PROGRAMS FOR THE COSMAC ELF GRAPHICS

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List of Sections

List of Programs

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Introduction

The programs in this booklet were written for the basic COSMAC 1802 "Elf" with Pixie graphics as described in the July, 1977 issue of *Popular Electronics.* All programs can be easily modified to work in expanded memory systems by initializing a few registers with high order memory addresses (see Registers and Expanded Memory). The programs are documented to aid understanding, but knowledge of the 1802 instruction set is presumed, and assembly language mnemonics are not provided because of space limitations.

The first four programs introduce new graphic interrupt routines which use 128 bytes or less for display purposes. This is necessary because the basic "Elf" has only 256 bytes of memory and some has to be reserved for programming. While these routines either produce a display with fewer spots or a reduced area with the same resolution as that given in the Pixie examples, they avoid showing active code. A discussion of graphic interrupt routines is provided as an aid to understanding these new routines (see Graphic Interrupt Routines).

As the basic "Elf" has so little memory a programming "trick" is used in programs 5, 7 and 8. This trick allows one to have an instruction that is varied each time a set of code is obeyed by changing the instruction after each pass through the code. See the section entitled "Variable Code" for a discussion of the method used.

Registers and Expanded Memory

The 1802 requires that register O be used for the direct memory access (DMA) address, and register 1 for the interrupt address. Register 2 is used as an X register in all the programs and in some programs additional X registers are employed. Register 3 is used as the main program counter in all programs and subroutines are called by the "SEP register technique" (see RCA's User Manual for the 1802 Cosmac Microprocessor, pp. 54-58). All programs make the high order DMA address the same as the high order interrupt address. Basic "Elf" owners may run the programs just as they are written. In order to work in an expanded memory system R(1), R(2), and R(3) together with any other memory addressing registers must have their high order bytes preset. For example if the first program was to be run in page 4 (block 4) of an expanded system it would be loaded just as written but to page 4 instead of page 0. The following ”patch” would be inserted on page 0:

Add.	Code	Notes
00 00	F8 04	load page number to D
02	B1 B2 B3	initialize high order bytes
05	B4 B5	of registers used by program 1
07	C0 04 00	transfer control to page 4 to run program

This patch when executed would initialize the necessary high order bytes and enter the program on page 4. Each program includes a list of registers which must be set to work in expanded systems.

Graphic Interrupt Routines

In the ”Elf” the generation of the interrupt and direct memory access (DMA) signals are all done under the control of the 1861 chip and its operation must be understood when writing or modifying interrupt routines. When enabled by an I/O signal from the microprocessor the 1861 chip generates interrupt requests at intervals of 1/61 seconds (3.579545/2 MHz clock). Twenty-nine machine cycles after each interrupt the first direct memory access (DMA) request occurs. Therefore when the 1861 generates an interrupt request we must use exactly 29 machine cycles to do the housekeeping required to get ready for the direct memory access requests. Things that must be done include saving the current designations of the X and P registers and saving the contents of the D register so that we can return from the interrupt routine. We can also use these instructions to set register 0 to the address where we wish the DMA to start. If we put a counter in these preliminary instructions it will be incremented 61 times a second and can serve as a convenient timer or clock.

After these 29 preliminary machine cycles we get the first "burst" of eight DMA's. Memory bytes with the addresses designated by the contents of register 0,R(0) incremented once, R(0) incremented twice, . . . to R(0) incremented seven times, are mapped to the top line of the TV screen; R(0) is left pointing + 8 memory locations from where it started (i.e. R(0) has been incremented 8 times). We are now given 6 machine cycles, which can be used as we wish, these are normally used to reset register 0. After 6 machine cycles another burst of 8 DMA's occur, followed by 6 machine cycles, and so on until a total of 128 DMA bursts have filled the TV screen. During the last four DMA bursts the EF1 flag is held low as an aid to returning from the interrupt routine.

In the one page interrupt used by the Pixie graphics the starting address of register 0 is held constant for 4 DMA bursts giving a display in which each bit represents a square and we have the display divided into a field of 64 x 32 squares.

If we were to hold the starting address of register 0 constant for 8 DMA bursts one set bit would form a rectangle twice as high as it is wide, and we would form an array of such rectangles 64 across by 16 down. An interrupt routine which does just this is given in program 1. If we chose to set 2 adjacent bits at a time we would then have an array of squares 32 across and 16 down.

In the same manner holding the starting address of register 0 constant for 16 DMA bursts would form rectangles 4 times as high as they are wide and if we set 4 bits at a time we would produce an array of squares 16 across and 8 down. Program 2 contains such an interrupt routine. Holding register 0 constant for 32 DMA bursts and setting one word at a time would give an array of squares 8 across and 4 down as in Program 3. Note that each doubling of the number of DMA bursts halves the number of store locations required for display; 256 locations for 4 DMA bursts, 128 for 8 DMA bursts, 64 for 16 DMA bursts,and 32 for 32 DMA bursts.

It isn't necessary to keep the number of DMA bursts constant at each starting address. There is nothing to prevent changing the resolutions across the TV screen if we so desire and we can save display locations in this way. Program 4 introduces such an interrupt routine, the top part of the screen is blanked by doing 108 DMA bursts on the same 8 locations, while the last 20 DMA bursts are used to produce an array of 64 x 5 squares with the resolution of a single page interrupt routine.

Variable Code

A simple way to set up code which can be varied is to save an instruction in a register and then modify the instruction by changing the contents of the register. The register contents must, of course, be transferred to memory before the instruction can be executed. The following example is taken from program 8 where it is used to load the low order part of seven registers with seven consecutive switch bytes.

Add.	Code	Notes
0B	F8 1A A4	load address of variable code to R(4)
0E	F8 AF A5	AF is the instruction to be executed in location 1A, 1st time it will be AF, 2nd time AE, then AD, etc. and finally A9
11	85 44	get the instruction and store it in location 1A
13	3F 13 37 15	wait for in on, off
17	6C 64 22	read and display switch byte
1A	XX	the variable instruction, first AF, etc.
1B	85 FB A9	check, are we done?
1E	32 23	yes—go on
20	25 30 11	no—change instruction and go back through code

A similar method is used to increment one of 4 registers in program 5 as follows:

Add.	Code	Notes
48	8E	R(E) contains the instruction to be executed, in program 5 it is one of 1A, 1B, 1C or 1D. The instruction is here loaded to the D register.
49	53	R(3) is the program counter and a 53 instruction writes 1A, 1C, or 1D to the next location (4A)
4A	XX	This location becomes 1A, 1B, 1C, or 1D depending upon the contents of R(E).0 and is executed.

Variable code has the drawback that it cannot be used in read only memory. However random access memory is available in the Elf and variable code can be used to get more work out of the limited memory available. Care must be taken to maintain control over the locations changed and the instructions allowed when using this method.

