COMPUTER MUSIC PROJECT

Report on Equipment Evaluation
and a
Provisional Proposal
for a
New Computer Music System

prepared by

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Oberlin Conservatory of Music

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1 Introduction

This proposal is a followup to my report on the Computer Music Project (March 1978). That report was included as Appendix B of the "request for proposals" (RFP) which was circulated to computer vendors by the Oberlin Computing Center in the late spring of 1978. In referring to that earlier report, I will give the pertinent section numbers in brackets.

In the present report, I will review the investigations and system evaluations which have been carried out since March 1978. I will then make a proposal for a new computer music system at Oberlin complete with an itemized hardware budget. Because of the speed at which hardware is developing in this field, this proposal should be considered "provisional". This term is meant to imply that an alternate proposal may be submitted at a later date if a more suitable system becomes available.

2 Review of Investigations and Evaluations

Since March of 1978, I have been able to gather more detailed information on a number of systems for computer music production. Some of my experience has been through direct "hands on" contact with the devices themselves. Other data was obtained through consultation with system designers.

Before I discuss the specific merits and drawbacks of each system, I think it would be helpful to list those characteristics which are deemed desirable in a computer music system.

1) The vendor must be able to supply complete hardware maintenance.

2) The system must have a proven high level of musical quality through commercial recordings or demonstration tapes.

3) A music system must be interactive and capable of live performance in realtime in addition to our current research and pedagogical applications.

4) The system must equal or surpass our present capabilities of 32 computer instruments.

5) The device must be in production with several systems already delivered and in use for music generation.

6) The cost of the system must be significantly less than the estimated cost of continuing our present software approach on a new central computing facility (see section 2.1). (A ceiling of $60,000 is assumed throughout this report.)

7) The system must arrive fully assembled and ready to produce sound.

8) The vendor must supply adequate software including an operating system, at least one high level language (FORTRAN, PASCAL, C, APL, etc.), an assembly language, a cross assembler for a larger computer (where required), and applications programs sufficient to begin sound production.

9) The system must be expansible and/or alterable to accommodate new synthesis techniques as such techniques are discovered and documented.

All of the systems examined seem to have problems or drawbacks which reduce their viability as a solution to Oberlin's needs in computer music. Indeed, no existing hardware system meets all of the criteria listed above. Each of these systems will be mentioned below along with the specific deficiencies I have pinpointed. The proposal detailed in section 3 of this report, therefore, puts forward the system which meets the greatest number of these specifications.

2.1 Software Synthesis

The present computer music system at Oberlin is implemented entirely in software (i.e. as computer programs). A similar implementation is possible on most large general-purpose computers [4]. The techniques [2], working environment [3.1-3.5], and drawbacks [3.6] are detailed in my earlier report and will not be repeated here. It is sufficient to emphasize that the software approach is not the best in terms of musical productivity, pedagogical strategy, or impact on the computing system as a whole. The specific difficulties stem from the large amounts of computing time and storage space required for music produced by software methods. In addition, the realtime operating system (used only by music at Oberlin) increases the cost of the central computer and considerably complicates the computing environment. Preliminary investigation has shown that one computer manufacturer (Digital Equipment Corporation) adds at least $100,000 to the cost of a machine if realtime processing is provided. Several manufacturers who could provide machines suitable for Oberlin's general administrative and instructional needs do not provide realtime capabilities at all. Clearly, a hardware solution would benefit both the music project and the computing community as a whole.

2.2 Hardware Synthesis

In this section, I will outline the results of further investigation of the various devices which have been designed for music generation under computer control. The first three devices have come to my attention since my earlier report. The remainder have been probed further and evaluated with the aid of additional data.

