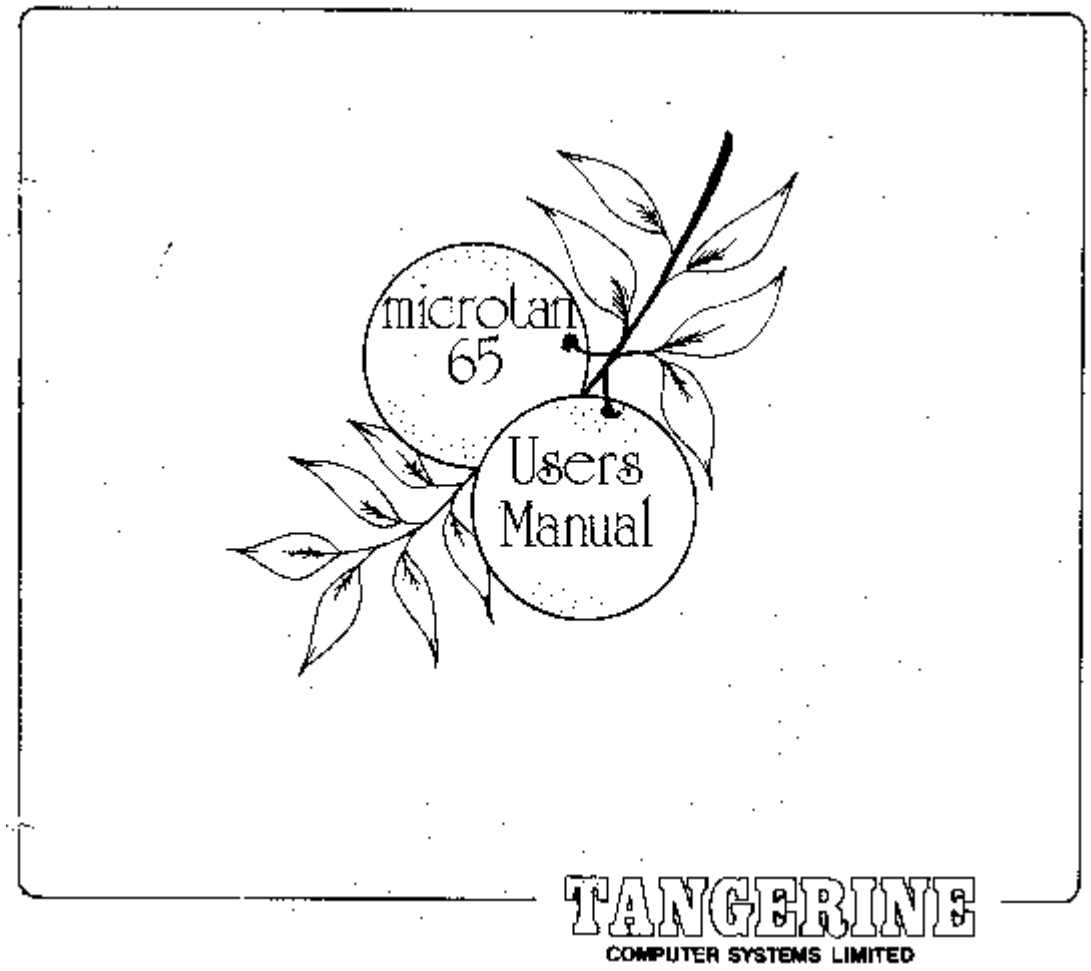
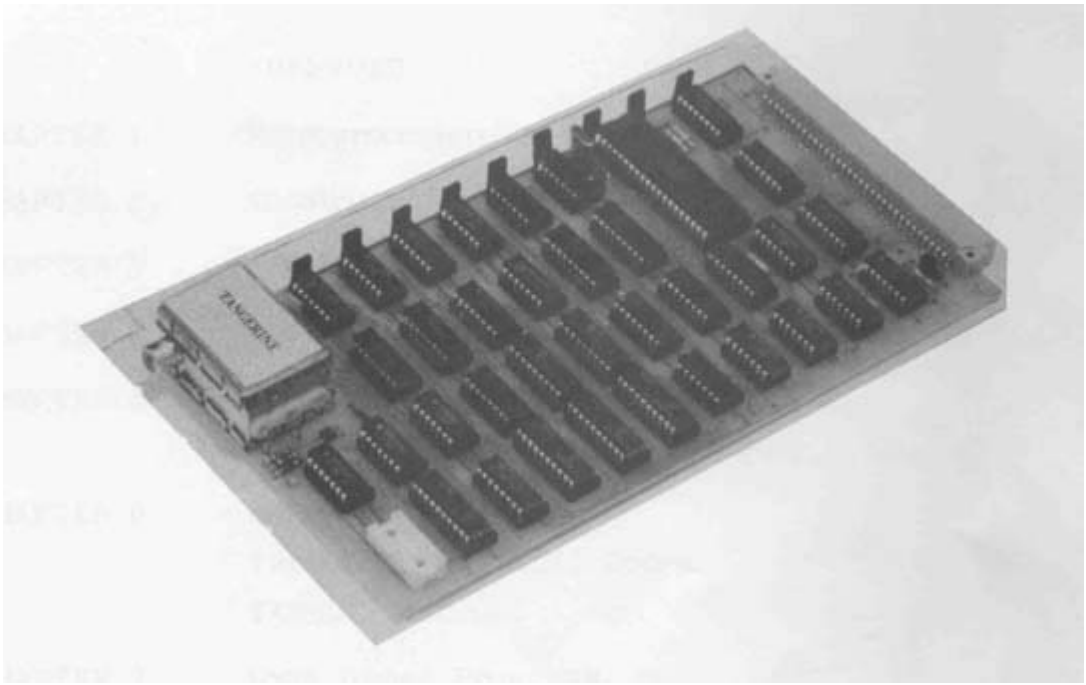