Program 1—Display Routine (128 Byte)

This program introduces an interrupt routine which displays 128 memory locations on the screen. Each bit is displayed as a rectangle twice as tall as it is wide; in order to get a square, two adjacent bits must be set. Such an interrupt routine could be written by simply extending RCA's single page interrupt, however a method is used in which a counter is incremented between DMA bursts. This method is more versatile and the number of similar DMA bursts can be made equal to 5 + 3N where N is any integer, in this case n = 1 to give 8 identical sets of DMA bursts. Program 3 employs a similar routine with N = 9 to produce 32 identical DMA bursts. Note that the routine must not go across a page boundary and that the locations displayed are actually 7F through FE. The memory locations are, however, addressed individually as 00 through 7F in hexadecimal.

The program has three modes depending on what is set in the switches on turning to run. If 01 is set, memory is examined, enter the address desired, (remember 00 to 7F) push the in button and the contents of that location will be displayed; successive pushes of the in button step through memory. If 02 is set memory locations are changed, enter the address desired, push the in button, then enter the new contents and push in again, successive pushes of the in button change successive memory locations. If CC is set the display area is cleared and the program automatically enters the input mode.

A picture which illustrates the use of this interrupt routine is listed at the end of the program. Each line of the listing contains 64 bits (8 words) and forms one of the lines of the TV display, there are 16 lines in all. If this picture is entered by means of the program it will be seen to form as memory is filled.

Registers 1, 2, 3, 4 and 5 must be set if this program is to be run in an expanded memory system.

Use of Registers

	High	Low
R(0)		DMA address
R(1)		interrupt address
R(2)		X register
R(3)		program counter
R(4)		memory pointer
R(5)		memory pointer
R(C)	counter for interrupt routine	
R(F)	work in interrupt	work in interrupt

Program Listing

Add.	Code	Notes
00	F8 4F A1	interrupt address
03	F8 7E A2	stack address
06	F8 09 A3	program counter
09	D3 E2 69	program counter 3, TV on
OC	F8 02 BC	counter for DMA cycles, see interrupt routine
OF	F8 7F A5	starting address of displayed locations
12	6C 64 22	read and display switch byte
15	FD CC	is it CC?
17	3A 24	go to 24 unless switch byte is CC
19	85 A4	otherwise clear store locations
1B	F8 00 54	and turn on Q line when
1E	14 84	through
20	3A 1B	
22	24 7B	
24	3F 24 37 26	wait for in on, off
28	FO	bring back original switch byte
29	F6 33 2D	skip next instruction if switch byte odd
2C	7B	turn Q on (memory to be changed)
2D	6C	read switch byte
2E	FA 7F	and it against 7F (prevents illegal addresses)
30	FC 7F	add starting address of displayed locations
32	A4	load to R(4).0—memory pointer
33	3F 33 37 35	wait for in on, off
37	84 FF FF	check R(4).0 if contents are FF we've run over displayed locations
3A	3A 3E	go to 3E if address OK
3C	85 A4	else reset to 7F
3E	04	load memory contents
3F	31 47	go to 47 if Q on—we have to change memory
41	52 64 22	else display memory
44	14	increment R(4)
45	30 33	go to wait for in on, off
47	6C 64 22	here if memory to be changed read and display switch byte
4A	54 30 44	store it and go to 44
4D	72 70	return from interrupt
4F	C4	entry to interrupt
50	22 78 22 52	save X, P and D
54	9C AF	load counter for DMA bursts to R(F).0
56	F8 7F BF	load starting address of displayed locations to R(F).1
59	91 BO	load high order DMA address
5B	E2 9F AO	load low order DMA address
——		DMA 1 occurs here (1st burst only)
5E	E2 9F AO	restore DMA address
——		DMA 2, 5 here
61	2F AO 8F	decrement counter, restore DMA address, load counter
——		DMA 3, 6 here
64	32 6A 9F AO	to 6A if counted out, else restore DMA address
——		DMA 4
68	30 5F	and go back to 5F
6A	9F AO	here if counted out, restore DMA address
——		DMA 7
6C	AO 9C 34 4D	restore DMA address, and reload counter, leave routine if done
——		DMA 8 (except last one)
70	AF 80 BF	restore counter and set new DMA address
——		new DMA 1
73	30 5F	back to 5F for DMA 2, etc.
74-7B		unused
7C-7E		stack
7F-FE		displayed locations

Picture

```
Add.  Code
00    98  00  00  60  00  60  00  00
08    88  00  00  20  00  10  01  80
10    F8  00  07  27  F8  18  01  80
18    00  00  1F  FE  DF  98  06  01
20    F8  00  07  FF  FF  FO  18  06
28    08  00  00  74  FF  F7  F9  98
30    F8  00  1F  80  3F  9F  FF  EO
38    00  00  F5  FF  CO  7E  1E  60
40    F8  00  1F  80  3F  9F  FF  EO
48    A8  00  00  7F  FF  F7  F9  98
50    F8  00  07  FF  FF  FO  18  06
58    A8  00  1F  FE  DF  98  06  01
60    00  00  07  27  F8  18  01  80
68    88  00  00  20  00  10  01  80
70    88  00  00  60  00  60  00  00
78    F8  00  00  00  00  00  00  00
```

Program 2 – Display Routine (64 Byte)

This program contains an interrupt routine which displays 64 memory locations on the screen. Each location is displayed as two adjacent squares, the screen is divided into 128 squares (16 wide by 8 high). Two sets of 64 locations are displayed so there are two displays which appear alternately, each for about 0.5 seconds.

The interrupt routine employs a counter similar to that used in program 1 except that the number of identical DMA bursts is 7 + 3N, where N is any integer. N is set to 3 to give 16 identical DMA cycles. Again the routine must not go across a page boundary and the locations displayed are actually 7F through FE. However in this program the individual squares are the things that are addressed and they are numbered 00 through FF as shown in the diagram. Set one is numbered 00 to 7F and set 2, 80 to FF, again in hexidecimal.

The program has only two modes of operation. If CC is set in the switch register when run is turned on the displayed locations are erased, otherwise they are unaltered. Once the program is running the numbers entered are square identifiers. Enter a square identifier and push in, that square will be changed to its opposite value, that is if it is off it will be turned on, if on it will be turned off. As a trial clear the display area and enter the 74 square *identifiers* listed after the program.

Registers 1, 2, 3, 4 and 5 must be set if this program is to be run in an expanded memory system.