2.2.1 Coupland Digital Synthesizer

The Coupland Digital Synthesizer (Micor, Inc. Box 26885, Phoenix, Arizona, 85036, 602/273-4381) has been widely publicized but few have seen it in person. At the recent International Conference on Computer Music (ICMC) it failed to make its advertised appearance. Photographs show a seven octave keyboard which indicates that the instrument is capable of live performance. Technical specifications are sketchy and no sound output seems to be available. I have determined by telephone that the cost is projected in the $25,000 to $50,000 range with delivery estimated to begin in fall 79. This system uses a TI9900 minicomputer but no provision is being made for direct user programming of that processor (a serious design fault). A programming console (not a general-purpose terminal)) is included, however. That console seems to permit only limited user interaction with the system in an "organ-stop" mode. Technical support could not be determined.

2.2.2 Digital Music Systems

The DMS-1000 (Digital Music Systems, 306 Court Street, Brooklyn, NY, 11231, 216/643-1077) is a general purpose signal processing microcomputer. The unit has been custom designed for very high speed operation using bit-slice processors and its specific function depends on the instructions which are written into its program memory. The unit can function as an oscillator bank [6.1.3], a filter network [6.1.4], and appears capable of executing most of the fundamental algorithms of music synthesis [6.1]. Only a prototype of the DMS-1000 exists at present and delivery of the production model is not planned until summer of 1979 at the earliest. A preliminary price of $8000 per unit is being quoted. The DMS-1000 would have to be interfaced to another "conductor" computer to fully exploit its power. A packaged system complete with controlling computer is planned for delivery in mid-79. Four to six of the DMS-1000 processors would be required to reach the size of our present computer orchestra of 32 instruments. A total system cost would probably reach $80,000 if the DMS-1000 were used as a basic component of a new computer music system at Oberlin. In addition, Digital Music Systems seems to be a one man corporation and commitments to hardware maintenance and software support are presently unspecified. My conclusion is that the attractive design of the DMS-1000 may be outbalanced by the uncertainty of its future. Sound output from the DMS-1000 will not be available for evaluation until summer or fall 1979.

2.2.3 General Development System

The General Development System (GDS) (Music Technology, Inc., 105 Fifth Avenue, Garden City Park, NY, 11040, 516/747-7890) is an offshoot of the synthesis modules [6.4.2] which were designed by Hal Alles at Bell Telephone Laboratories, Murray Hill, New Jersey. Only a smaller version of the Bell oscillator module]6.4.2.1] is included in the GDS. However, a reverberation module [6.4.2.3] is planned as I learned from a representative of GDS by phone. The oscillator in the GDS is actually a "stripped down" version of the Bell module. The module contains only 32 oscillators compared to 64 in the Bell equivalent. Two GDS modules would be required to match our present orchestra of 32 instruments. A GDS representative indicated that they have not determined whether their control processor (Zilog Z80) will be fast enough to service two modules. In an attempt to reduce the unit price of the module for commercial reasons, a number of design modifications were made which may reduce the value of the instrument as a general tool for composition and musical research. A prejudice toward 12-tone tempered tuning is particularly unfortunate. Although the GDS is a programmable system, the obvious thrust of the company is toward keyboard performance and the rock market. The GDS is, however, a complete system and would presumably be delivered ready to play. Delivery is planned for mid-79 and the cost was estimated at $27,000-35,000 depending on the options which are ordered (second oscillator module, reverberation module, additional memory, etc.). No sound output is available for evaluation.

2.2.4 Moore Digital Synthesizer

The Moore Digital Synthesizer [6.5.3] was the subject of the doctoral dissertation of F.R. Moore of Bell Telephone Laboratories. The only copy of this elegantly designed device resides at Stanford University. No commercial distribution is planned.

2.2.5 Systems Concepts Digital Synthesizer

The Systems Concepts Synthesizer [6.5.2] continues to be an attractive device and is probably the most powerful of all of the systems I have discussed. Unfortunately, its cost remains above $100,000 and it must be controlled by a general purpose minicomputer at additional cost.