FOREWORD

Unlike most other microcomputers, microtan 65 has been designed from the start with a small system in mind, therefore expansion of microtan 65 is a concept, not an after thought. We hope that this manual will be the first of many, as each Tangerine product is supplied with thorough and useful documentation, an absolute necessity with anything related to computers. The first chapter of this manual provides an introduction to microprocessors and the binary number system, it is by no means complete as this subject requires a complete book to be dedicated to it. Chapter two gives contructional notes for the kit version but purchasers of ready built microtan 65's are still advised to read it as it contains relevant information. Chapters three and four describe the microtan 65 and the microtan system respectively. The 6502 microprocessor is described in sufficient detail in chapter five which also contains complete tables of all of the 6502 machine code instructions.

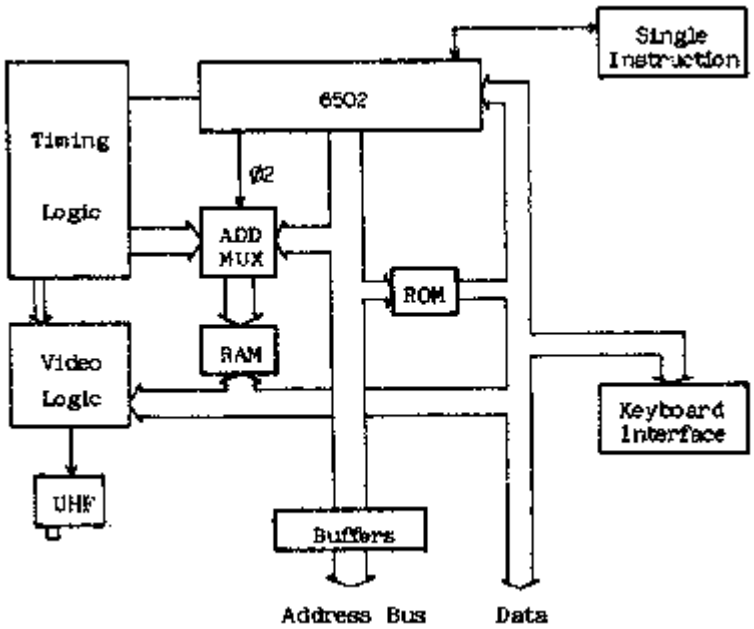
TANBUG, the most important item, is fully described in chapter six with a step by step guide and an example program to demonstrate the power of TANBUG's debugging aids. Also given in chapter six is a table of hex ASCII codes and the complete TANBUG listing. Games programs have been provided in chapter seven.



CHAPTER 3: The Microtan 65

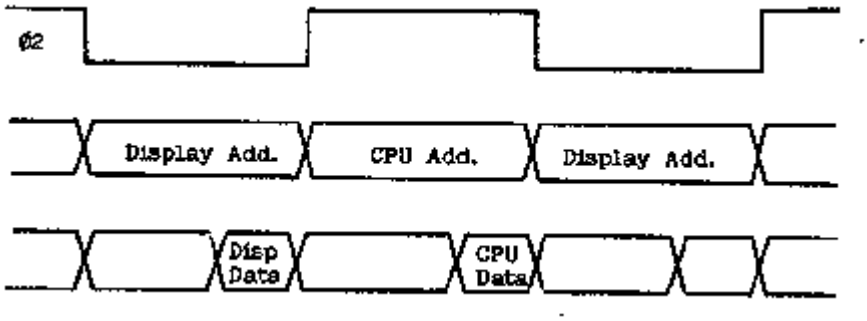
The microtan 65 is an exceptional microcomputer kit and the purpose of this section is to describe its design. It was considered that the majority of microkit users would initially benefit from a machine that was very easy to use rather than one that has parallel I/O, but was very awkward to use. Therefore microtan 65 is supplied with a VDU on-board, and because of this the ability to use an alphanumeric keyboard is an immediate asset. The 6502 microprocessor was chosen mainly for its very simple yet elegant hardware structure. Of course, as most readers will know, the 6502 also has a very powerful instruction set and addressing modes.

A fully expanded microtan 65 contains the 6502 microprocessor, 1K rom containing TANBUG, 1K RAM which is used for display memory and user program, keyboard interface, VDU logic and tri-state address buffers. The basic block diagram of the microtan 65 is shown below.

