EDITING AND PRINTING

The computerized production of printed music presents two main problems which must be treated. These have to do with the preparation and editing of the text and the actual creation of the master copies which will be used as the basis for conventional photo offset printing. This last step in the computer process, which is most dependent upon particular hardware, will be touched on first.

The earliest music printing was done at the end of the fifteenth century. Since then many processes have been tried. Woodblocks, movable type, engraved plates, and, lately, music typewriters have been used. Although movable type schemes persisted into the nineteenth century and various forms of music typewriters are widely used today, the engraving process re-

MUSIC BY COMPUTER

LELAND SMITH

mains dominant because of its flexibility in dealing with the need for a wide range of both fixed and variable shapes in musical code.

The vast majority of musical symbols are fixed as to shape and size; however, a certain number of these items require complete flexibility in positioning as well as the appearance of overlapping other items. The problem of overprinting notes on staff lines with consistent accuracy proved a major stumbling block to movable type schemes. The idea of breaking up the staff lines into small segments which included the desired notes never produced fine copy. Skillful use of a music typewriter can usually overcome the problems connected with the items of fixed shape and size.

The question of how to deal with the variable items has remained a major problem. In many scores composed during the past twenty years practically everything is variable. Some of these scores are admittedly closer to free hand drawing than musical notation. The older methods of music printing have been unable to cope with these works.

In what I will call conventional notation, the major variable items are the ligatures, or ties and slurs, the lengths of note stems, and the lengths and angles of the connecting beams for the quicker rhythmic values. Several other items may, in fact, be treated as variable, but usually only a few variants of each are ever used.

In the system of computerized music printing now operating at the Artificial Intelligence Project of Stanford University, the master copy of each page is drawn by a Calcomp 563 plotter using a felt pen. When this plotter draws diagonals, minutely jagged lines result. Also, all curves must be broken down into a finite number of straight-line segments. For these reasons the master copy is made at about 150% of the size of the desired final format. This master is photographically reduced when the offset plate is made, thereby minimizing the shortcomings of the plotter.

Most of the fixed shapes for this printing system are put into the computer program in terms of data lists of x-y coordinates. Because of this it is not at all difficult to change details of these shapes to suit individual tastes. In the first few months of operation of this program, there has been a continuous process of refining the shapes so that they more closely resemble those in engraved music. The treble clef used originally was made up of thirty-one straight lines. The appearance of this item has been improved by increasing the number of lines to over one hundred.

Many musical symbols have traditionally required a changing line width, and several require filled-in black areas. (The ballpoint pen has been of limited use to music copyists.) Thus a heavy vertical bar drawn by the plotter uses seven lines, a single cross beam uses five lines, etc. Using the plotter in this way has both advantages and disadvantages. By producing an oversize master, a great variety of line widths may be created, but since the plotter moves at a fixed rate, the time required to draw a page of music can become considerable when there are many solid areas to be filled in.

It would seem that a combination plotter-line printer device of high accuracy would be the ideal solution to the problem. Or perhaps some sort of device involving the projection of microfilm could be successfully adapted to this task. The development of special hardware of adequate capability will surely come when its commercial potential is appreciated. In any case, the Stanford music printing program, being written in standard FORTRAN IV, can easily be used in connection with any normal computer interface.

The music printing program, which is called MSS, includes a switch whereby the output can be directed to either the plotter, as is the case when the final copy is made, or to a cathode ray tube display, where further editing may take place. This switch is quite simple, since exactly the same type of instructions are used to draw vectors on both the plotter and the CRT.

A complete page of music is prepared in sections whose sizes are limited by the quality of definition and the storage characteristics of the CRT display terminal. There is no limit to how many sections may be combined to make up a full page on the plotter. The digital instructions for drawing each of the sections are stored on separate files in the disk memory. When the operator calls up a section to be displayed, each item is processed internally in the order in which it was created and then the complete file is displayed at once. If there are no time-sharing delays, this process takes very little time. If the same file is to be drawn by the plotter, a juggling routine rearranges the order so that items appearing in the lower left-hand corner will be drawn first, with the material in the upper right corner appearing last. Thus, the time required to move to each succeeding item, with pen raised, will be kept to a minimum.