Use of Registers

	High	Low
R(0)		DMA address
R(1)		interrupt address
R(2)		X register, stack
R(3)		program counter
R(4)		memory pointer
R(5)		memory pointer
R(9)		counter for timer in interrupt routine
R(C)	counter for interrupt routine	
R(F)	work in interrupt	work in interrupt

Program Listing

```
Add.  Code          Notes
00    F8 54 A1      interrupt address
03    F8 7E A2      stack address
05    F8 09 A3      program counter
09    D3 E2         establish program counter
                    and X register
OB    F8 04 BC      Counter for DMA bursts, see
                    interrupt routine
OE    F8 7F A5      starting address of displayed
                    memory locations
11    6C 64 22      read and display switch byte
14    FD CC         is the switch byte CC?
16    3A 22         unless it is go to 22
18    85 A4         if it is CC clear memory
1A    F8 00 54      locations
1D    14 84
1F    3A 1A 24
22    69            turn on TV
23    3F 3E         wait for in on (part of waiting
                    loop)
25    37 25         wait for in off if pushed
27    6C 64 22      read and display switch byte
2A    F6 FC 7F      shift (i.e. divide by 2) and
                    add 7F the starting address of
                    displayed memory
2D    A4            save result in R(4).0
2E    F0 F6         bring back switch byte, shift
30    3B 38         to 38 if switch byte was even,
                    else go on
32    04 FB OF 54   here if switch byte odd, x'or
                    memory against OF and re-
                    place
```

```
36    30 23          return to waiting loop
38    04 FB FO 54    here if switch byte even, x'or
                     memory against FO and re-
                     place
3C    30 23          return to waiting loop
3E    89 FD 40       waiting loop, examine timer
41    33 23          continue wait unless time up
43    F8 00 A9       here if time up, reset timer
46    85             get starting address of cur-
                     rently displayed locations
47    FB BF          is it set 2?
49    32 4D          go to set 1 if set 2 is now
                     being displayed
4B    FF 80          else set to display set 2
4D    FC 7F A5       store correct starting address
50    30 23          back to waiting loop
52    72 70          return from interrupt
54    C4             entry to interrupt
55    22 78 22 52    save X, P and D
59    9C AF          load counter for DMA bursts
                     to R(F).0
5B    85 BF          load starting address of dis-
                     played locations to R(F).1
5D    91 BO          load high order DMA address
5F    9F AO 19       load low order DMA address,
                     increment timer
--                   DMA 1 occurs here (1st burst
                     only)
62    30 67 9F AO    skip to 67, reenters at 64 for
                     2nd and subsequent bursts
--                   DMA 4, 7, 10 and 13 here
66    2F AO 8F       decrement counter, restore
                     DMA address, load counter
```

```
--                   DMA 2, 5, 8, 11 and 14 here
69    32 6F 9F AO    to 6F if counted out, else
                     restore DMA address
--                   DMA 3, 6, 9 and 12 here
6D    30 64          and go back to 64
6F    9F AO          here if counted out, restore
                     DMA address
--                   DMA 15
71    AO 9C 34 52    restore DMA address, and re-
                     load counter, leave routine
                     if done
--                   DMA 16 (except last one)
75    AF 80 BF       restore counter and set new
                     DMA address
--                   new DMA 1
78    30 67          back to 67 for new DMA 2,
                     etc.
7A-7B                unused
7C-7E                stack
7F-FE                displayed locations
```

Picture
(Note that bytes given are square identifiers.)

```
00  03  04  08  09  OD  OE  10
12  15  17  1A  1C  1F  20  22
25  27  2A  2F  30  33  34  37
3A  3D  3E  40  42  45  47  4A
4C  50  52  55  57  5A  5C  60
63  64  68  69  6C  6D  6E  6F
80  81  82  83  84  86  8B  8C
8D  8E  8F  90  96  9B  AO  A6
AB  BO  B1  B2  B3  B6  BB  BC
BD  BE  CO  C6  CB  DO  D6  DB
EO  E1  E2  E3  E4  E6  E7  E8
E9  EB
```

Diagram – Program 2

Set No. 1

00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F
10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E	1F
20	21	22	23	24	25	26	27	28	29	2A	2B	2C	2D	2E	2F
30	31	32	33	34	35	36	37	38	39	3A	3B	3C	3D	3E	3F
40	41	42	43	44	45	46	47	48	49	4A	4B	4C	4D	4E	4F
50	51	52	53	54	55	56	57	58	59	5A	5B	5C	5D	5E	5F
60	61	62	63	64	65	66	67	68	69	6A	6B	6C	6D	6E	6F
70	71	72	73	74	75	76	77	78	79	7A	7B	7C	7D	7E	7F

80	81	82	83	84	85	86	87	88	89	8A	8B	8C	8D	8E	8F
90	91	92	93	94	95	96	97	98	99	9A	9B	9C	9D	9E	9F
A0	A1	A2	A3	A4	A5	A6	A7	A8	A9	AA	AB	AC	AD	AE	AF
B0	B1	B2	B3	B4	B5	B6	B7	B8	B9	BA	BB	BC	BD	BE	BF
C0	C1	C2	C3	C4	C5	C6	C7	C8	C9	CA	CB	CC	CD	CE	CF
D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	DA	DB	DC	DD	DE	DF
E0	E1	E2	E3	E4	E5	E6	E7	E8	E9	EA	EB	EC	ED	EE	EF
F0	F1	F2	F3	F4	F5	F6	F7	F8	F9	FA	FB	FC	FD	FE	FF

Set No. 2

The points in the above diagram represent squares arranged in arrays 16 wide by 8 high. An easy way to create and encode pictures is to use graph paper.

Program 3 — Display Routine (32 Byte)

The third interrupt routine displays 32 store locations on the screen. Each location is displayed as a single square and the screen is divided into 32 squares (8 wide by 4 high). Four sets of 32 locations are displayed so there are four displays which appear one after the other for about 0.5 seconds each.

This program uses an interrupt routine like that of program 1 except that 32 identical DMA bursts are produced. Again the routine must not go across a page boundary and the locations displayed are actually 7F through FE. The individual squares are the things that are addressed and they are numbered 00 through 7F as shown in the diagram.

The program has the same modes of operation as program 2. If CC is set in the switch register when run is turned on the displayed locations are erased, otherwise they are unaltered. Once the program is running the numbers entered are square identifiers. Enter a square identifier and push in, that square will be changed to its opposite value, that is if it is off it will be turned on, if on it will be turned off. As a trial the program should be entered so as to clear the display and the 78 square identifiers given at the end of the program entered.

Registers 1, 2, 3, 4 and 5 must be set if this program is to be run in an expanded memory system.