2.2.6 Bell Digital Synthesizer

In March 1978, the Bell Synthesizer [6.4] appeared to be the best choice for Oberlin. It is powerful in its computing capabilities, musically viable as judged by auditioning its sound output, and cost effective ($50,000-60,000). During October 1978, I had an opportunity for extended "hands on" experience with the prototype at Bell Laboratories in Murray Hill, New Jersey. During that month-long visit, I was able to pinpoint a number of problems with the system which could reduce its value to Oberlin. Unfortunately, the people at Bell plan to construct the system only as a favor to musical researchers. They apparently plan no hardware maintenance or software support. Indeed, the operating system they are using to program the prototype is LSX, an in-house product. LSX is a microcomputer version of UNIX. Although UNIX is widely available to users of Digital Equipment Corporation's PDP-11 series minicomputers, Bell does not plan to release LSX to the public. In short, the Bell system would arrive naked and we could look forward to approximately a year of program development before the synthesizer could be used by students and faculty. If a Bell system were to arrive in winter of 79, this period of software development might not be a problem (assuming that we would continue music synthesis on the SIGMA 9 through summer of 1980).

Two other points should be raised in regard to the Bell Synthesizer. First, David Clark of the Oberlin Development Office is approaching some Oberlin contacts within Bell management with an eye toward obtaining a grant to support the continuation of computer music here. Our initial strategy is to request an outright gift of synthesis equipment by appealing to Bell's recently advertised intent to fund activities in the arts. Second, I have been invited to spend three months at the Institute for Research and Coordination of Acoustics and Music (IRCAM) in Paris. During this visit, I will be working with a synthesis system which is a direct outgrowth of the Bell system. The engineers at IRCAM have apparently made modifications to the Bell modules which improve their performance and flexibility. I understand that they have at least three identical but physically separate systems in operation. They are using DEC's PDP-11/03 microprocessor to control these synthesizers under a standard DEC operating system (RT-11). I hope to have some information on cost, performance, and availability of the IRCAM system upon my return to Oberlin in mid-April, 1979.

2.2.7 Dartmouth Digital Synthesizer

The Dartmouth Digital Synthesizer is now called the "Synclavier" (New England Digital Corporation (NEDCO), Box 305, Norwich, Vermont, 05055, 802/649-5183). The sound quality problems which I observed in the prototype in 1976 have been corrected and the device is now expandable to 32 computer instruments. About a dozen systems have been delivered in the USA and Europe. At least two commercial recordings are available to demonstrate the musical capabilities of the Synclavier and a concert at ICMC revealed the flexibility and diversity of the instrument in several modes of live performance. NEDCO has developed several fully-integrated "turn-key" systems (i.e. assembled and ready to use on delivery) which come with a complete software package for music production. In addition, NEDCO is a growing corporation with products in areas other than music. This condition speaks well for future support. Delivery for the Synclavier is currently 90 days and the cost of the system I have specified is under $60,000 including a 20% educational discount. In section 3 of this report I will go into specific detail regarding the components of the system and the capabilities they provide.

3 Provisional Proposal

The music synthesis system which appears to be most viable as of this writing is the NEDCO Synclavier outlined below. As proposed, the NEDCO system would be a powerful tool for musical research and teaching at Oberlin. As I stated in the introduction to this report, this proposal is primarily intended to give some indication of the needs of the Computer Music Studio as a change of computers is contemplated in the Oberlin Computing Center. However, I reserve the right to present an alternate proposal if hardware developments in music synthesis warrant such a change of direction. Note, that several of the systems evaluated above are under the ceiling of $60,000. Also, these other systems should be available for further evaluation before Oberlin makes a final decision regarding a new computer system for the College as a whole.

In the remainder of this report, I will describe the components of the NEDCO synthesis system. An itemized price quotation for this system is attached.

3.1 Control Computer

The control unit for the proposed system is the ABLE computer which was designed by NEDCO for music processing and other high speed scientific applications. The ABLE is a 16-bit, 16-register minicomputer which compares favorably in speed and computing power with the mid-size members of the DEC PDP-11 family. The specific configuration for computer music at Oberlin is the A/60. The A/60 package includes the ABLE processor, 16K memory, dual 8" floppy diskette subsystem (616K bytes of random access storage for system and applications program storage), serial port for interfacing our present computer terminals, program load, realtime clock, power supply, chasis, and cabinet. For additional computing power (see below), a hardware multiple/divide unit is added along with an additional 40K of memory. The additional memory would "fill" the machine to its maximum of 64K (8K ROM + 56K RAM).