In the spring of 1973 a Xerox Graphics Printer (LDX) was installed at the Artificial Intelligence Project. This device produces very good music copy on 8 1/2" width paper at many times the speed of the plotter. This copy is completely adequate for casual use, though it cannot compete with the quality of photo-reduced plotter output.

The preparation and editing of each unit of music is the most useful, and most complex, work of MSS. Basically, each item to appear must be entered as a specific list of parameters. However, several automatic features in the program enable the operator to ignore many of the details. The first parameter, P1, always holds a code number for a particular item or group of items. P2 indicates the left-right position. A scale dividing the width of the display screen into 200 parts can be projected at any level on the CRT. The position of most items is figured from the left leading edge.

The third parameter gives the staff number. With the present system, it is practical to display up to eight staves at one time. (There is no fixed limit on how many staves can be included on a page drawn by the plotter.) A staff in the middle of the screen would be numbered zero with those above being numbered one to four and those below minus one to minus three. Where applicable, P4 indicates up-down spacing in terms of note numbers. The position of middle C in the treble clef, one ledger line below the staff, has been given the number one. This basis was chosen because of simplicity for a musician to think in terms of upward-moving diatonic intervals. Thus G above middle C is five, the C above is eight, etc. This musical logic breaks down somewhat when descending below middle C. The position for B is zero, A is minus one, and so forth as the scale goes down. Since decimal numbers may be used, great flexibility in positioning is available. Up to eight more parameter entries can be given for a single item.

For ordinary notes, the code number in P1 is one. The position of the note is set in P2, P3, and P4. P5 serves the double purpose of controlling stem direction (or absence of stem) and accidental, i.e., whether the note has a flat, sharp, or natural sign. Usually this parameter will have two digits. If the first (left) digit is zero (or doesn't exist) there will be no stem. If the first digit is one the stem will be up; if it is two, down. The second digit will indicate the accidental which is to appear in front of the note. Zero means no accidental, one is a flat, two is a sharp, and three is a natural. By adding further digits beyond a decimal point, it is possible to increase the space between the accidental and the note to any distance desired. This extra space is often necessary in complex chord structures where accidentals would otherwise overlap.

Notes will be filled in, or "black," unless P6 is given a negative number, in which case they will be "white," or open notes. P6 also aids in the automatic alignment of a note with other previously-set notes to create chords. If P6 is ten (plus or minus), the note will shift to the correct position on the right side of an upward note stem. The number twenty will cause the note to shift to the left side of a downward note stem.

A single digit in P7 will show the number of tails or rhythmic indication which will appear on the note stem. If a sixteenth note (with two tails) is to be printed, P7 will have a two. When P7 has two digits the note will be dotted and the second digit will give the number of tails. Decimal values can be added to P7 to move a dot farther out from the standard spacing, this being necessary in some chords.

P8 is used for changing the standard length of note stems. This is usually necessary when chords are printed. The unit for extensions is the vertical distance between one note of the scale and the next. Since notes can appear on both lines and spaces of the staff, the number two would extend a stem by one complete space. The proper number of ledger lines appears automatically for notes above and below the staff. If for any reason the ledger lines are not desired, the number one in P9 will cause them to be suppressed.

To display F♯ above middle C as a dotted sixteenth note on the middle of the screen, the following parameters would be given.

P1	P2	P3	P4	P5	P6	P7	P8	P9
1	100	0	4	12	0	12	0	0

Note that P5 and P7 serve double duty. The first digit in P5 indicates that the stem goes up and the two calls a sharp. The first digit in P7 causes the dot to appear and the two calls for two tails.

Used in this way this parameter system could become rather cumbersome. The multiple use of some parameters was arranged in order to save storage space in the program at a time when program size was a factor in speed under a time-sharing system. However, as shall be seen later, most of the more complicated aspects of this system, as applied to setting up individual notes, seldom need be considered by the operator. The important thing is that if any particular detail requires changing, the right numbers for the situation are not too hard to find.

The choice of the specific code numbers to be used in P1 to designate the various item groups was completely arbitrary. Words might have been used instead of numbers, but there are many situations where, after a little practice, an all-number system can be easier and faster to operate.

The item put on the screen first is usually a five-line staff.