Use of Registers

	High	Low
R(O)		DMA address
R(1)		interrupt address
R(2)		X register, stack
R(3)		program counter
R(4)		memory pointer
R(5)		memory pointer
R(9)		counter for timer in interrupt routine
R(C)	counter for interrupt routine	
R(F)	work in interrupt	work in interrupt

Program Listing

Add.	Code	Notes
00	F8 4F A1	interrupt address
03	F8 7E A2	stack address
06	F8 09 A3	program counter
09	D3 E2	establish program counter and X register
OB	F8 OA BC	counter for DMA bursts, see interrupt routine
OE	F8 7F A5	starting address of displayed memory locations
11	6C 64 22	read and display switch byte
14	FD CC	is it CC
16	3A 22	no–go to 22
18	85 A4	if switch byte is CC clear display locations
1A	F8 00 54	
1D	14 84	
1F	3A 1A 24	
22	69	turn on TV
23	3F 36	wait for in on (part of waiting loop)
25	37 25	wait for in off if pushed
27	6C FA 7F	read switch byte, and against 7F to get legal square identifier
2A	52 64 22	display square to be changed
2D	FC 7F A4	add starting address of locations
30	04 FB FF 54	pick up location, x'or against FF, put it back
34	30 23	return to waiting loop
36	89 FD 20	waiting loop, examine timer
39	33 23	continue wait unless time up
3B	F8 00 A9	here if time up, reset timer
3E	85	get starting address of currently displayed locations
3F	FB DF	are we on the last set?
41	32 48	if we are go to 48 to start over
43	85 FC 20	if not add 20 to starting address of displayed bytes
46	30 4A	and return to in loop
48	F8 7F	here if starting over
4A	A5 30 23	restore R(5) and back to waiting loop
4D	72 70	return from interrupt
4F	C4	entry to interrupt
50	22 78 22 52	save X, P and D
54	9C AF	load counter for DMA bursts to R(F).0
56	19	increment timer
57	85 BF	load starting address of displayed locations
59	91 BO	load high order DMA address
5B	9F AO	load low order DMA address
— —		DMA 1 here (1st burst only)

```
5D    E2 9F AO       restore DMA address
--                   DMA 2, 5, 8, 11, 14, 17, 20,
                     23, 26 and 29 here
60    2F AO 8F       decrement counter, restore
                     DMA address, load counter
--                   DMA 3, 6, 9, 12, 15, 18, 21,
                     24, 27 and 30 here
63    32 69 9F AO    to 69 if counted out, else
                     restore DMA address
--                   DMA 4, 7, 10, 13, 16, 19, 22,
                     25 and 28 here
67    30 5E          and go back to 5E
69    9F AO          here if counted out, restore
                     DMA address
--                   DMA 31 here
6B    AO 9C 34 4D    restore DMA address, and re-
                     load counter, leave routine
                     if done
--                   DMA 32 here
6F    AF 80 BF       restore counter and set new
                     DMA address
--                   new DMA 1 here
72    30 5E          back to 5E for DMA 2, etc.
74-7B                unused
7C-7E                stack
7F-FE                displayed locations
```

Picture

(Note that bytes given are square identifiers.)

```
01  02  03  04  05  08  09  OB
OD  OE  11  12  14  15  19  1A
1B  1C  1D  21  22  23  24  25
28  29  2A  2B  2D  2E  31  32
34  35  39  3A  3B  3C  3D  41
42  43  44  45  48  49  4B  4D
4E  51  52  54  55  59  5A  5B
5C  5D  61  62  63  64  65  68
69  6B  6C  6D  6E  71  72  74
75  79  7A  7B  7C  7D
```

Diagram – Program 3

Set No. 1

00	01	02	03	04	05	06	07
08	09	0A	0B	0C	0D	0E	0F
10	11	12	13	14	15	16	17
18	19	1A	1B	1C	1D	1E	1F

Set No. 2

20	21	22	23	24	25	26	27
28	29	2A	2B	2C	2D	2E	2F
30	31	32	33	34	35	36	37
38	39	3A	3B	3C	3D	3E	3F

40	41	42	43	44	45	46	47
48	49	4A	4B	4C	4D	4E	4F
50	51	52	53	54	55	56	57
58	59	5A	5B	5C	5D	5E	5F

Set No. 3

60	61	62	63	64	65	66	67
68	69	6A	6B	6C	6D	6E	6F
70	71	72	73	74	75	76	77
78	79	7A	7B	7C	7D	7E	7F

Set No. 4

The points in the above diagram represent squares arranged in arrays 8 wide by 4 high. An easy way to create and encode pictures is to use graph paper.

Program 4 – Variable Resolution Display Routine (48 Bytes)

Program 4 introduces a more complex interrupt routine. This interrupt routine displays 48 memory locations with a variable number of DMA bursts. The first 8 locations are used in producing 108 identical DMA bursts which fill most of the television screen. The last 40 store locations are used in 5 groups of 8, each group of which is used to produce 4 DMA bursts. In these last 40 locations, therefore, each bit produces a square of the same size that it would produce if a one page interrupt routine were used. That is the last 40 locations produces a display 64 squares wide and 5 squares high. The first 8 locations produce 64 bars 27 times as high as they are wide. If the first 8 locations are set to 00 the top 27/32 of the screen will be blank while the bottom 5/32 becomes the display area.

The program that uses this interrupt routine produces a "tickertape" display. The material to be displayed is coded in 11 sets of 5 bytes as shown in the diagram. After loading the program switch to run and enter bytes 5 at a time through the switches. When 5 bytes have been entered they are shifted into the tickertape display area and when all 11 sets have been entered the display area moves continuously.

Registers 1, 2, 3, 4, 5, and 6 must be set if this program is to be run in an expanded memory system.

Use of Registers

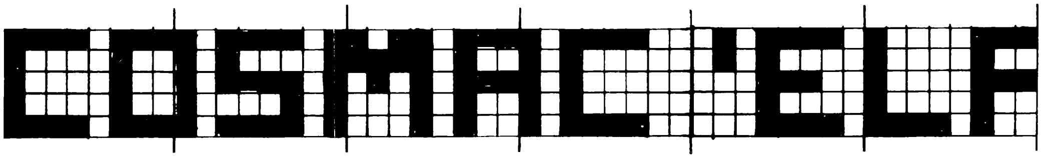
	High	Low
R(0)		DMA address
R(1)		interrupt address
R(2)		X register, stack
R(3)		program counter
R(4)		points to locations where data to be moved to display area is stored
R(5)		memory pointer to display area
R(6)		holds address of display subroutine
R(7)		counter, 8 bits/word
R(8)		counter, 5 words vertically
R(9)		counter for timer in interrupt routine
R(A)		counter, 8 words/line
R(B)		another 5 counter
R(F)	work in interrupt (stores counter)	work in interrupt