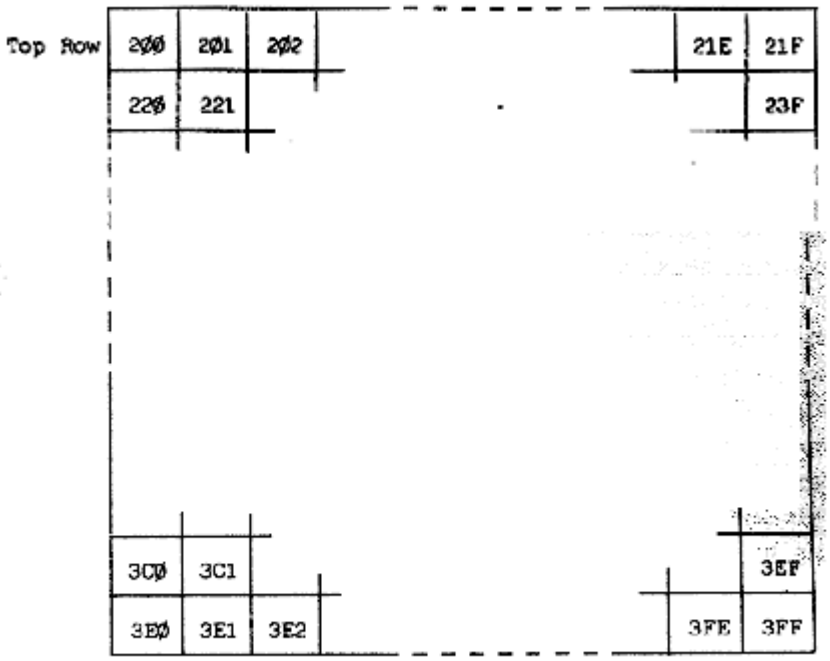


The most important aspect of the design is that the address multiplexer is switching at the processor clock rate. This can be done with the 6502 as memory accesses will only occur on one phase of the clock i.e. when 02 is high. WHen 02 is low the memory is not selected. During this time the VDU logic reads the display memory, one location at a time and decodes memory contents as alphanumeric or graphics characters. You will also notice when

using microtan 65 that the display is free from annoying speckles, spots and flashes. This is because there is no conflict of access to display memory between processor and display refresh logic. In fact you can run a program that actually resides in display memory and it will run at full speed without upsetting the display ! The address and data bus timing is shown below to illustrate this.



Memory mapped display: Pages 2 and 3 of the address space (see chapter on the 6502) are used as the display memory, that is from hex location 200 to hex 3FF. Location 200 is the top left hand corner character position. Location 201 is the second character position in the top row and so on. The diagram below illustrates this more clearly.



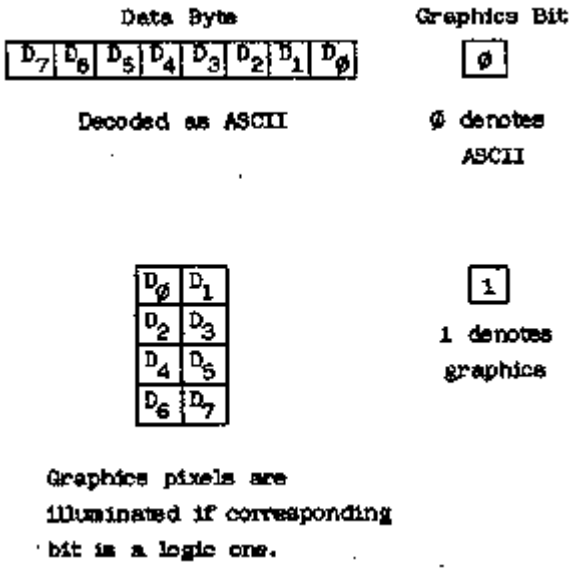
To write a particular character into a character cell in the display the user must write the ASCII code, or whatever, for that character in the correct memory location. For example, if it was required to write the character "W" in the bottom row third column then the ASCII code 57 (for W) should be placed in memory loaction 3E2. If you use TANBUG's memory modify command M to load characters into the display remember that the display scrolls automatically and the character may be output onto a different row than intended.

Memory mapping of the microtan 65 is controlled on-board by three wire links, when used without the TANEX exapansion board. As there is only 1K RAM, 1K ROM and 6 I/O locations on the microtan 65 each of the three are allowed to repeat through defined areas of the 64K address space to simplify design. The address map is represented diagramatically below.

As can be seen the address space is divided into only three blocks and therefore only two bits of the address bus are necessary to control this map. The two bits used for memory mapping are the most significant address bits A15 and A14. Three links are used to wire in this address map on the microtan 65. When TANEX is used however, all memory mapping is controlled on the TANEX board and not on the microtan 65. To modify the microtan 65 it is only necessary to cut these three links.

RAM and ROM hardware is of really no consequence to the user but a knowledge of the on-board I/O ports is useful. There are six peripheral ports used on the microtan 65 cpu board and these control graphics on and off, keyboard read and write, keyboard interrupt flag clear and delayed non-maskable interrupt (used for single instruction and breakpoints). Each one of these will be taken in turn:

a) Graphics on and off: The display refresh controller reads the display memory a byte at a time and interprets the bottom seven bits of each byte to be an ASCII coded character. There is however a ninth bit which can only be written to by the cpu. This ninth bit comes from the 2102 1K x 1 bit RAM chip in the graphics option. If at a certain display location the ninth bit, or graphics bit, is a logic one the data byte read is not decoded as an ASCII character but is instead used to build up a graphics block of 2 x 4 pixels, in the character cell position.