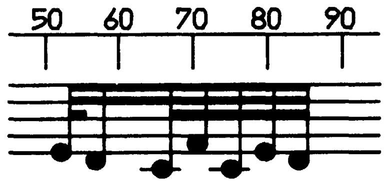
For this the code number in P1 is ten. P2 will give the horizontal position for the left end of the staff, P3 the vertical position number (from minus three to four), P4 the horizontal position for the right end of the staff, and a number in P5 will cause any desired vertical displacement. From this point on, any item that is to appear in relation to this staff will use the same value for P3 (vertical position number). If P5 has displaced the staff by any amount, automatic adjustment will be made for all items appearing on that staff. P6 can be used to alter the vertical size of the staff. The dimensions of all items thereafter put on that staff will be controlled by the number put in P6. In music engraving only a few basic sizes are ordinarily available. With this computer system the flexibility is complete.

Because of their variable lengths and slopes, the heavy cross beams which connect the notes of smaller rhythmic values present a number of problems. The code number for beams is nine. P2 has the position of the left side of the beam or beams. Since it would be time consuming to ascertain the precise position of any note stem, this number need by only approximate. Before the beam is drawn the exact position is found by the program, and the number in P2 is properly adjusted. As usual, P3 holds the staff number. P4 and P5 are the vertical levels of the first and last notes to be connected by the beam. The approximate horizontal position of the last note is put into P6. As with P2, the precise position is found automatically. The proper slope for the beam is determined by the program's consideration of P2, P4, P5, and P6. Of course it is necessary to tell whether the stems are to go up or down. A first digit of one (up) or two (down) in P7 conveys this information. The second digit in P7 will tell how many beams are to be drawn.

Partial beams are sometimes needed. If P8 has a ten, the partial beam will be attached to the first note stem; a twenty puts it on the last stem of the group. The end point of the partial beam is put in P9. P10 is used to displace the beam from the outer limit of the stems toward the note heads (necessary with partial beams). After all the beams are in place a special feature may be used which automatically adjusts to the proper length every note stem falling within the span of each beam. An example of beam drawing parameters is given in Example 1.

The upper two beams are described within one set of parameters since they have the same characteristics. The two partial beams must be described separately. It must again be pointed out that the operator need be concerned with these

EXAMPLE 1



P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	
9	51	0	3	2	83	12	0	0	0	(sets the two upper beams)
9	51	0	3	2	83	11	10	54.5	2	(sets right partial beam)
9	51	0	3	1	83	11	20	68	2	(sets left partial beam)

details only when making changes after the original input stage. In the first input the rhythms must be given, and then it is only necessary to state that the group of notes from 1 to 7 are to be beamed; then the program creates the three parameter lists shown above. The "homing" features used in beam drawing are also used to facilitate the precise placement of various markings such as accents and staccato dots.

There are some code numbers which are used to produce groups of items which can later be edited separately if desired. The number sixteen allows the writing of any letters or numbers into the score. It is possible to place the beginning of a line of text at any position, and the size of the letters is flexible. Boldface printing is simulated by duplicating each letter with a slight displacement. The elegance of the letter shapes has not yet been considered since it is planned to have a wide variety of type faces when different hardware for the creation of the master pages is developed. The code number eighteen causes key signatures of any number of sharps or flats to be written when only the clef name and the major key are entered. The accidentals will automatically be positioned in their proper places for the given clef.

The most useful item-grouping in MSS is available under the code number fourteen. With this number, extended strings of notes, along with most of their accompanying details, can be entered at once. The program prompts the operator for the various kinds of information required. The first prompt asks for the notes to be typed. All notes are typed by letter names with an octave number and a letter (F, S, or N) for the accidental if needed. *1 So that the notes will appear at the proper levels, the clef must be given at the beginning of the line and each time a change of clef occurs. A colon following a note indicates that the note will appear in the same rhythmic position as the previous note so as to produce a chord. In some close-knit chords the notes must appear on alternate sides of the stem and accidentals must be spaced out. This section of MSS takes care of these things automatically. The following example shows some results of this chord-spacing procedure.

The second prompt asks for position one and position two. These numbers will set the horizontal limits within which all the given notes will fall. At this point the notes will appear on the CRT as equally spaced quarter-note values. Next, the operator will be asked to "TYPE RHYTHM." The denominators of conventional musical fractions are used. Thus four equals a quarter note, eight an eighth note, etc. Dots added to these numbers will produce musical dots. Now the music on the screen will be repositioned relative to the given rhythmic values. All the proper rhythmic tails will appear and the half notes and whole notes will change to "white" notes.