3.2 Communication with CPU

Since I plan to continue using Oberlin's time sharing system for encoding and editing musical data via my Musical Program Library (MPL), a serial port (D4042) is included to permit the ABLE computer to communicate with Oberlin's central processing unit (CPU). Data prepared with MPL would be downloaded from the CPU into the memory or disks of the ABLE system for performance on the synthesizer. Modifications which are made in that data during an interactive work session with the synthesizer would be available for updating the user's files on the CPU system disks. Such updates would return to the CPU via the same data line. The serial port would ideally be connected to the CPU on a 9600 baud line.

3.3 Synthesizer Modules

The NEDCO Synclavier Digital Synthesizer contains 16 oscillators. These oscillators may be paired to compute the equivalent of 8 computer instruments as defined in our present software synthesis system. Four Synclavier modules would be required, therefore, to reach a total of 32 voices.

3.4 Mass Storage

As indicated in 3.1, the A/60 package includes two 8" floppy disk drives. One drive would be used to store system programs while the other would constitute a removable resource for user programs. The larger moving head disk (25 megabyte) would be used for temporary storage of data downloaded from the CPU. In live performances at remote locations (offline from the CPU), this disk would hold score data for an entire concert. For applications related to acoustic research and software synthesis (see below), this disk would provide a scratch area for about three minutes of music (32768 samples per second in stereo).

3.5 Research Applications

The ABLE system was designed to meet the needs of various scientific laboratories. Therefore, I have decided to include some of the NEDCO research modules in the present proposal. These modules include a 16-input 12-bit analog-to-digital convertor (ADC) (D12) and related input panel (AP1), a scientific timer (D16), an oscilloscope interface (D70), and a digital I/O module (D34). These components would enable the Computer Music Studio to enter several new areas of research and instruction. These areas include speech analysis and synthesis, Fourier analysis of conventional musical instruments, digital recording of natural signals for computer editing, manipulation, and combination with computer generated sound. Since the Synclavier does not include a reverberator, its output could be routed back through the system via the ADCs for addition of reverberation by software techniques. The oscilloscope interface would convert our present Hewlett-Packard oscilloscope into a graphics device for display of waveforms and musical notation. The digital I/O would allow research into custom-designed user interfaces and triggering protocols. In addition, these modules have several applications which are discussed below.

3.6 Software Synthesis

The principal advantage of the Synclavier is that it is a hardware implementation of the two most commonly used and versatile synthesis techniques: fixed waveform and frequency modulation (FM). The success of the FM technique at Oberlin is a particular source of interest in the Synclavier. However, there are many other techniques which are in various stages of development including: additive synthesis, subtractive synthesis (filtering), band-limited pulse (BLP) synthesis, vocal simulation (VOSIM), and a number of techniques which employ summation series formulae which are similar in concept to FM. In short, selection of the Synclavier as the only means of digital synthesis at Oberlin would close the door to many promising areas of acoustic investigation.

In order to leave this door ajar, I have included a limited software synthesis capability in this proposal in the spirit of my original Proposal Two [5]. This capability would be directed primarily at research problems and pedagogical exercises in acoustics while the Synclavier would provide the principal means of production for musical compositions and other creative projects.

Software synthesis programs would be written in XPL, NEDCO's operating system and high level programming language. XPL is a structured language similar to ALGOL, PL/I, and PASCAL. The ABLE computer is designed around this language and the need for an assembly language is therefore obviated. The hardware components of the software synthesis system include the full complement of memory to allow large in-core programs and the hardware multiply/divide to speed sample computation. The 25M disk would be used for sample storage during the computation [3.5.3] and rescaling [3.5.4] stages. A second digital I/O module (D34) would be used to interface to our present digital-to-analog conversion (DAC) system [3.3]. This approach would produce the benefits to the CPU system which were detailed in my earlier report [5.8].