The graphics on and graphics off I/O ports control an R-S flip-flop, the output of which is the data input to the 2102 RAM chip. Therefore if the graphics flip-flop is in the on position each character written to the display memory will be decoded as a graphics character. Because the cpu cannot read the graphics bit directly it is not possible to scroll displays containing graphics. As displays containing graphics are rarely scrolled anyway this should not prove to be too much of a handicap.

The operations required to write graphics characters to the display is to firstly turn the graphics on by executing the assembly code instruction LDA BFF0. Each character then written to display will be a graphics character until graphics are turned off by executing the assembly code instruction STA BFF3.

b) Keyboard read, write and interrupt clear: There is both an input and output port on the keyboard socket. The output port is used only for strobing the 20 key keypad. This output port is used by executing the assembly code instruction STA BFF2. The input port is used for both types of keyboard. When using the alphanumeric keyboard the strobe from the keyboard is used to clock a flip-flop (the keyboard interrupt flip-flop). The output of this flip-flop is the keyboard interrupt flag and forms the eight input bit to the keyboard input port. If interrupts are enabled in the cpu then an interrupt will be generated by the keyboard strobe. Reading the keayboard input port will then allow the cpu to test whether or not the interrupt was generated by the keyboard or some other device. If interrupts are not enabled then the keyboard interrupt flag will still be set but will not generate an interrupt. It is possible to read the flag by reading the keyboard interrupt port, thus a strobe from an alphanumeric keyboard can be detected either by an interrupt or by software polling. Which ever technique is used though it

will be necessary to reset the keyboard interrupt flag after is has been set and detected in order that is its ready to register a further keyboard strobe. To reset the keyboard interrupt flag the assembly instruction STA BFF0 should be executed. The keyboard port is read by the instruction LDA BFF3.

c) Delayed non-maskable interrupt: This facility is used by the monitor program TANBUG when executing single instructions and breakpoints. It should not be used in a used program. Users who will contemplate using the non-maskable interrupt in special applications will probably not be using TANBUG. In these cases the link LKNMI should be broken and the non-maskable interrupt may be driven via the board connector.

CHAPTER 6 : TANBUG

The TANBUG monitor program is located in 1K bytes of read only memory (ROM) at the top of the address space i.e. pages 252-255. It contains facilities to enter, modify, run and debug programs. This chapter of the manual gives full details of the command facilities and subroutines available to the user.

TANBUG will only operate in the memory map of the microtan system, it is not a general purpose 6502 software and has been specifically written for microtan. Locations F7F7, F7F8 and F7F9 are reserved for a jump to an expansion monitor ROM which is positioned on the expansion board, more about this later.
Locations 200-3FF i.e. pages 2 and 3 are the visual display memory -TANBUG writes to these locations whenever a command is typed to the monitor. Locations 100-1FF i.e. page 1, are used as the stack by the microprocessor. Since the stack is of the push down variety it follows that the whole of the page will not be used as stack storage in the majority of programs. TANBUG requires to use locations 1F0-1FF as stack storage (only 16 locations). The rest of this area is free for user programs. Locations 40-FF are also available as user RAM, the preceeding locations 0-3F being reserved for use by TANBUG. User programs which do not use the stack may therefore be loaded anywhere i.e. the area 40-1EF. For user programs which do use the stack, the user must calculate how many stack locations are required and reduce the upper limit accordingly.

TANBUG conatins coding to automatically identify whether the keypad or full ASCII keyboard is connected to the keyboard socket. This coding is executed every time a reset is issued, and thereafter a sequence of code particular to the keyboard type in use is executed. Reset must therefore always be issued after changing the keyboard type.

When using an ASCII encoded alphanumeric keyboard monitor commands are typed in as shown in this chapter. There is however, no reset key on an ASCII keyboard, one must be fitted as shown in the chapter describing assembly of the microtan kit. TANBUG drives this type of keyboard in the interrupt mode.

The keypad is used somewhat differently, its layout being shown below.

SHIFT	DEL LF	SP CR	RST
M C	G D	S E	N F
P 8	ESC 9	B A	L B
 4	0 5	C 6	R 7
 0	 1	 2	, 3

TANBUG interrogates the keypad for a depressed key, then translates the matrix encoded signal into an ASCII character which it puts up on the visual display just as if the equivalent key were depressed on an ASCII encoded keyboard. Because of the limited number of keys it has been necessary to incorporate a shift function on the keypad. So, to obtain the character P for example, the user presses and releases SHIFT, then depresses and releases P. The

SHIFT key contains a self cancelling facility - if the user presses SHIFT twice in succession the pending shift operation is cancelled. So as an example, using the two keys SHIFT and 8 the operations SHIFT P yields P on the display. SHIFT SHIFT P yields 8 on the display. Other special purpose keys on the keypad are RST, which issues a reset to the microtan, and DEL which deletes the last character typed. Repeated deletes erase characters back to the beginning of the line.

From now on in this chapter the microtan will be treated as having one type of keyboard only, since all functions required can be derived by depressing the appropriate key or keys on whatever is used - keyboard or keypad.