Program Listing

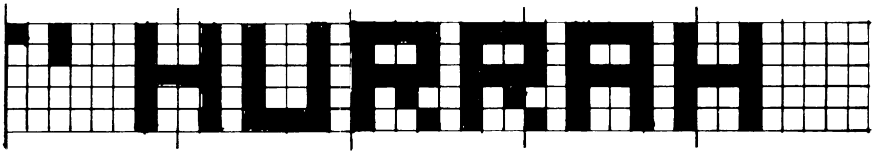
Add.	Code	Notes
00	F8 A5 A1	interrupt address
03	F8 3A A2	X register, stack
06	F8 3C A6	address of subroutine that shifts 5 bytes into display area
09	F8 A3 A4	A3 is one more than address to write first data point to
OC	F8 OF A3	program counter
OF	D3 E2	establish program counter and X register
11	69	turn on TV
12	7B	Q light on
13	F8 05 AB	set counter to read 5 bytes
16	24	decrement R(4)–points to place to store byte
17	3F 17 37 19	wait for in on, off
1B	6C 64 22	read and display byte
1E	54	store it in M(R(4))
1F	2B 8B	decrement 5 counter and load it
21	3A 16	if not counted out back to 16 for another
23	7A D6	else turn Q off and call routine to shift these 5 bytes to display
25	84 FB 6C	load R(4).0 if it equals 6C all data has been entered
28	3A 12	else go back for 5 more bytes
2A	F8 9E A4	here if all data loaded, restore R(4) address for display
2D	D6	this section of code repeatedly
2E	84 FF 05	calls display subroutine to
31	A4	shift the message into the dis-
32	FB 67 3A 2D	play area
36	30 2A	
38	xx xx xx	stack
3B	D3	return from subroutine, this subroutine shifts the bytes in M(R(4)), M(R(4)+ 1), M(R(4) +2) M(R(4) + 3) and M(R(4) + 4) into the display area - R(4) and the memory locations are restored on return
3C	F8 08 A7	entry to routine, establish counter 8 bits/word

3F	F8 FF A5	display location where entry starts at
42	F8 05 A8	5 words to shift in—another counter
45	F8 00 A9	routine to give a brief delay
48	89 FB 06	
4B	3A 48	
4D	F8 08 AA	counter—8 words/line of display
50	04 FE	load D, shift left to fill DF
52	04 7E 54	load, circular shift left and restore
55	05 7E 55	load, circular shift left and restore
58	25 2A	repeat 8 times till bit shifted
5A	8A 3A 55	in to line
5D	28 88 14	repeat till a bit is shifted into
60	3A 4D	all five lines
62	84 FF 05 A4	reset R(4)
66	27 87	check if all bits shifted in
68	32 3B	if so return
6A	30 3F	else go and shift another set in, this is end of subroutine
6C-A2	——	portion of memory used to store data for display
A3	72 70	return from interrupt
A5	C4	entry to interrupt
A6	22 78 22 52	save X, P and D
AA	F8 24 AF	counter for 108 DMA bursts
AD	19	increment R(9), timer
AE	F8 DO BF	load starting address for DMA
B1	91 BO	load high order DMA address
B3	9F AO	load low order DMA address
——		DMA 1 here (only once)
B5	E2 9F AO	restore DMA address
——		DMA 2, 5, 8, 11, 14, . . . 104, and 107
B8	2F AO 8F	decrement counter, restore DMA address, load counter
——		DMA 3, 6, 9, 12, 15, . . . 105, and 108
BB	32 C1 9F AO	to C1 if counted out, else restore DMA address
——		DMA 4, 7, 10, 13, 16, . . . and 106
BF	30 B6	and go back to B6
C1	80 E2	here if counted out, new DMA address and change to 4 bursts with same DMA address
——		new DMA 1 here
C3	E2 20 AO	restore DMA address
——		DMA 2 here
C6	E2 20 AO	restore DMA address
——		DMA 3 here
C9	E2 20 AO	restore DMA address
——		DMA 4 here
CC	3C C1 30 A3	back for another line or exit if done
DO-FF		the displayed locations, DO-D7 are the locations displayed with 108 identical DMA bursts and should be cleared to blank upper part of display

Diagram – Program 4



F7	BD	B7	BC	5E	87
84	A1	F4	A0	50	84
84	BD	57	A0	1C	87
84	85	14	A0	10	84
F7	BD	14	BC	1E	F4



A2	52	F7	BD	20
22	52	94	A5	20
03	D2	F7	BD	E0
02	52	A5	25	20
02	5E	94	A5	20

The above message was written and encoded on a piece of graph paper 88 squares wide and 5 squares high. Your own messages can be done in a similar way.

Program 5 – Horse Race

Four horses, represented by bars, race across the screen. The first to reach the finish line blinks to indicate the winner. The idea is to bet on the outcome.

This program uses the interrupt routine which displays 64 store locations divided into 128 squares (see program 2). The squares are addressed individually in hex (00 through 7F) as they are in set 1 of program 2. Horse 1 lights squares 10 through 1F, horse 2 lights 30 through 3F, horse 3 lights 50 - 5F, and horse 4 lights squares 70 - 7F. The current position of each horse is held in registers A through D and each horse's position is incremented randomly to produce a fair race. To run the program simply switch to run; the horses appear at the starting gate and then race across the screen.

Registers 1, 2, 3, 4, 5, 6, and 7 must be set if this program is to be run in an expanded memory system.

Use of Registers

	High	Low
R(0)		DMA address
R(1)		interrupt address
R(2)		stack
R(3)		program counter
R(4)		memory pointer and work
R(5)		address of delay subroutine
R(6)		address of display subroutine
R(7)		points to table of winning positions
R(8)	used to generate random number	used to generate random number
R(9)		counter for timer in interrupt routine
R(A)	work in display routine	position of horse 1
R(B)		position of horse 2
R(C)	holds counter for interrupt routine	position of horse 3
R(D)		position of horse 4
R(E)		used to hold variable instruction
R(F)	work in interrupt	work in interrupt

