A POLYPHONIC ELECTRONIC ORGAN

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Summary

A simple method is developed to encode polyphonic music. This method allow us to assign up to 16 voices to be played out on that many speakers. Thus we are able to spatially separate the voices in polyphonic music. Many of Bach's organ pieces were coded to demonstrate this effect.

1. Spatial Separation of Voices in Polyphonic Music

In polyphonic music of the Baroque period, many independent voices are interwoven together. These voices would carry the thematical phrases alternatively or in succession. This type of music played on keyboard instruments like organ or harpsichord is very difficult for the listener to identify and to follow the individual voices. This is particularly true in Bach's organ compositions.

I built a simple electronic organ using an IBM-PC as the host. It is capable of outputing 12 independently programmable voices through 12 loudspeakers. With this organ I can test the idea of spatially separating voices in polyphonic music. Four Intel 8253 counter-timer chips are used on a peripheral card for PC. Up to 12 counter-timers can be configured to operate in Mode 2 to generate square waves. The frequency of each counter-timer channel can be programmed by writing a 16 bit count word into the control register.

2. Coding Polyphonic Music

The syntax to specify a cord or a note group is as follows:

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note1 note2 ... note'n mask duration
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Up to 16 notes can be specified before the mask. Bits in the mask word specify which note is to be sent to which channel so that its frequency can be updated. An example to change 6 channels of voices is as follows:

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HEX   C2 G2 C3 E3 G3 C5   707  1/8
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which assigns C2 to channel 9, G2 to channel 8, C3 to channel 7, E3 to channel 3, G3 to channel 2, and C5 to channel 1. The duration of this cord group is an 1/8 note. The note words, C2, ..., are defined as constants, leaving the counter valued on the stack. 707 is the mask, specifying 6 channels to be updated with 6 note values on the stack. 1/8 is the real actor which takes the mask and used the bit pattern in the mask to store note values into individual counter registers.

Cords are grouped together to form phrases or measures. If any of the phrases or measures are to be repeated, it is advantageous to define then as new words. Forth thus allows us to code music pieces in small modules, which can be checked and edited incrementally.

Specialized tools are built whenever situation calls for them. Tools greatly simplifies coding, especially when the music pieces contain regular structures and patterns, as shown in Prelude in C major. When passages are repeated, the program can simply repeat measures already coded.

3. Program Listing

Screens 2 and 3 contains the program to play cords. Screens 4 to 8 are the notes defined as constants to be entered into the count registers in 8253's. Screens 9 to 12 contain a sample program to play Bach's Prelude in C Major in his Well-Tempered Clavier.

PLAY is the command which notes to different counter-timers according to the specifications in the mask word, and then enters a delay loop to sustain the cord. Actual cord playing words, such as 1/1, 1/2, 1/4, 1/8, 3/4, 3/8, etc., are defined in terms of PLAY with the length of delay specified.

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     2                                                    5
 0 \ Muliple notes                          04jan86cht \ Notes                                    31dec85cht
 1 25 FUDGE ! ( 1 mili-second)                          13081 10000 NOTE C3        13859 10000 NOTE C3#
 2 HEX 310 CONSTANT CHANNEL DECIMAL                     14683 10000 NOTE D3        15556 10000 NOTE D3#
 3 : (PLAY) ( period channel -)                         16481 10000 NOTE E3        17461 10000 NOTE F3
 4    CHANNEL + >R   DUP R@ PC!   FLIP R> PC!   ;       18500 10000 NOTE F3#       19600 10000 NOTE G3
 5 : PLAY ( .. n ms -, send notes to channels specified by mask n)  20765 10000 NOTE G3#  22000 10000 NOTE A3
 6    >R ( time)   16 0 DO   DUP 1 AND                  23308 10000 NOTE A3#       24694 10000 NOTE B3
 7       IF SWAP I (PLAY) THEN   2/   LOOP   DROP
 8    R>   0 DO 20 MS LOOP   KEY? ABORT" killed"   ;    2616 1000 NOTE C4          2772 1000 NOTE C4#
 9                                                      2937 1000 NOTE D4          3111 1000 NOTE D4#
10                                                      3296 1000 NOTE E4          3492 1000 NOTE F4
11                                                      3700 1000 NOTE F4#         3920 1000 NOTE G4
12                                                      4153 1000 NOTE G4#         4400 1000 NOTE A4
13                                                      4662 1000 NOTE A4#         4939 1000 NOTE B4
14
15