Having described some of the background to TANBUG it is now possible to describe the commands and syntax of TANBUG i.e. how to use it. An example is shown later on. All numerical values of address, data and monitor command arguments are in hexadecimal. The symbol <CR> means on depression of the carriage return key, <SP> the space key or bar, <ESC> the escape key (ALT on some keyboards) and <LF> line feed. In all examples, text to be typed by the user will be underlined, while TANBUG responses will not. ▮ indicates the cursor. <ADDR> means a hexadecimal address, <ARG> means hexadecimal data and <TERM> means one of terminators <CR>, <SP>, <ESC> or <LF>.

All commands are of the form

<COMMAND><TERM>
or <COMMAND><ARG><TERM>
or <COMMAND><ARG>, <ARG><TERM>
or <COMMAND><ARG>, <ARG>, <ARG><TERM>

where <COMMAND> is one of the mnemonic commands and <ARG> is a hexadecimal argument applicable to the command being used. The required argument is defined for each command. It should be noted at an early stage that the longest argument will contain 4 hexadecimal characters. If more are typed all but the last 4 are ignored. As an example consider the memory modify command M12340078 <CR>. In this case location 0078 will be modified or examined as all but the last 4 characters are ignored.

<TERM> is one of the terminating characters <CR>, <SP>, <LF> or <ESC>. In fact TANBUG accepts any of the "control" characters (HEX code 0-20) as terminator. TANBUG will reply with a ? if an illegal command is encountered.

Starting the monitor TANBUG:

Press the RST key on the keypad or the reset key or button connected to the microtan. TANBUG will scroll the display and respond with

TANBUG
▮

Note that on initial power up the top part of the display will be filled with spurious characters. These will disappear as new commands are entered and the display scrolls up. On subsequent resets the previous operations remain displayed to facilitate debugging.

Memory modify/examine command M:

The M command allows the user to enter and modify programs by changing the RAM locations to the desired values. The command also allows the user to inspect ROM locations, modify registers etc. To open a location type the following

M <ADDR><TERM>

TANBUG then replies with the current contents of that location. For example to examine the contents of RAM location 100 type M100<CR>
TANBUG then responds on the display with

M100,0E,▮

assuming the current contents of the location were 0E.

There are now several options open to the user. If any terminator is typed the location is closed and not altered and the cursor moves to the next line scrolling up the display by one row. If however, a value is typed followed by one of the terminators <CR>, <LF> or <ESC> the location is modified and then closed. For example using <CR>

```
M100,0E,FF
```

location 100 will now contain FF. If however <SP> is typed, the location is re-opened and unmodified.

```
M100,0E,FF
M0100,0E,
```

This facility is useful if an erroneous value has been typed. The terminators <LF> and <ESC> modify the current location being examined, then opens the next and previous locations respectively
i.e. using <LF>

```
M100,0E,FF
M0101,AB,
```

and using <ESC>

```
M100,0E,FF
M00FF,56,
```

Using <LF> makes for very easy program entry, it only being necessary to type the initial address of the program followed by its data and <LF>, the responding to the cursor prompt for subsequent data words.

NOTE that locations 1FE and 1FF should not be modified. These are the stack locations which contain the monitor return addresses. If they are corrupted TANBUG will almost certainly "crash" and it will be necessary to issue a reset in order to recover.

List command L:

The list command allows the user to list out sections of memory onto the display. It is possible to display the contents of a maximum of one hundred and twenty consecutive memory locations simultaneously. To list a series of location type

```
L <ADDR>, <NUMBER><TERM>
```

where <ADDR> is the address of the first location to be printed and <NUMBER> is the number of lines of eight consecutive locations to be printed. TANBUG pauses briefly between each line to allow the user to scan them. For example, to list the first 16 locations of TANBUG (which resides at FC00-FFFF) type LFC00,2<CR>.
The display will then be

```
LFC00,2
FC00  A2  FF  9A  E8  86  17  20  B7
FC08  FF  8D  F3  BF  A2 0E  BD DF
```

If zero line are requested (i.e. <NUMBER> = 0) then 256 lines will be given.

Go command G:

Having entered a program using the M command and verified it using the L command the user can use the G command to start running his own program. The command is of the format G <ADDR><TERM>. For example, to start a program whose first instruction is at location 100 type G100<CR>. When the user program is started the cursor disappears. On a return to the monitor it re-appears.

The G command automatically sets up two of the microprocessors internal registers

a) The program counter (PC) is set to the start address given in the G command
b) The stack pointer (SP) is set to location 1FF.

The contents of the other four internal registers, namely the status word (PSW), index X (IX), index Y (IY) and accumulator (A), are taken from the monitor pseudo registers (described next). Thus the user can either set up the pseudo registers before typing the G command, or use instructions within his/her program to manipulate them directly.

Register modify/examine command R:

Locations 15 to 1B within the RAM reserved for TANBUG are the user pseudo registers. The user can set these locations prior to issuing a G command. The values are then transferred to the micro-processors internal registers immediately before the user program is started. The pseudo register locations are also used by the monitor to save the user internal register values when a breakpoint is encountered. These values are then transferred back into the microprocessor when a P command is issued, so that to all intents and purposes the user program appears to be uninterrupted.

The R command allows the user to modify these registers in conjunction with the M command. To modify/examine registers type R<CR> and the following display will appear (location 15 containing 00 say)

```
R
M0015,00,
```

Now proceed as for the M command.

