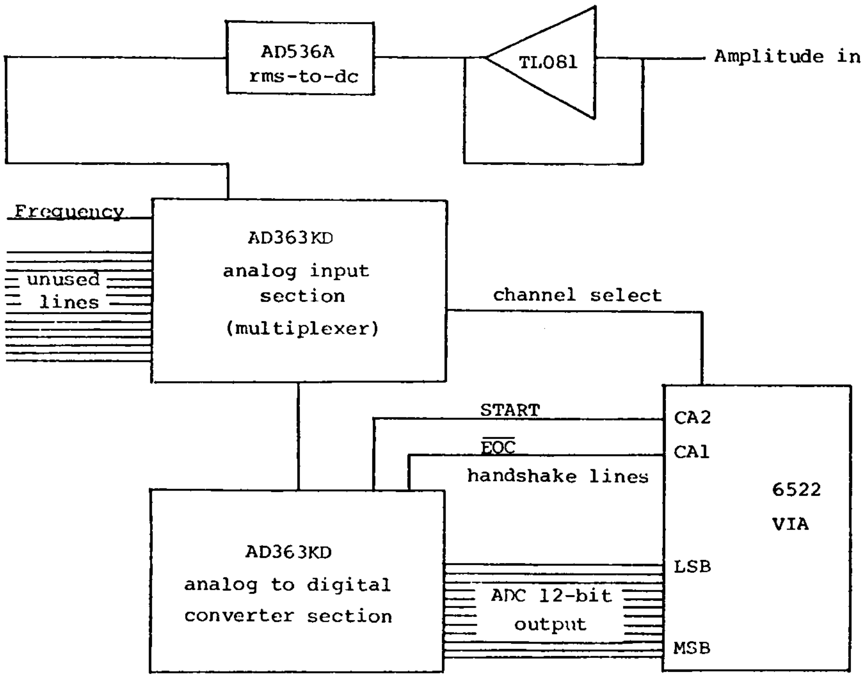

Fig. 2. Schematic of the electronic connections of the AIM-65/vibrating reed interface ($\overline{\text{EOC}}$ denotes "end of convert" signal).

user alterable parameters, which can broadly be classified into two types. The fist class denotes those necessary to specify experimental conditions such as temperature and resonance frequency of the sample. The parameters of the second class are those necessary to optimize the quality of the data acquired, for example, an offset parameter used to reduce the effect of noise in the experimental curve. The data used to perform the calculations leading to tan δ are stored in a BASIC array in decimal form. This has the advantage of facilitating troubleshooting in the event of system malfunction.

The experimental curve is stored in memory through the acquisition of 252 points, each specifying two coordinates, these being frequency and amplitude of vibration. Data acquisition is performed in machine language to ensure adequate speed. Typically, an experimental curve is swept out in a time period ranging between 10 and 20 s. This gives the program a maximum of 39 ms to acquire each point, in the case of a 10-s sweep. This acquisition rate could not be achieved in BASIC. The delay necessary between the acquisition of subsequent points is controlled by the software so as to optimize curve definition.

The values obtained for tan δ at one fixed temperature yield a relative precision of 0.3%. This value may be improved by increasing the number of points used to define the experimental curve. With additional RAM, the software can be expanded to allow collection of data from up to eight experiments run concurrently.

TABLE III
Software Used in the Vibrating Reed Interface

Monitor, ROM	8K
Assembler, ROM	4K
Microsoft® BASIC, ROM	8K
Machine language, R/W	2K
BASIC, R/W	14K

CONCLUSION

A low cost data acquisition and processing system can be developed by users, who need have only a basic knowledge of computing and electronics or who have access to specialized help. It will provide increased speed and precision, and will maximize sample throughput. Any general purpose computer incorporating features equivalent to those described for the AIM-65 could be used. The same holds true for the other hardware components. Approximate cost is indicated in Table II as proof that the expense of laboratory computerization can be decreased by an order of magnitude if the user is willing to assemble standard, readily available components.

Listings and schematics are available on request.

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