     3                                                    6
 0 \ Initiate 8253 and hush them            04jan86cht \ Notes                                    31dec85cht
 1 HEX                                                  5233 1000 NOTE C5          5544 1000 NOTE C5#
 2 : CONTROL-PORTS ( n)                                 5873 1000 NOTE D5          6223 1000 NOTE D5#
 3    320 313 DO   DUP I PC!   4 +LOOP DROP ;           6593 1000 NOTE E5          6985 1000 NOTE F5
 4 : INITIATE ( set up all ports to be mode 3)          7400 1000 NOTE F5#         7840 1000 NOTE G5
 5    36 CONTROL-PORTS   76 CONTROL-PORTS   B6 CONTROL-PORTS ;  8306 1000 NOTE G5#  8800 1000 NOTE A5
 6 : ! ( silence all channels with 300 KHz output)      9323 1000 NOTE A5#         9878 1000 NOTE B5
 7    4 4 4   4 4 4   4 4 4   4 4 4   7777 1 PLAY   ;
 8 : HUSH   ! ;                                         10465 1000 NOTE C6         11087 1000 NOTE C6#
 9 INITIATE HUSH   DECIMAL                              11747 1000 NOTE D6         12445 1000 NOTE D6#
10 : BEAT   CONSTANT   DOES> @ PLAY ;                   13185 1000 NOTE E6         13969 1000 NOTE F6
11 128 BEAT 1/1    64 BEAT 1/2    32 BEAT 1/4   16 BEAT 1/8    14800 1000 NOTE F6#  15680 1000 NOTE G6
12   8 BEAT 1/16    4 BEAT 1/32    2 BEAT 1/64   1 BEAT 1/128   16612 1000 NOTE G6#  17600 1000 NOTE A6
13  96 BEAT 3/4    48 BEAT 3/8    24 BEAT 3/16  12 BEAT 3/32    18647 1000 NOTE A6#  19755 1000 NOTE B6
14 192 BEAT 3/2
15