Naturally the M command could be used to modify/examine location 15 without using the R command - the R command merely saving the user the need to remember and type in the start location of the pseudo registers. Pseudo registers locations are as follows.

Location	Function
15	Low order byte of program counter (PCL)
16	High order byte of program counter (PCH)
17	Processor status word (PSW)
18	Stack pointer (SP)
19	Index X (IX)
1A	Index Y (IY)
1B	Accumulator (A)

Two typical instances of the use of the R command are:-

a) Setting up PSW, IX, IY and A before starting a user program.
b) Modifying registers after a breakpoint but before proceeding with program execution (executing the P command) for debugging purposes.

Note that when modifying registers in case (b) care must be taken if PCL, PCH or SP are modified, since the proceed command P uses these to determine the address of the next instructions to be executed (PCL, PCH) and the user stack pointer (SP).

Single instruction mode S:

Single instruction mode is a very powerful debugging aid. When set TANBUG executes the user program one instruction at a time, re-entering the monitor between each instruction and printing out the status of all of the microprocessor's internal registers as they were after the last instruction executed in the user program. The S command is used in conjunction with the proceed command P and the normal mode command N. Examples are given in the description of the P command.

Normal mode command N:

The N command is the complement of the S command and is used to cancel the S command so that the microprocessor executes the user program in the normal manner without returning to the monitor between each instruction. Reset automatically sets the normal mode of operation.

Proceed command P:

The P command is used to instruct TANBUG to execute the next instruction in the user program when in single instruction mode. Pseudo register contents are transferred into the microprocessors internal registers and the next instruction in the users program is executed. The monitor is then re-entered. P may also be used with an argument thus P <NUMBER><CR> where NUMBER is less than or equal to FF. In this case the program executes the specified number of instructions before returning to the monitor.

Each time the monitor is re-entered after execution of an instruction or instructions, the status of the microprocessor internal registers as they were in the user program are printed across the screen in the following order:

Address of next instruction to be executed.
Processor status word.
Stack pointer.
Index register X.
Index register Y.
Accumulator.

Note that these are in the same order as the pseudo registers described earlier.

Whenever the user program is entered, the cursor is removed from the display. Whenever the monitor is entered, the cursor returns to the display as a user prompt. While in the monitor between user instructions, any monitor command can be typed. A program must always be started by the G command, then P used if in single instruction mode. A P command used before a G command is issued is likely to cause a program "crash" and should not be attempted.

As an example consider the simple program which repeatedly adds 1 to the accumulator.

Address	Data	Mnemonic	Comment
100	69	ADC #1	add 1 to acc
101	01		
102	4C	JMP 100	
103	00		
104	01		

Set the single instruction mode and start the program. The user may wish to initially set the accumulator to 00 by using the M command.

```
S
G100
0102  20 FF  00 00 01
```

TANBUG then responds with the characters shown above.

0102 is the address of the next instruction to be executed.
20 is the processor status word value.
FF is the low byt value of the stack pointer. The high byte is always set to 1, the stack is therefore pointing at location 1FF.
00 is the value of the index X register.
00 is the value of the index Y register.

01 is the value of the accumulator. It is a 1 as 1 has been added to the accumulator and it is assumed that the user cleared the accumulator before starting the program.

Since the cursor has re-appeared, TANBUG is ready for any monitor command. For example, registers or memory locations can be modified, or the program may be re-started from scratch by typing G100<CR> again. If the user wishes to continue then type P<CR>. The resulting display is

```
S
G100
0102  20 FF  00 00 01
P
0100  20 FF  00 00 01
```

Since the instruction at location 102 was "Jump to 100", the status print out shows that this has indeed occurred. Registers, since they were not modified by any program instruction, remain unchanged. To proceed further type P<CR> again.

```
S
G100
0102  20 FF  00 00 01
P
0100  20 FF  00 00 01
P
0102  20 FF  00 00 02
```

The add instruction has been executed again, so the accumulator has incremented by 1 to become 2. Now typing P4 <CR> gives a display.

```
S
G100
0102  20 FF  00 00 01
P
0100  20 FF  00 00 01
P
0102  20 FF  00 00 02
P4
0102  20 FF  00 00 04
```

TANBUG allowed execution of 4 instructions before again returning to the monitor. The 4 instructions were 2 add instructions and 2 jump instructions thus giving the accumulator the value 4.

By typing N<CR> then P<CR> removes the single instruction mode and causes the program to proceed. It now does not return to the monitor but continues to race around this small program loop continually adding and jumping back. There is no way to exit from this trivial program except by a microprocessor reset or, if using an alphanumeric keyboard, by typing ESC.

It can be seen that the S and P commands are particularly useful when tracing a program which contains instructions that transfer program control e.g. jumps, branches and subroutines, since these commands allow the user to interrogate the order of execution of his/her program.

Breakpoint command B:

A breakpoint is a complementary debugging aid to single instruction mode. Instead of stepping singly through all instructions in a program, the breakpoint facility allows the user to specify the address at which he requires the monitor to be re-entered from his/her program. As an example, consider a long program in which a fault is suspected to exist near the end. It would be very tedious and time consuming to single step through the program to

the problem area. A breakpoint can be set just previous to where the fault is suspected to exist and the program started with the G command. Normal execution occurs until the breakpoint is reached, then the monitor is re-entered with the same status print-out as for single instruction mode. Any monitor commands can then be used and the program continued.

