POLYPHONIC COMPOSITION

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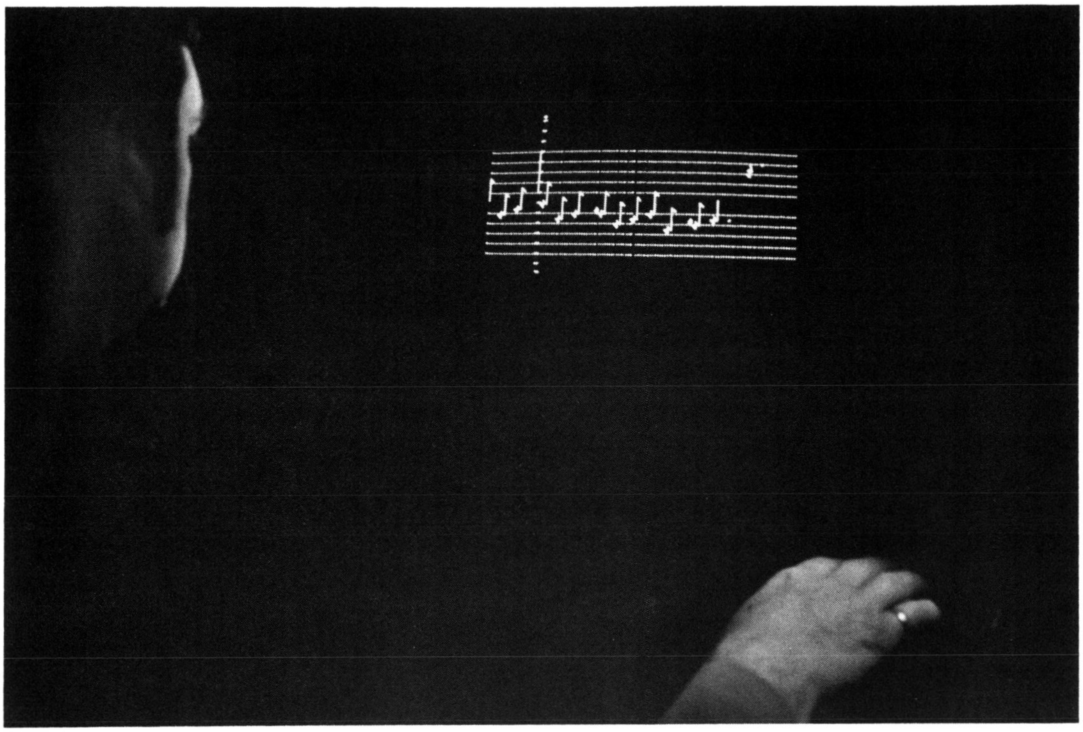

Fig. 1 Melody of a Musical Composition as it is Entered Directly on the Computer Display

INTRODUCTION

At the Radio and Electrical Engineering Division of the National Research Council, we have developed programs for a Systems Engineering Laboratory (SEL) 840A computer so that it may be used as an aid to composers. A computer controlled cathode ray tube is used to display the standard treble and bass staves. By using a simple array of buttons one can write notes of any length, i.e., whole notes, half notes, sixteenth notes, etc. over a range of four and a half octaves. These notes are stored in the computer core memory and appear on the screen (see Fig. 1). When a composer has written as much as he wants, he can, by pushing a button, get the computer to play his melody while he watches the written music follow along on the screen.

In this way a composer can hear what he has written as often as, and whenever he wants. By using the choices available to him on a menu on the CRT, the composer can insert, delete, or change notes; insert commands that change the timbre, decays, amplitudes or tempo, and commands that turn on the percussion generator, start glissoindo, or make the amplitude follow a preset envelope. He can also draw timbres and envelopes, and can store on disc for later retrieval the timbres, envelopes, and melodies he has written.

After a composer has written his music, inserted all the commands and has modified it to his satisfaction, he may then record it on analogue magnetic tape. The recording and alignment of many tracks is synchronized by a starting marker on the tape, which signals the computer to begin playing.

Until recently the computer was not programmed to play more than one line of music at a time so that some errors in the writing of the music would not become apparent until all the parts had been recorded. This showed the need for sound generator programs that would play many lines of music simultaneously. Further investigation of this need showed that such programs coupled with the program that allows the viewing of any line of the music on the display while it is playing would help considerably in finding errors (debugging, if you wish) in the writing of the music. This would save much time that would otherwise have been spent in rerecording a faulty melody.

POLYPHONIC SOUND GENERATORS

All of the polyphonic sound generators developed at NRC are based on a method of sound production which originated at M.I.T. This system utilizes a short loop in the computer program which is responsible for outputting the digital data to the D/A converter. For each voice that is being played, there is a special memory location. Each time the computer executes the instructions in the loop,a constant, dependent on the frequency of the note being played, is added to the contents of this memory location eventually causing it to overflow and reverse sign. The contents of this memory location continuously alternates between positive and negative values at a rate proportional to the constant added. The sign of this memory location is used to determine the sign of the amplitude thus creating a square wave for each voice. For instance, to produce middle C (261.63 Hz), a constant is added to the contents of the memory location corresponding to the first line each time through the play loop, such that this memory word turns negative and back to positive again 261.63 times a second.

Digital data are outputted to the D/A converter during every play loop. When four lines of music are being played the output from the converter is the resultant addition of four square waves.

On the SEL computer, the melody is stored in a 2000_8 word long portion of core memory. The polyphonic programs have to be able to find the beginning of the different lines of music in core. This is done by a short search for words which represent the letters A, B, or C in the melody portion of the memory. These letters are easily inserted by the composer whenever he wishes to start a new line of music.