     4                                                    7
 0 \ Notes                                  01jan86cht \ Notes                                    31dec85cht
 1 : NOTE ( n)   11900 ROT */  CONSTANT  ( DOES> @ PERIOD)  ;   2093 100 NOTE C7     2218 100 NOTE C7#
 2 3270 10000 NOTE C1          3465 10000 NOTE C1#      2349 100 NOTE D7          2489 100 NOTE D7#
 3 3671 10000 NOTE D1          3889 10000 NOTE D1#      2637 100 NOTE E7          2794 100 NOTE F7
 4 4120 10000 NOTE E1          4365 10000 NOTE F1       2960 100 NOTE F7#         3136 100 NOTE G7
 5 4625 10000 NOTE F1#         4900 10000 NOTE G1       3322 100 NOTE G7#         3520 100 NOTE A7
 6 5191 10000 NOTE G1#         5500 10000 NOTE A1       3729 100 NOTE A7#         3951 100 NOTE B7
 7 5827 10000 NOTE A1#         6174 10000 NOTE B1
 8 6541 10000 NOTE C2          6930 10000 NOTE C2#      4186 100 NOTE C8          4435 100 NOTE C8#
 9 7342 10000 NOTE D2          7778 10000 NOTE D2#      4699 100 NOTE D8          4978 100 NOTE D8#
10 8241 10000 NOTE E2          8731 10000 NOTE F2       5274 100 NOTE E8          5588 100 NOTE F8
11 9250 10000 NOTE F2#         9800 10000 NOTE G2       5920 100 NOTE F8#         6272 100 NOTE G8
12 10383 10000 NOTE G2#        11000 10000 NOTE A2      6645 100 NOTE G8#         7040 100 NOTE A8
13 11654 10000 NOTE A2#        12347 10000 NOTE B2      7459 100 NOTE A8#         7902 100 NOTE B8
14
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                                Forth 83 Model
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    8
 0 \ Flat notes                                    31dec85cht
 1 C1♭ CONSTANT D1b    D1♯ CONSTANT E1b   F1♯ CONSTANT G1b
 2 C2♭ CONSTANT D2b    D2♯ CONSTANT E2b   F2♯ CONSTANT G2b
 3 C3♭ CONSTANT D3b    D3♯ CONSTANT E3b   F3♯ CONSTANT G3b
 4 C4♭ CONSTANT D4b    D4♯ CONSTANT E4b   F4♯ CONSTANT G4b
 5 C5♭ CONSTANT D5b    D5♯ CONSTANT E5b   F5♯ CONSTANT G5b
 6 C6♭ CONSTANT D6b    D6♯ CONSTANT E6b   F6♯ CONSTANT G6b
 7 C7♭ CONSTANT D7b    D7♯ CONSTANT E7b   F7♯ CONSTANT G7b
 8 C8♭ CONSTANT D8b    D8♯ CONSTANT E8b   F8♯ CONSTANT G8b
 9 G1♭ CONSTANT A1b    A1♯ CONSTANT B1b
10 G2♭ CONSTANT A2b    A2♯ CONSTANT B2b
11 G3♭ CONSTANT A3b    A3♯ CONSTANT B3b
12 G4♭ CONSTANT A4b    A4♯ CONSTANT B4b
13 G5♭ CONSTANT A5b    A5♯ CONSTANT B5b
14 G6♭ CONSTANT A6b    A6♯ CONSTANT B6b
15 G7♭ CONSTANT A7b    A7♯ CONSTANT B7b

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 0 \ Prelude 1, C Major                            02jan86cht
 1 : CORD ( n1 n2 n3)   SWAP ROT   3 0 DO   1 1/16   LOOP ;
 2 : K1   G4 C5 E5 CORD ;
 3 : M1   C4 4 4 7 1/16   E4 2 1/16   K1 K1 ! ;
 4 : K2   A4 D5 F5 CORD ;
 5 : M2   C4 4 4 7 1/16   D4 2 1/16   K2 K2 ! ;
 6 : K3   G4 D5 F5 CORD ;
 7 : M3   B3 4 4 7 1/16   D4 2 1/16   K3 K3 ! ;
 8 : K4   A4 E5 A5 CORD ;
 9 : M4   C4 4 4 7 1/16   E4 2 1/16   K4 K4 ! ;
10 : K5   F4♯ A4 D5 CORD ;
11 : M5   C4 4 4 7 1/16   D4 2 1/16   K5 K5 ! ;
12 : K6   G4 D5 G5 CORD ;
13 : M6   B3 4 4 7 1/16   D4 2 1/16   K6 K6 ! ;
14 : P1   M1 M1   M2 M2   M3 M3   M1 M1   M4 M4   M5 M5   M6 M6 ;
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    10
 0 \ Prelude 1, C Major                            02jan86cht
 1 : LEAD ( n1 n2)   SWAP 4 4 7 1/16   2 1/16 ;
 2 : K7   E4 G4 C5 CORD ;
 3 : M7   B3 C4 LEAD   K7 K7 ! ;
 4 : M8   A3 C4 LEAD   K7 K7 ! ;
 5 : K9   D4 F4♯ C5 CORD ;
 6 : M9   D3 A3 LEAD   K9 K9 ! ;
 7 : K10   D4 G4 B4 CORD ;
 8 : M10   G3 B3 LEAD   K10 K10 ! ;
 9 : K11   E4 G4 C5♯ CORD ;
10 : M11   G3 A3♯ LEAD   K11 K11 ! ;
11 : K12   D4 A4 D5 CORD ;
12 : M12   F3 A3 LEAD   K12 K12 ! ;
13 : K13   D4 F4 B4 CORD ;
14 : M13   F3 G3♯ LEAD   K13 K13 ! ;
15 : P2   M7 M7 M8 M8 M9 M9 M10 M10 M11 M11 M12 M12 M13 M13 ;