The format of the breakpoint command is

B <ADDR>, <NUMBER> <CR>

where <ADDR> is the address of any instruction OPCODE (but not argument), <NUMBER> is any number from 0-7 defining one of 8 breakpoints. B <CR> removes all breakpoints. As an example consider the following program

```
100 E8       LOOP: INX
101 C8             INY
102 C9 01          ADC #1
104 4C 00 01       JMP LOOP
```

Firstly set index X, index Y and the accumulator to 00 using the R command. To set breakpoint 0 at the jump instruction and start the program type B104,0<CR>. The display will then be

```
B104,0
G100
0104  20  FF  01  01  01
```

The jump instruction was reached and the breakpoint re-directed control back to TANBUG. If it were required, single instruction mode could be set for further debugging. However, assume that we wish to execute the loop again by typing P<CR>.

```
B104,0
G100
0104  20  FF  01  01  01
P
0104  20  FF  02  02  02
```

The proceed command P has gone once through the breakpoint and then re-entered the monitor. If P<NUMBER> <CR> was typed it would have proceeded through the breakpoint <NUMBER> times.

Up to 8 breakpoints can be set at 8 different locations. The B <CR> command removes all breakpoints. A single breakpoint can be removed by setting its address to 0. For example, imagine a breakpoint is set as follows; B102,2, and it is subsequently wished to remove it but leave any others unaltered; type B0,2<CR> to remove it.

Caution. The breakpoint system works by replacing the users instruction with a special instruction (BRK) whose opcode is 00. Replacement is carried out when G or P is typed. On return to the monitor the original opcode is replaced. It is therefore possible to corrupt the user program under some circumstances. The following points should therefore be observed:

a) Breakpoints must only be set at the opcode part of a user instruction and nowhere else.
b) If the user program utilises the BRK instruction as part of the user code, then the user must have his own special interrupt routine and cannot use breakpoints.
c) If breakpoints are set in the user program and a reset is issued while the microprocessor is executing the user program rather than the monitor, the breakpoints are lost and those locations at which breakpoints were set in the user program will be corrupted. These locations must be re-entered using the M command before restarting the user program.
d) Setting more than one breakpoint at the same address causes the user program to be corrupted.
e) To use breakpoints, the user must not have modified the interrupt link, i.e. the interrupt code within

TANBUG must be executed.

The status of breakpoints may be inspected by using the M command to examine the breakpoint status table. This is located in RAM locations 20-2F and are as follows:

Address	Contents
20	PCL B0
21	PCH B0
22	PCL B1
23	PCH B1
24	PCL B2
25	PCH B2
26	PCL B3
27	PCH B3
28	PCL B4
29	PCH B4
2A	PCL B5
2B	PCH B5
2C	PCL B6
2D	PCH B6
2E	PCL B7
2F	PCH B7

For example, typing M20<CR> followed by <LF> gives

```
M20,00,
M0021,01,
```

This indicates that breakpoint 0 is set to location 100 by taking the contents of location 20 as PCL and of location 21 as PCH. If the breakpoint is set at location 0 then this particular breakpoint is disabled.

Offset command O:

The offset command O is a program writing aid. It calculates branch offsets for the user for incorporation as arguments in branch instructions. Consider the example:-

```
100 E8  LOOP: INX
101 C8        INY
102 69        ADC #1
103 01        .
              .
              .
120 D0        BNE LOOP
121           (branch argument)
```

To calculate the number to enter into location 121 is quite tedious without a facility such as the O command. It is used with the following format.

O <ADDR. OF BRANCH OPCODE><ADDR. OF DEST.><CR>

and in this case it would be necessary to type O120,100<CR>. The display would be

O120,100 = DE

DE is the number that should be entered into location 121 such that if the BNE instruction is true the program counter will jump to the label LOOP.

Note that the maximum branch range is 7F forwards and backwards. If the range is exceeded a ? is displayed.

Copy command C:

The copy command allows copying of the contents of one block of memory to another. Its format is

C <START ADDR. SOURCE><END ADDR. SOURCE><START ADDR. DEST>

Suppose it is required to copy the block of data in locations FC00-FD00 into a block starting at location 200. This may be achieved by typing CFC00,FD00,200<CR>. The display will be

CFC00,FD00,200

As 200 is the starting address of the display memory the user will notice that the top half of the screen has been over written with all sorts of weird and wonderful characters. What this example has done is to take the first 256 bytes of TANBUG and copy them into the top half of the display. The display then scrolled having the top 7 rows filled with these characters.

Breakpoints and the ESC key

If an alphanumeric keyboard is being used, depression of the ESC key (ALT on some keyboards) will cause a re-entry into the monitor from the user program. This is possible because the alphanumeric keyboard is interrupt driven. For example, if the trivial program

```
100 69  LOOP: ADC #1
101 01
102 4C        JMP LOOP
103 00
104 01
```

has been started by typing the G command the program continues to loop around continuously with no exit path to the monitor, except by issuing a reset. Instead of a reset the user can press the ESC key, TANBUG responding thus

0100 20 FF 01 01 01

Using the ESC key has caused a breakpoint to be executed and the monitor invoked. The register print-out above is only typical, the value of each beaing that when the ESC was depressed. Any monitor command may now be typed, for example P causes the user program to proceed once again.