Program Listing

Add.	Code	Notes
00	F8 93 A1	interrupt address
03	F8 BE A2	stack address
06	F8 09 A3	assign program counter
09	D3	program counter now R(3)
OA	F8 6C A5	address of delay subroutine
OD	F8 77 A6	address of display subroutine
10	F8 04 BC	counter for interrupt routine
13	F8 BF A4	clear the display locations
16	F8 00 54	
19	14 84	
1B	3A 16 24	
1E	E2 69	R(2) is X, turn on TV
20	F8 10 AA D6	set horses at the starting gate
24	F8 30 AB D6	and call the display routine to
28	F8 50 AC D6	show them
2C	F8 70 AD D6	
30	D5	call delay routine
31	F8 62 A7	point R(7) is address of 1st entry of table of winning positions
34	F8 1A AE	load R(E).0 with instruction 1A
37	88 F6 A4	this code together with in-
3A	E4 98 A4	structions 8C through 90 gen-
3D	B8 F6 A4	erates a random byte in D
40	98 F4	
42	E7	make R(7) the X register
43	FA 01	is random no. odd or even?
45	32 59	if even go to 59 do not increment horses position, if odd go on
47	D5	call delay routine
48	8E 53 XX	location 4A becomes 1A, 1B, 1C, or 1D and increments a horses position
4B	8E FC 70	change instruction to 8A, 8B, 8C, or 8D
4E	53 XX	location 4F becomes 8A, 8B, 8C, or 8D and loads a horses position
50	F3	check to see if horse has won by x'or against table of winning positions
51	32 66	if it has won go to 66 and blink
53	8E FC 70	else load horses position to D
56	53 XX D6	and call display routine
59	8E FB 1D	is instruction 1D?

```
5C   32 31         yes–go to 31 to start over
5E   1E 17 30 37   no–increment R(E) and R(7)
                   and go back to generate
                   another random number
62   1F 3F 5F 7F   table of winning positions
66   07 D6 D5      comes here when horse has
69   30 66         won and blinks by calling de-
                   lay and display
6B   D3            return from delay subroutine,
6C   F8 00 A9      R(9) is incremented in the
6F   89 FB 08      interrupt routine
72   3A 6F
74   30 6B
76   D3            return from display routine,
                   this display routine works
                   like program 2, the square
                   identifier is passed to the sub-
                   routine in D
77   BA F6         enter subroutine, save D in
                   R(A).1 and shift right
79   FC BF A4      add starting address of dis-
                   played locations, save in R(4)
7C   9A F6         bring back passed byte, shift
7E   3B 86         to 86 if passed byte even
80   04 FB OF 54   byte odd, load x'or against
                   OF and restore
84   30 76         return from subroutine
86   04 FB FO 54   byte even, load, x'or against
                   FO and restore
8A   30 76         return from subroutine, end
                   of subroutine
8C   18 98         part of interrupt routine, here
8E   FF 01 B8      just before returning, add 1
                   to R(8).0 and subtract 1 from
                   R(8).1 as part of random
                   number generator
91   72 70         return from interrupt
93   C4            entry to interrupt–this inter-
94   22 78 22 52   rupt routine is very similar to
98   9C AF         that given in program 2 but is
9A   F8 BF BF      located in a different position
9D   91 BO         in memory
9F   9F AO 19
A2   30 A7 9F AO
A6   2F AO 8F
A9   32 AF 9F AO
AD   30 A4
AF   9F AO
B1   AO 9C 34 8C
B5   AF 80 BF
B8   30 A7         end of interrupt routine
```

BA-BB	unused
BC-BD	stack
BF-FE	displayed locations

Program 6 – Pattern Generator

Program 6, like program 5, uses the 64 byte interrupt routine to display 8 rows of 16 squares. The area is divided into 4 quarters and used to generate patterns (see diagram).

An additive shift byte is used together with the identification numbers of up to 15 points in the upper left quarter of the display area. The logical exclusive or operation is carried out with each point and the display field and also with 3 related points in the 3 other quarters. The relationship between the points is such that the dotted lines in the diagram are "mirrors". After all of the entered points are exclusively ored the additive shift is applied to each point and the process repeats indefinitely.

To run the program put the additive shift in the switch byte and turn to run, the shift byte will be stored and displayed. Then enter the points to be displayed. Terminate entry with EE (entry is otherwise automatically terminated when 15 points have been entered) and pattern generation begins. It is suggested that a trial run be made with 11 as the shift byte and 00, 01, 12, 23, and EE as the data points.

Registers 1, 2, 3, 4, 5, 6, and 7 must be set if this program is to be run in an expanded memory system.

Note: .The following changes will generate a pattern in which the points in the upper left quarter are exactly repeated in the other 3 quarters. Change memory location 65 to F4 and the table entries at locations 80 through 83 to 00, 08, 40 and 48.

Use of Registers

	High	Low
R(0)		DMA address
R(1)		interrupt address
R(2)		stack
R(3)		program counter
R(4)		memory pointer to display locations
R(5)		address of display subroutine
R(6)		points to locations of entered points
R(7)		points to a table of 4 constants
R(8)		counter

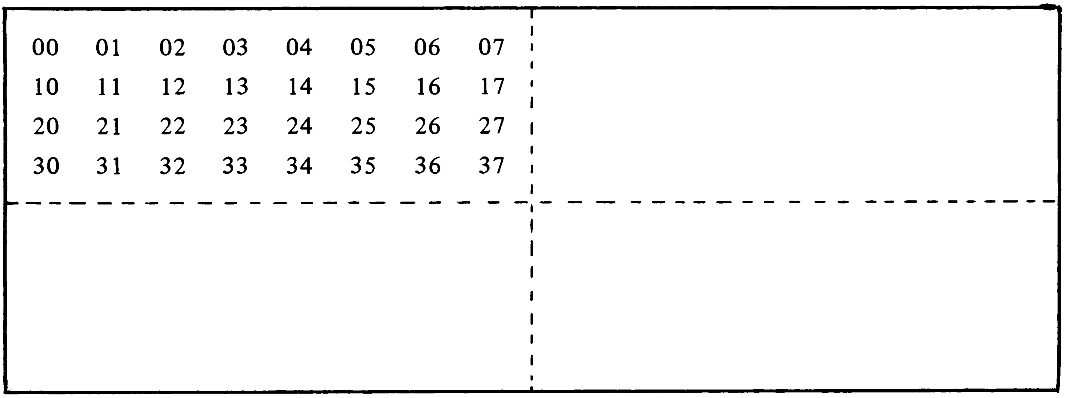
R(9)		counter for timer in interrupt routine
R(B)	work for display subroutine	counter—4 bytes displayed at a time
R(C)	holds counter for interrupt routine	
R(D)		holds shift byte
R(E)		counter, number of bytes entered
R(F)	work in interrupt	work in interrupt

Program Listing

Add.	Code	Notes
00	F8 86 A1	interrupt address
03	F8 AF A2	stack
06	F8 09 A3 D3	program counter
OA	F8 04 BC	constant for interrupt routine
OD	F8 5D A5	address of display routine
10	F8 B0 A6	starting address of table of entered points
13	F8 BF A4	starting address of displayed locations
16	F8 00 AE	clear display locations and leave R(E).0 equal to 00, R(E).0 will later contain number of points entered
19	54 14 84	
1C	3A 16	
1E	24	
1F	E2 69	R(X) is 2, turn on TV
21	6C 64 22	read and display shift byte
24	AD	save shift byte in R(D).0
25	3F 25 37 27	wait for in on, off
29	6C 64 22	read and display entered point
2C	FB EE	check, is it EE?
2E	32 3B	yes—all points entered, go to 3B
30	F0 56	no—save in table of entered points
32	16 1E	and increment table pointer and counter for number of points
34	8E FB 0F	check counter, 15 points entered?
37	32 3B	yes—table full, go to 3B
39	30 25	no—go back for more
——		all points entered, code from 3B through 5A controls display while code from 5B through 83 is display subroutine
3B	F8 B0 A6	reload starting address of table of entered points
3E	8E A8	load no. of points to R(8).0
40	06 FA 37	load point, and against 37 to get into upper left quarter of display
43	52 64 22	save it on stack, display it
46	F8 00 A9	brief delay between calls to subroutine
49	89 FB 20	
4C	3A 49	
4E	D5	call display subroutine, display point is passed on stack
4F	8D	get shift byte
50	E6	make pointer to table of entered bytes R(X)
51	F4 56	add shift byte to table entry and write new entry
53	E2	restore R(X) as 2
54	16 28	shift pointer to next location and decrement counter
56	88	check, done with all points?
57	3A 40	no—go and do next point
59	30 3B	yes—start over
——		start of display subroutine, this display routine works like program 2 except that that 4 squares are changed, the one passed on the stack and 3 related ones
5B	E2 D3	restore R(X) as 2 and return to main
5D	F8 04 AB	entry point, load counter to display 4 points
60	F8 80 A7	load starting address of table of four constants
63	E7	make table pointer R(X)
64	02 F3 BB	load saved point and x'or against one of the table entries
67	F6	shift result right
68	FC BF A4	add starting address of displayed locations and save in R(4)
6B	9B F6	get result back, shift
6D	3B 75	result even—go to 75
6F	04 FB 0F 54	result odd—x'or location against 0F and replace
73	30 79	go to 79