3.7 User Interface

In addition to our present computer terminals [3.1], the user interface to the Synclavier and ABLE computer would include a 61-step organ keyboard and a 96-button control panel. The keyboard may be used to play the Synclavier in the traditional sense or to record a complex score a part at a time for subsequent automated playback. The control panel facilitates certain editing tasks in the score file. The panel may also be used for interactive timbre design since successive modifications in a musical sound may be heard immediately.

Additional user devices could be constructed locally and interfaced to the system via the ADCs and the digital I/O module described in section 3.5. Such devices might include controls over large dimension musical parameters like tempo and dynamics. With joysticks, potentiometers, foot pedals, and the like, the user could perform the functions of a conductor while the Synclavier plays a prescribed score.

3.8 Drawbacks

Although the ABLE/Synclavier meets the first eight specifications listed in section 2, it is deficient on point 9 (expansibility and alterability). The device is a hardware optimization of a small subset of known digital synthesis techniques. The principal design goal was realtime performance and little thought was given to future development. The software synthesis capabilities of the proposed configuration provide some room for growth but realtime music generation with alternate techniques would not be possible without additional hardware investment. The ideal digital synthesizer would combine the generality of a software system with the speed of a hardware implementation.

In my opinion, the Synclavier has one serious design flaw with respect to its output configuration. Each instrument in the device is "frozen" in a particular audio output channel. The 32 instruments of the orchestra are distributed in pairs over 16 channels. For quadraphonic output, these channels would have to be merged by means of an audio mixer. Reverberation and spatial location would have to be produced in the analog domain with conventional recording studio technology. Although this approach is feasible, it represents a backward step in music technology. This mixing and reverberation facility would carry a price tag of $2,000 to 8,000 (not included in the present proposal).

A further difficulty with the Synclavier is that its only output is analog. There is no means of accessing the digital data before it enters the DACs. If such a facility were available, the mixing and panning functions might have been handled in software. A possible alternative (which is being investigated) would be to bring the analog outputs back into the computer for further processing via the ADCs. It has not been determined as yet whether the system can perform at the speeds which would be necessary to accomplish this processing.

In summary, the deficiencies of the proposed system would effect our ability to keep abreast of new developments in digital synthesis technique in the interactive realtime production mode. The software synthesis capabilities would allow us access to these techniques for research and pedagogical purposes, however.

4 Conclusion

The system described in section 3 should be regarded as a solution to Oberlin's needs in computer music for the immediate future (five years, more or less). The ABLE/Synclavier is viable from artistic, pedagogical, and research viewpoints. I must emphasize, however, that it emerged as my first choice by default. As outlined in section 3.8, it is no longer "state-of-the-art" in a number of important respects. If it were approved, funded, and delivered within the next year, we would be trading the immediate benefits of a proven system for almost immediate obsolescence. As I have indicated, the technical developments which are presently afoot in digital sound synthesis may make it possible to bring forward an alternate proposal in as little as six months from this writing. In a sense, therefore, this document should be seen as a progress report and as a measure of the depth of the evaluation process.

I realize that my continued investigations cannot delay the Computing Center's progress in evaluating solutions to general computing needs at Oberlin. Therefore, I offer the following working assumptions which (hopefully) will allow both processes to proceed in parallel toward satisfactory solutions:

1) The total cost of a new computer music system would fall at or under the $60,000 working figure assumed above. We are investigating sources of outside funding for this project. However, if (as a last resort) the music system must be included in the cost of a new central computing system, this would represent a significant savings (using DEC's $100,000 estimate for realtime processing on its PDP-10 or PDP-20 computers).

2) The music system would be interfaced to the CPU via a high speed data line (9600 baud) and would function in the same manner as the PDP-11 system presently operating in the Physics Department. In this mode, the music system would appear to the CPU as a terminal with the least complicated mode of communication possible. A realtime operating system on the CPU would not be required.