Next the operator will be asked, "ADD BEAMS?" If these are needed, pairs of numbers, indicating the first and last note of each beamed group, must be entered. If a group is to have its stems turned downward, the second number of the pair must be negative. Most combinations of partial and complete beams will be created automatically according to the rhythmic values previously given for the notes in the group. After the beams appear, all unnecessary tails will disappear and the stem lengths will be normalized. After this, similar procedures are followed to add accents and staccato dots, etc., to the passage and then slurs and ties. Following is the operator's input to create Example 2:

TR/K2S/4 4/D5//E/R/M/F///B4/E5/G/M/G/F/E/D/E/F/M/ F/E/D/E/F/M/*

4./8/4//4./8 X 6/4/8///4/8/16//4/2*

7 9/ 16 18*

7 9 2/ 10 11 1/ 15 16 1/ 15 18 2*

In the first line TR stands for treble clef. K2S indicates a key signature of two sharps. 4 4 is the meter. The note D is to appear in the fifth octave of the piano keyboard. R is a rest and M is a measure line. The second line gives the denominators of all the rhythmic values. The third line tells which notes are to be beamed together. The line for accents, etc., is omitted. The last line gives the location of the ligatures. The third number of each group indicates the curvature desired.

The horizontal spacing of printed music is usually related to the rhythm in only a general way. Following the directions outlined above, the sections with quicker values will be closely bunched together while the slow values will occupy rather large areas. By using the editing techniques available in MSS, a special line of rhythms may be set up at the top of the screen which will control the spacing of everything put below. What this does, in effect, is to change internally the values of the horizontal spacing numbers. For example, if a whole note is made to occupy the same space on this highest line as a following quarter note, then the program will consider the space under the whole note as being four times as great as that under the quarter when the automatic "equal" spacing takes place. In this way the practical, readable spacing of the music is easily managed.

Example 3a shows an extreme case of what can happen if strict rhythmic spacing is adhered to. Example 3b shows how the use of the spacing line can produce a readable form of the same input.

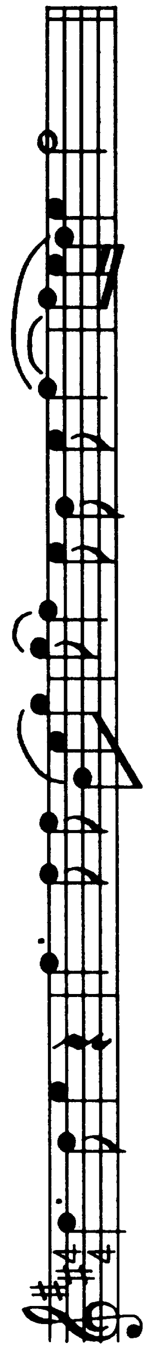
The spatial problems of entering the text in vocal music are greatly facilitated by a feature which displays order numbers over the notes of a given line. The various syllables and dashes are typed in with slashes separating each group of characters requiring a unique position. Then a parallel series of numbers is entered which will designate the precise position for each of the groups. (See Example 4.)

Most of the conventional musical symbols are available in MSS. Any special shapes may be created by use of a subsidiary program which allows you to draw on the display screen either by typed commands or by use of a light pen. Expanded outline drawings are made and then any areas may be designated for filling in. One of the more complicated parts of MSS is the routine whereby the dark areas are given exactly the right number of lines to fill them properly regardless of the overall size factors. Once a shape is completed it may be freely edited. Points may be moved, inserted, or deleted. When the shape is used in a score it may be inverted or reversed or expanded or contracted by varying the proper parameters. Scores including a combination of ordinary and non-conventional graphic notation will be easily produced, as in Example 5.