75	04 FB F0 54	result even–x'or location against F0 and replace
79	2B 17 8B	decrement counter, increment table pointer, examine counter
7C	3A 64	not done–go to 64
7E	30 5B	done–return from subroutine
80	00 0F 70 7F	table of constants, end of display subroutine
84	72 70	return from interrupt
86	C4	entry to interrupt–this interrupt routine is very similar to the one used in program 2
87	22 78 22 52	
8B	9C AF	
8D	F8 BF BF	and program 5
90	91 B0	
92	9F A0 19	
95	30 9A 9F A0	
99	2F A0 8F	
9C	32 A2 9F A0	
A0	30 97	
A2	9F A0	
A4	A0 9C 34 84	
A8	AF 80 BF	
AB	30 9A	end of interrupt routine
AD-AF		stack
BO-BE		entered bytes
BF-BE		displayed locations

Diagram – Program 6



00	01	02	03	04	05	06	07
10	11	12	13	14	15	16	17
20	21	22	23	24	25	26	27
30	31	32	33	34	35	36	37

Program 7 – Stop Watch

This stop watch program displays hours, minutes, and seconds and uses the interrupt routine of program 4. A character table is used to generate the numbers. The operation of the program is simple; R(9) is incremented 61 times a second in the interrupt routine, and this count is propagated through registers A through E to generate seconds, minutes, and hours. Whenever the contents of registers A through E are changed a display routine is called to indicate the new time. Both the timing routine and the display routine make use of variable code and one should read the section on variable code if one has difficulty following the program. Note that with the interrupt routine of program 4 the time is displayed in the last five lines of the display while the top 27/32 of the display is blanked.

On entry to the program the time is reset to zero (however the display is not cleared) and on pushing the in button the timer is started, a second push of the in button stops it, and a third push starts it again from where it left off. To reset the stop watch turn the run switch off and then on again. The maximum time that can be shown is 9 hours, 59 minutes, and 59 seconds.

Registers 1, 2, 3, 4, 5, and 6 must be set if this program is to be run in an expanded memory system.

Use of Registers

	High	Low
R(0)		DMA address
R(1)		interrupt address
R(2)		stack
R(3)		program counter
R(4)		memory pointer
R(5)		memory pointer
R(6)		memory pointer, also used to store variable instruction
R(7)		holds variable instruction
R(8)		counter in display routine
R(9)		counts 61 times a second, incremented in interrupt routine
R(A)		seconds counter, units
R(B)		seconds counter, tens
R(C)		minute counter, units
R(D)		minute counter, tens
R(E)		hours counter, units
R(F)	work in interrupt	work in interrupt

Program Listing

Add.	Code	Notes
00	F8 7E A1	interrupt address
03	F8 49 A2	stack
06	F8 09 A3	program counter
09	D3 E2	establish program counter, X register
0B	F8 00 AE AD	clear registers for hours,
0F	AC AB AA	minutes and seconds
12	69	turn on TV
13	37 13	wait for in off–comes here from 21
15	3F 15 37 17	wait for in on, off
19	F8 00 A9	set interrupt counter to 0
1C	30 4F	go to display routine–note display routine always returns to 1E
1E	89 FB 3D	here we look for 61 interrupt cycles
21	37 13	or did someone push the in button
23	3A 1E A9	to 1E unless 1 second has passed–else goes on first clear R(9).0
26	F8 3D A5	load address of variable code to R(5)
29	F8 4A A4	load starting address of table of 5 entries to R(4)
2C	E4	make R(4) the X register
2D	F8 1A A6	load instruction (1A) to R(6).0, first obeyed as 1A, then 1B, . . . and finally as 1E, increments registers
30	86 53 XX	carry out above instruction
33	FC 90 55	write AA to M(3D), first pass, second time write AB, . . . and finally write AE
36	FF 20 53	create and obey 8A first time, then 8B, . . . and finally 8E
39	XX	contents of one of the counting registers loaded here
3A	F3	x'or against table entry, maximum count allow in register
3B	3A 4F	if register contents are not equal to maximum go to display routine
3D	XX 86	3D becomes one of AA - AE, register which has reached maximum value is here zeroed

		out, load instruction in R(6) to see where we are
3F	FB 1E	if instruction is 1E we're done
41	32 4F	and should go to display routine
43	16 60	else change instruction, increment X to point to new table entry
45	30 30	and go back to 30 for another pass
47	XX XX XX	stack
4A	0A 06 0A	table of maximum values
4D	06 0A	allowed in the counting registers
– –		the display routine starts here, it uses a character table to show the contents of registers A through E in the display locations
4F	F8 74 A6	load starting address of table of memory locations to write to
52	F8 8F A7	load variable instruction (8F) to R(7), it will be obeyed as one of 8E, 8D, 8C, 8B, or 8A
55	87 FB 8A	check variable instruction, if it's 8A we're done and should return
58	32 1E	all done–return
5A	27	more to do–decrement variable instruction
5B	46 A4	load display location to R(4)
5D	87 53 XX	obey variable instruction, loads contents of one of the counting registers to D
60	FC A9	add the starting address of the character table
62	A5 05 A5	and pick up the address of the character to be displayed
65	F8 05 A8	establish counter, 5 words per character
68	45 54	load and write word of character
6A	28 88	decrement no. words/character
6C	32 55	to 55 for next register contents if done
6E	84	else load R(4).0
6F	FC 08 A4	and set address for next word to write

72	30 68	go and write it
74	D9 DB DC	table of 5 locations to write characters to
78	DE DF	
79	XX XX XX	unused
7C	72 70	return from interrupt
7E	C4	entry to interrupt–this interrupt routine is identical to that used in program 4 except that it is located in a different place in memory
7F	22 78 22 52	
83	F8 24 AF	
86	19	
87	F8 D0 BF	
8A	91 B0 9F A0	
8E	E2 9F A0	
91	2F A0 8F	
94	32 9A 9F A0	
98	30 8F	
9A	80 E2	
9C	E2 20 A0	
9F	E2 20 A0	
A2	E2 20 A0	
A5	3C 9A	
A7	30 7C	end of interrupt routine
– –		locations A9 through CF are the character table
A9	B3	starting address of 0
AA	C6	starting address of 1
AB	BB	starting address of 2
AC	B9	starting address of 3
AD	CB	starting address of 4
AE	B7	starting address of 5
AF	BD	starting address of 6
B0	C5	starting address of 7
B1	BF	starting address of 8
B2	C1	starting address of 9
B3	F0	character 0, (5 words/character
B4	90	
B5	90	
B6	90	
B7	F0	character 5
B8	80	
B9	F0	character 3
BA	10	
BB	F0	character 2
BC	10	
BD	F0	character 6
BE	80	
BF	F0	character 8
C0	90	
C1	F0	character 9
C2	90	
C3	F0	
C4	10	
C5	F0	character 7
C6	10	character 1