A letter D following the written melody may be used to start a line of percussion. In this case, a percussion generator is controlled by specially coded notes following the D, e.g., a low C causes the bass drum to sound, the D above middle C sounds the rim, bass, and symbol simultaneously.

When a polyphonic generator is executed it starts by setting up all the default values for decays, amplitudes, and timbres for those generators that require them. The program then tests to see whether the written music on the CRT has been requested along with the playing music. This is determined by the combination of buttons selected at the interactive display when the program is initiated.

After the beginning of each of the four lines of music are found by searching for the letters A,B,C, as mentioned above, the program branches to an interrupt. This interrupt will be repeatedly requested by a real time clock at intervals equal in time to a 32nd note, to check if new notes are to be loaded. For instance, if the first note in all four parts was a quarter note, nothing would happen during the next three interrupts, but during the 4th interrupt all the old notes would be replaced by the next note in each part. After all the notes have been loaded, the computer branches to the playing loop until the next interrupt.

Four polyphonic sound generators have been developed which follow this system of producing music. These are described below.

1. PLAIN TWO. This program plays two lines of music at the same time, produces only square waves and has no facilities for decays on the individual notes. This is the simplest of the four programs; consequently, the execution time of the playing loop is much shorter and it is capable of outputting a change in amplitude 21,000 times a second. This allows a pitch range of 8 1/2 octaves, representing a range of frequencies from 16.35 Hz to 5919.92 Hz. In this, as in all the other programs, there is a limitation on the quality of the higher pitched notes. In this case, the highest frequency, 6000 Hz, changes amplitude 12,000 times a second and these changes are made to the nearest 21,000th of a second. As a result, the period of each individual period jitters, but the average frequency is accurate to better than 99.999%. In the other programs, the output data rate is much slower and causes more inaccuracy in the individual periods of the higher frequency notes.

2. PLAIN FOUR. This program is similar to PLAIN TWO in that it is a square wave music generator with no facility for decays, but, as the name suggests, it plays up to four lines of music at once. This reduces the output data rate to 10,550 Hz with a corresponding reduction of the useful pitch range.

3. DKAY FOUR. This program adds more variety to the music by including the facility for exponential decays on each note. There are eight rates of decay which produce notes from a very short stacatto to a long legato depending on the level chosen. To make the decay possible, the current amplitude of each note is loaded and multiplied by a number between .98 and 1 (depending on the decay level), and restored in memory. As this is done during each play loop for each note being played, it nearly doubles the length of the playing loop so that there is a data output only 7000 times a second. This further reduces the quality of the sound by adding a slight fuzziness.

4. TIMBRE TWO. This program enables the computer to play two lines of music in which both decay and timbre can be specified. Each of 13 timbres is defined by a table of eight values. The overflow of the counter in the playing loop signals the program to get the next step in the waveform. This means that eight overflows are necessary per period instead of the two that were required before. The added computation time limits the pitch range to 4 1/2 octaves.

Fig. 2 Music can be Entered Directly into the Computer Memory from an Organ Keyboard

KEYBOARD PROGRAM

As mentioned before, the idea behind the design of the computer music system was not just to develop an elaborate musical instrument but to provide a facility for the composition of music.

To help accomplish this goal a program has been developed which enables a composer to write up to four lines of music simultaneously into the computer core memory using a standard organ keyboard (see Fig. 2). This program also allows the composer to play the keyboard with the computer accompanying him, and everything up to a maximum of four voices that he plays on the keyboard will be stored in the memory so that the computer can play it back. For example, a composer can play a monophonic melody on the keyboard, then play a mono harmony while the computer plays back his first part, then add a third part while the computer plays the first two, etc., until a maximum of four parts has been reached. If the composer wishes, he can build up his four lines of music two at a time instead of one by one.

In any case he cannot have more than four lines of music in the computer at a time. The computer always works from the top of the keyboard down, so if the composer is writing one line of music and plays two notes on the keyboard it is the upper note that is sounded and stored, if he is writing three lines of music it is the upper three that are stored. In this case, if he lifts his finger from the top note, the second and third notes then become the first and second notes and are, therefore, written into the first and second lines of music instead of the second and third lines as they were before.

Any single line of the music can be displayed on the screen while that line is either being played from core memory by the computer or being played on the keyboard and simultaneously written into the memory. If the line of music being displayed is one being played by the computer from memory, the music advances on the display when the last note on the screen is sounded which is the same as the other sound generators. If the displayed line is a line being played on the keyboard, the display will show the last five notes that have been played plus the note that is being played at the moment. This current note, or rest, as the case may be, will be represented by a 32nd note because its actual length cannot be determined until the next note is started. The display will advance one note at the start of each note.

In this program as in the other four part programs, A's, B's or C's are used as flags to start the second, third, or fourth parts. If these letters haven't been written into the music when the composer wishes to play in music from the keyboard, the program will check the amount of memory space available and divide this space amongst the remaining parts and insert the necessary letters. For example, if two parts have been written into the computer the computer will divide the remaining core area evenly between the last two parts and at the beginning of the third part write in the letter B and at the beginning of the fourth part, the letter C. Any of the three letters would do, but it is easier to identify each line of music if A is associated with the second part, B with the third, etc.

When using this program, a composer can modify the music he has played into the computer just as he would with music written in the normal way. He can insert, delete, and change notes at will. He is still limited to one available timbre and no decays in this program, but by getting other sound generator programs from disc, he can have the music played as he would any other piece.

Many computers have been programmed to compose music, analyze it, and to synthesize it. Composers have had to learn special computer languages to use these computers. At NRC the emphasis has been placed on musical composition by people who need no computer knowledge. This I feel has the greatest potential of all.

ACKNOWLEDGEMENT

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