3) The disk and computing requirements of music users on the central system would be no greater than the requirements of other users of the time-sharing facilities. The continued availability of APL is assumed.

I hope this report will be helpful to all those who are concerned with at interested in the development of the Oberlin Computer Music System. As always, I will be happy to receive comments on this report and to answer any questions which arise from its reading.

NEW ENGLAND DIGITAL CORP.
P.O. Box 305
Norwich, Vermont 05055

QUOTATION

TO: Prof. Gary Nelson
Oberlin Conservatory of Music
Oberlin College
Oberlin, Ohio 44074

DATE: 11/8/73

Item	Quantity	Description	Price
1.	1	NEDCO Model A/60 Computer, including processor, memory, power supply, chasis, cabinet, 8" diskette subsystem (dual), terminal port, program load, real time clock	$9,650.00
2.	5	m8K Memory units for additional 40,960 words (16-bit) of memory (total of 57,344 16-bit words. $1250.00 ea	6,250.00
3.	1	D4567 Hardware Multiply Divide Unit	600.00
4.	1	D4042 Dual Serial Port	375.00
5.	1	d12 Analog to Digital Converter	775.00
6.	1	AP1 Analog Input Panel (phone jack)	100.00
7.	1	D16 Scientific Timer	420.00
8.	1	D70 Oscilloscope Interface	800.00
9.	1	D34 Digital IO Module	345.00
10.	4	Synclavier Digital Synthesizers 7,987.50 ea.	31,950.00
11.	1	Control Panel and Clavier, with interface	2,500.00
12.	1	25 Megabyte Disk Unit, 100,000 words per second trensfer rate	14,000.00
13.	1	D34 Digital IO MOdule for connection to existing DAC subsystem	345.00

DELIVERY:

This quotation shall remain firm for 30 days from the date hereof unless modified in writing by: New England Digital Corp. prior to the acceptance of the above agreements.

In the event that payment is received in excess of 30 days from date of invoice, a Service Fee of 1½% per month (18% annual rate) shall be assessed. In the event that collection procedures are required by New England Digital, the buyer shall pay all costs of collecting, including, but not limited to collection fees, reasonable

Authorized Signature

NEW ENGLAND DIGITAL CORP.
P.O. Box 305
Norwich, Vermont 05055

QUOTATION

TO: Gary Nelson, page 2

DATE: 11/8/78

Item	Quantity	Description	Price
14.	10	Boxes of 10 diskettes each $125/box	1,250.00

		TOTAL SYSTEM PRICE:	$69,360.00
		LESS 20% EDUCATIONAL DISCOUNT:	-13,872.00

		NET EDUCATIONAL PRICE:	$55,488.00
		Included at no charge: 1. Scientific XPL Operating System 2. Synclavier System Program 3. Program Diskette #1 - Format, Duplicat, Configur	
		Scheduled delivery will be 90 days after receipt of purchase order. Complete 90 day warranty (parts and labor) included.	

DELIVERY:

This quotation shall remain firm for 30 days from the date hereof unless modified in writing by: New England Digital Corp. prior to the acceptance of the above agreements.

In the event that payment is received in excess of 30 days from date of invoice, a Service Fee of 1½% per month (18% annual rate) shall be assessed. In the event that collection procedures are required by New England Digital, the buyer shall pay all costs of collecting, including, but not limited to collection fees, reasonable

Cameron W Jones

Authorized Signature

28 Mar 80

John -

Here is the second report/proposal for Oberlin's CMS.

Many positive reactions to your concert. "Stria" was especially appreciated.

I am working on an implementation of the singing voice model. Did you say you had some data tables to send me to complete the picture?

Also, I would appreciate a copy of Julius Smith's 1/f algorithm. Has he looked at the spectrum which results from using a 1/f UG in audio range as modulator of sine oscil? As I indicated I would like to try the algorithm for generating band-pass noise by means of FM.

Best to everyone at Stanford. Thanks much for your visit and support.

Sincerly,

Gary Nelson