Perhaps the most important elements of MSS are its various editing features. Once any group of items is set up, it is essential that corrections of all sorts can be made with a minimum of effort. The program has given each symbol entered an item number and it is quite easy to seek out a particular item for edition. The items may be searched for by number, by category (i.e. notes, beams, letters, etc.), or by position. A box appears around each item as it is brought up for editing. Once the correct item is found, all its current parameters are listed on the bottom of the screen. New values may be given for any or all of the parameters. The old form of the symbol remains on the screen while the newly edited form is created. When the edit mode is left, it is possible to delete or save the

EXAMPLE

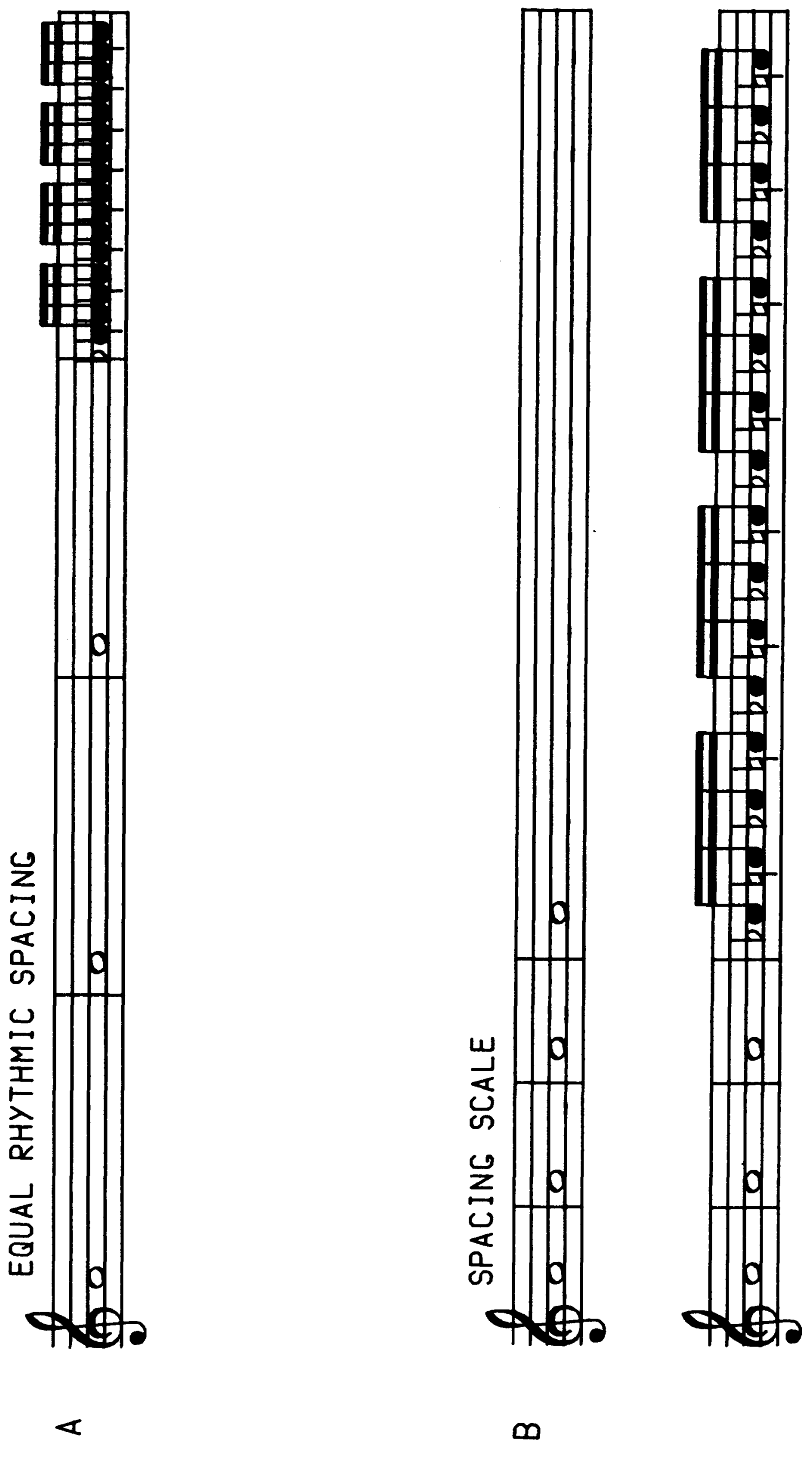
2



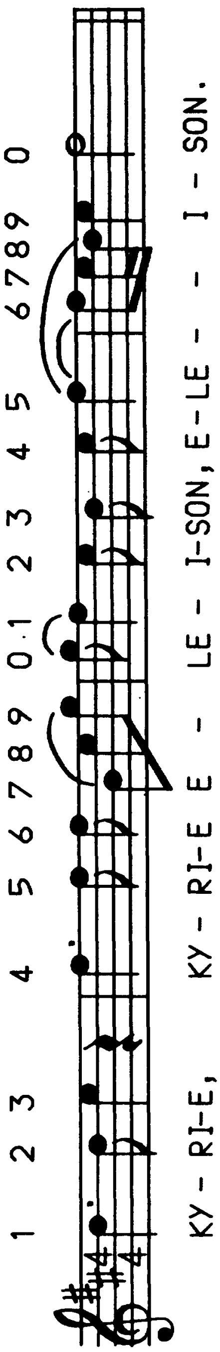
304

EXAMPLE

3

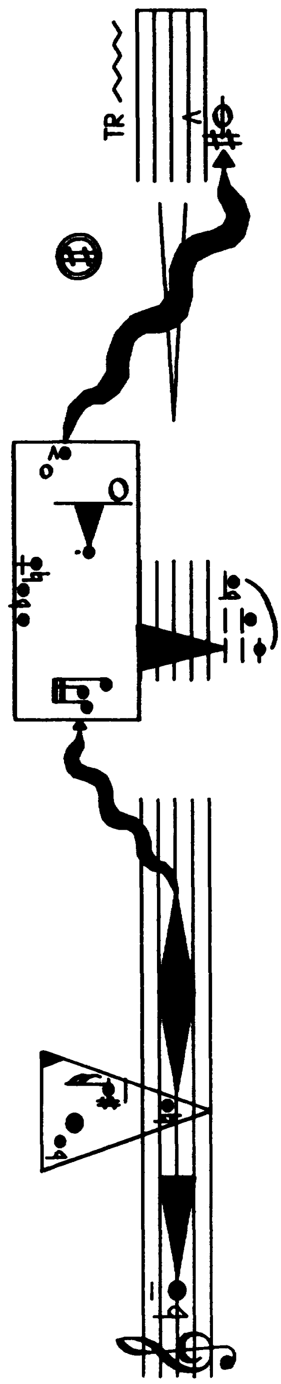


EXAMPLE



Input to MSS for text: KY/-/RI/-/E, /KY/-/RI/-/E/ etc.
1/1.6/2/2.6/3/4/4.7/5/ etc.

4



5

old form of the symbol. In this way it is possible to copy any single item from one place to another by typing only the new position parameters. There are also ways to copy whole groups of items from one position to another. MSS allows for the expansion or contraction of the horizontal spacing on any staff, or on all staves at once. This is usually used as a last step to arrange the various parts of completed lines into a visually pleasing and readable whole. By typing J, an entire brace of music, including several staves, can be properly justified at once. Space will be "stolen" from the slower rhythmic values and from notes without accidentals in order to provide the minimum space requirements for each type of item. (See Example 6.)

All work done with MSS can be stored on various memory devices for further use. When a particular unit of work is called back into the program, it may be combined with other units or edited some more or sent to the plotter for the production of hard copy. When a section is plotted, the overall dimensions may be adjusted to any size desired.