C7	10	
C8	10	
C9	10	
CA	10	
CB	A0	character 4
CC	A0	
CD	F0	
CE	20	
CF	20	
--		display locations are DO through FF, XX means doesn't matter, other locations must be set to give legible display

Add.	Code							
D0	00	00	00	00	00	00	00	00
D8	00	XX	00	XX	XX	00	XX	XX
E0	00	XX	20	XX	XX	20	XX	XX
E8	00	XX	00	XX	XX	00	XX	XX
F0	00	XX	20	XX	XX	20	XX	XX
F8	00	XX	00	XX	XX	00	XX	XX

Note: It is probably easiest to clear memory before loading this program; then set locations E2, E5, F2 and F5 to 20.

Program 8—Twelve Hour Clock

This clock program is similar to the stop watch program but displays a settable twelve hour clock instead of a stop watch. It was not possible to use the interrupt routine of program 4 and a one page interrupt is used instead. Register 9 is incremented within the interrupt routine to act as the timer. The count in register 9 is propagated through registers A to F to generate seconds, minutes and hours.

The clock is a 12 hour one and changes from 12:59:59 to 01:00:00 at 1:00 AM and 1:00 PM. To set the clock each digit is set individually. For example say we wish to set the time 12:03:48. First turn to run, then:
set tens digit of hours (01) to switch byte, push in,
set units digit of hours (02) to switch byte, push in,
set tens digit of minutes (00) to switch byte, push in,
set units digit of minutes (03) to switch byte, push in,
set tens digit of seconds (04) to switch byte, push in,
set units digit of seconds (08) to switch byte, push in,
and finally to start clock,
set 00 on switch byte, push in.

Registers 1, 2, 3, 4, 5, and 6 must be set if this program is to be run in an expanded memory system.

Use of Registers

Register use is the same as in program 7 except that register F is used as the tens of hours counter and is not employed in the interrupt routine.

Program Listing

Add.	Code	Notes
00	F8 8D A1	interrupt
03	F8 4D A2	stack
06	F8 09 A3	program counter
09	D3 E2	establish program counter, X register
0B	F8 1A A4	address of location whose contents will be variable code
0E	F8 AF A5	variable instruction to R(5).0 first time will be AF
11	85 54	write instruction to 1A, first time AF
13	3F 13 37 15	wait for in on, off
17	6C 64 22	read and display switch byte
1A	XX	variable instruction, saves switch byte in a register to set clock, first AF, then AE, etc. and finally A9
1B	85 FB A9	check is instruction A9
1E	32 23	yes—go to 23 and start clock
20	25 30 11	no—change variable instruction and go back to read another switch byte.
23	69	ready to start clock—turn on TV
24	89 FB 3D	get timer from interrupt— is it 61
27	3A 24	no—go and check again
29	A9	yes—reset interrupt timer and go on
- -		This portion of code—2A through 53 is almost identical to that of program 7 (26 through 4E) it propagates the second count through the registers
2A	F8 41 A5	load address of variable code to R(5)
2D	F8 4E A4	load starting address of table of 6 entries to R(4)
30	E4	make R(4) the X register
31	F8 1A A6	load instruction (1A) to R(6).0 first obeyed as 1A, then 1B, and finally 1F, increments counting registers
34	86 53 XX	carry out above instruction
37	FC 90 55	write AA to location 41, first pass, then AB, . . . and finally write AF
3A	FF 20 53	create and obey 8A first time then 8B, . . . and finally 8F
3D	XX	8A through 8F obeyed here, loads one of counting registers to D
3E	F3	x'or aginst table entry, maximum count allowed in register
3F	3A 54	if register contents are not equal to maximum go to check hours and then to display routine
41	XX 86	41 becomes one of AA—AF, register which has reached maximum value is here zeroed out, load instruction in R(6) to see where we are
43	FB 1F	if instruction is 1F we're done
45	32 54	and go to check hours and then to display routine

47	16 60	else change instruction, increment X to point to new table entry
49	30 34	and go back to 34 for another pass
4B	XX XX XX	stack
4E	0A 06 0A	table of maximum values al-
51	06 0A 0A	lowed in the counting registers
- -		comes here to check hours, following code resets 13:00:00 to 01:00:00, else does nothing
54	8F F6	load hours counter, tens, shift right
56	3B 60	to display if DF is zero, else go on
58	8E FB 03	loads hours counter, units, is it 3?
5B	3A 60	if not go to display
5D	AF AE 1E	if R(E).0 is 3 reset hours to 01
- -		this display routine is almost identical to the one in program 7, it returns to location 24
60	F8 85 A6	entry point, load starting address of table of memory locations to write to
63	F8 90 A7	load variable instruction (90) to R(7), it be obeyed as one of 8F, 8E, 8D, 8C, 8B, or 8A
66	87 FB 8A	check variable instruction, if it's 8A we're done and should return
69	32 24	all done–return
6B	27	more to do–decrement variable instruction
6C	46 A4	load display location to R(4)
6E	87 53 XX	obey variable instruction, loads contents of one of the counting registers to D
71	FC A9	add the starting address of the character table
73	A5 05 A5	and pick up the address of the character to be displayed
76	F8 05 A8	establish counter, 5 words per character
79	45 54	load and write word of character
7B	28 88	decrement no. words/character
7D	32 66	to 66 for next register contents if done
7F	84	else load R(4).0
80	FC 08 A4	and set address for next word to write
83	30 79	go and write it
85	D8 D9 DB	table of 6 locations to write
88	DC DE DF	characters to
- -		end of display routine–begin one page interrupt
8B	72 70	return from interrupt
8D	C4	entry to interrupt
8E	22 78 22 52	save X, P and D
92	E2 E2 19	increment R(9)
95	91 B0	load high order DMA address
97	F8 00 A0	load low order DMA address
9A	80 E2	DMA address to D
- -		DMA 1, here
9C	E2 20 A0	restore DMA address
- -		DMA 2, here
9F	E2 20 A0	restore DMA address
- -		DMA 3, here
A2	E2 20 A0	restore DMA address
- -		DMA 4, here
A5	3C 9A	not done, back to set new DMA address
A7	30 8B	done, return
A9-FF		The character table and display locations are the same as for program 7.