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 0 \ Prelude 1, C Major                            02jan86cht
 1 : K14   C4 G4 C5 CORD ;       : M14   E3 G3 LEAD K14 K14 ! ;
 2 : K15   A3 C4 F4 CORD ;       : M15   E3 F3 LEAD K15 K15 ! ;
 3 : M16   D3 F3 LEAD   K15 K15 ! ;
 4 : K17   G3 B3 F4 CORD ;       : M17   G2 D3 LEAD K17 K17 ! ;
 5 : K18   G3 C4 E4 CORD ;       : M18   C3 E3 LEAD K18 K18 ! ;
 6 : K19   A3♯ C4 E4 CORD ;      : M19   C3 G3 LEAD K19 K19 ! ;
 7 : K20   A3 C4 E4 CORD ;       : M20   F2 F3 LEAD K20 K20 ! ;
 8 : K21   A3 C4 D4♯ CORD ;      : M21   F2♯ C3 LEAD K21 K21 ! ;
 9 : K22   B3 C4 D4 CORD ;       : M22   G2♯ F3 LEAD K22 K22 ! ;
10 : K23   G3 B3 D4 CORD ;       : M23   G2 F3 LEAD K23 K23 ! ;
11 : K24   K18 ;                 : M24   G2 E3 LEAD K18 K18 ! ;
12 : K25   G3 C4 F4 CORD ;       : M25   G2 D3 LEAD K25 K25 ! ;
13 : K26   G3 B3 F4 CORD ;       : M26   G2 D3 LEAD K26 K26 ! ;
14 : P3   M14 M14 M15 M15 M16 M16 M17 M17 M18 M18 M19 M19
15    M20 M20 M21 M21 M22 M22 M23 M23 M24 M24 M25 M25 M26 M26 ;

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 0 \ Prelude 1, C Major                            02jan86cht
 1 : K27   A3 C3 F3♯ CORD ;      : M27   G2 D3♯ LEAD K27 K27 ! ;
 2 : K28   G3 C4 G4 CORD ;       : M28   G2 E3 LEAD K28 K28 ! ;
 3 : K29   G3 C4 F4 CORD ;       : M29   G2 D2 LEAD K29 K29 ! ;
 4 : K30   G3 B3 F4 CORD ;       : M30   G2 D2 LEAD K30 K30 ! ;
 5 : K31   G3 A3♯ E4 CORD ;      : M31   C2 C3 LEAD K31 K31 ! ;
 6 : 14NOTES   14 0 DO 1 1/16 LOOP ;
 7 : K32   D3 F3 D3 F3 A3 F3 A3 C4 A3 C4 F4 C4 A3 F3 14NOTES ! ;
 8 : M32   C2 C3 LEAD K32 ;
 9 : K33   D4 E4 F4 D4 B4 G4 B4 D5 B4 D5 F5 D5 B4 G4 14NOTES ! ;
10 : M33   C2 B2 LEAD K33 ;
11 : FINALE C2 512 1/16 C3 256 1/16 E4 4 1/16 G4 2 1/16 C5 1 1/1 ;
12 : P4   M27 M27 M28 M28 M29 M29 M30 M30 M31 M31 M32 M33
13    FINALE HUSH ;
14 : PRELUDE-1   P1 P2 P3 P4 ;
15 32 FUDGE !

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 0 \ BACH ORGAN RECITAL, January 17, 1986          15jan86cht
 1 LITTLE ( Little prelude)
 2 MUSETTE-1 ( Musette in D major)
 3 2-INV-1 ( Two part invention, No. 1)
 4 2-INV-4 ( Two part invention, No. 4)
 5 PRELUDE-1 ( Prelude in C major)
 6 FUGUE-1 ( Fugue in C major)
 7 PRELUDE-2 ( Prelude in C minor)
 8 FUGUE-2 ( Fugue in C minor)
 9 TOCCATA ( Toccata in G major)
10 ADAGIO ( Toccata in G major)
11 ALLEGRO ( Toccata in G major)
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