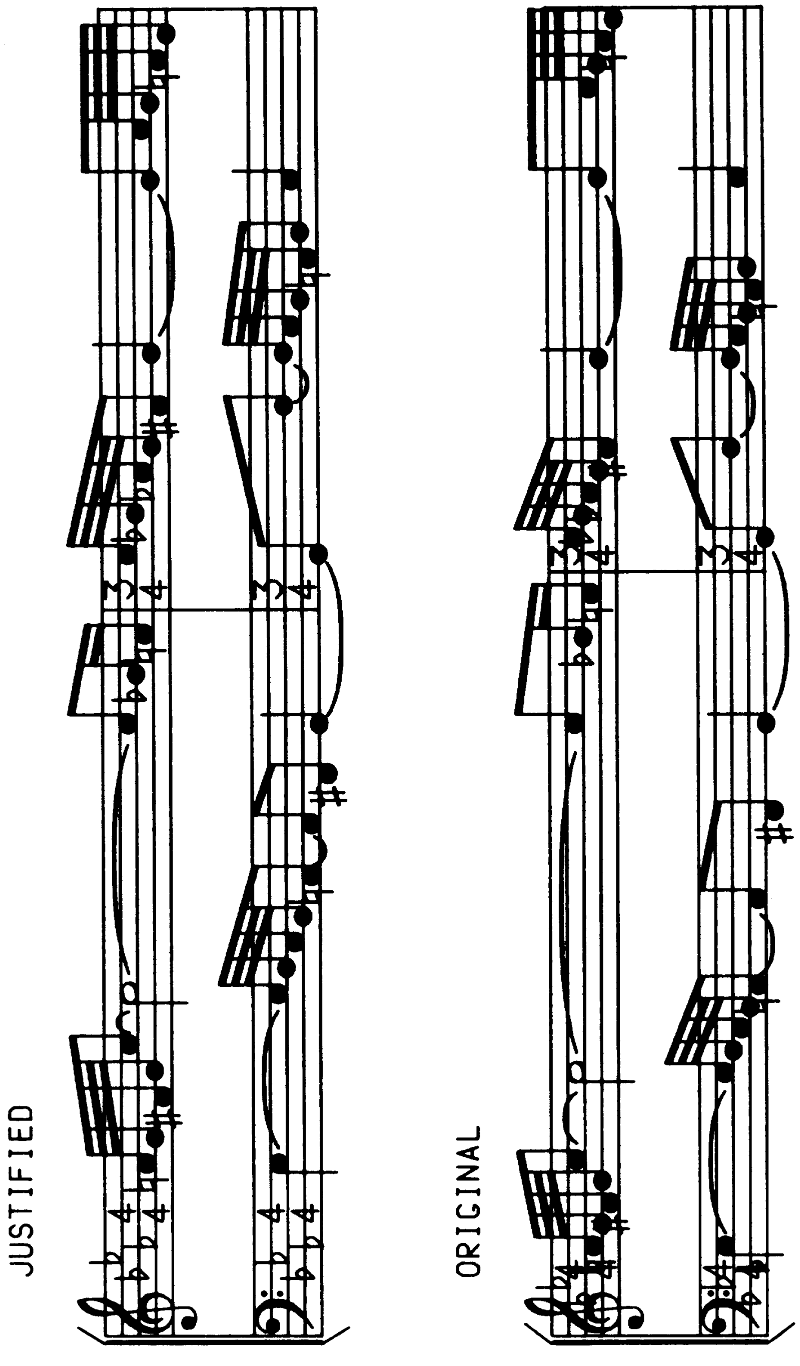
With older music printing methods, the parts for individual players of an ensemble piece had to be created separately. With MSS, the extraction of parts from a full score can be done automatically using a small subsidiary program. Some spacings may have to be changed and full measures of rests combined, but little other editing should be necessary.

While MSS has been conceived for use on a time-sharing display-oriented computer system, a practical variant of the program could be developed for the archaic punched card system. In this case a considerable amount of advance planning of layout would be advisable so that not too many plotter runs for proofs would be needed.

It is reasonable to predict that some computerized system such as the one described will eventually be utilized for most music publication. The time required to set up a page with this system is already competitive with good hand copy work. This time is much less than that needed for engraving or music typewriting. None of these older methods can match the ease of editing and entering corrections of all sorts that a computer program can offer. As computer time and equipment become less and less expensive, it seems likely that this method for printing music will prove to be economically attractive and, as a result, present day composers will gain much more ready access to quality publication.

EXAMPLE

6



REFERENCES

1 The conventions for musical input in MSS are very similar to those used in an extensive program written by this author for translating musical terminology to input for a computer sound generation system. A description of this is found in Leland Smith, "SCORE – A Musician's Approach to Computer Music," JOURNAL OF THE AUDIO ENGINEERING SOCIETY, Jan./Feb. 1972, vol. 20, number 1. Especially useful in SCORE are the several ways of efficiently dealing with the various kinds of repetition found in most music.

TRIO FOR WOODWINDS

FOR MADELEINE AND DARIUS MILHAUD

I.

LELAND SMITH

GRAPHIC REALIZATION BY PDP10 COMPUTER - 1973

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