The ESC facility is most useful in debugging where the user program gets into an unforseen loop where breakpoints have not been set. It enables the user to rejoin the monitor withour using reset and losing the breakpoints that have been set.

Notes:

a) The ESC facility is only implemented on interrupt driven keyboard i.e. alphanumeric ASCII keyboards, and is not implemented on the keypad.
b) Interrupts must be enabled for the ESC facility to operate. TANBUG enables interrupts when entering a user program, therefore do not disable interrupts if the ESC facility is required.

c) The user must not have modified the interrupt jump link. TANBUG's interrupt code must be executed.

USER SUBROUTINES

(I haven't typed this part, but instead OCR'ed it, so there are some glitches....)

Certain input/output subroutines are available to the user. Since these rely on a standard display format, this will be described first, followed by the user subroutine descriptions.

Display format

TANBUG uses the bottom line of the display for all text operations. Initially the cursor is at the left hand edge of the screen, and moves gradually to the right as a line is filled. When either a carriage return is output, or the bottom line overflows, the display is scrolled (all lines shift up one row) and the bottom line becomes available for more output. Therefore the cursor always remains on the bottom line. However, there is no reason why users should restrict themselves to this mode of operation unless they intend to use TANBUG's subroutines to control the display in their own programs. It should be noted that the display memory is read/ write memory and may be used as a character buffer prior to processing thus saving RAM locations for a user program.

Subroutine POLLKB

Subroutine POLLKB is used to interrogate the keyboard for a typed key. (Appropriate software for the type of keyboard in use is automatically set-up by TANBUG when a reset is issued). On exit from the subroutine the RAM location labelled ICHAR (address W01) contains the ASCII code of the character typed, whether it is typed on the keypad or on an alphanumeric keyboard. When using the alphanumeric keyboard, interrupts must be in the enabled state. As an example consider the user code

```
1)  C LI          enable interrupts
2)  JSR  POLLKB   poll the keyboard
3)  LDA  ICHAR    load acc. with character
```

The sequence of operations here are

1) Enable interrupts so that alphanumeric keyboard may be interrogated.
2) The program loops around within the POLLKB sub-routine until a key is pressed.
3) The program exits from POLLKB with the -ASCII code for the key pressed in the location label-led ICHAR. The accumulator is loaded with this value.

Notes: Address of subroutine POLLKB is FDFA. Address of ICHAR is W01. The registers IX, IY and A are corrupted, therefore the user must save and restore their values if necessary.

Subroutine OUTPCR

This subroutine causes the display to scroll up one line by out-putting a carriage return to it. It also reinstates the cursor, which is switched off when a user program is started. This sub-routine should be called in a user program prior to any display input or output to clear the bottom line.

Notes: Address of subroutine OUTPCR is FE73. Registers IX and IY are unaffected. Register A is corrupted and must be saved if re quire d.

Subroutine OPCHR

This subroutine is called to output a character held in the accumulator, to the display. The cursor, obliterated on a user program start, is re-instated. As an example, consider the code

```
LDA#30
JSR OPCHR
LDA#31
JSR OPCHR
```

6-17

Since 30 is the ASCII code for the character "Oll and 31 is the ASCII code for the character 11111, the result (assuming this is the first call to this subroutine) on the botbom line of the display is

Oil

Repetitive calls of OPCHR will fill the bottom line of the display with the appropriate characters. When the end of the line is reached, OPCHR scrous the display up one line and then writes characters in the newly vacatbd bottom line and so on.
Notes: Address of subroutine OPCHR is FE75. Registers IX and IY are unaltered. Register A is corrupted and must be saved if re quire d.

Subroutine HEXPNT

Subroutine HEXPNT takes a binary value from the accumulator and outputs it as two hexadecimal characters on the display. Consider the code

```
PHA             save A on stack
JSR OUTPCR      scroll display
PLA             recover A
JSR HEXPNT      output A in hex
JSR OUTPCR      scrol 1 display
```

This code will display the contents of the accumulator as two hex characters. For example if the accumulator contained the value 2C the resulting display would be

2C

Notes: Address of subroutine HEXPNT is FFOB. Register IY is unaltered. Registers IX and A are corrupted and must be saved if re quire d.

Subroutine HEXPCK

This subroutine reads hex characters from the bottom line of the display and packs them up into two eight bit binary values,

enabling a sixteen bit word to be assembled. It is useful for incorporation into programs which require numerical keyboard input.

Usually POLLKB is used in conjunction with OPCHR to enter data to the display, then HEXPCK called when a carriage return is encountered. The following user code could be used to do this

```
          JSR   OUTPCR        scrol 1 display
NXTCHR:   JSR   POLLKB        wait for chwacte r
          LDA   ICHAR         put it in A
          CMP#  $0D           carriage return ?
          EE Q  GOPACK        yes, p ack it
          JSR   OPCHR         else store in display
          JM P  NXTCHR        get next character
1) GOPACK: LDY# 00            set IY to first char.
2)         JSR  HEXPCK        pack it
3)
```

In this example the subroutine is used in the following way:

1) Set IY with the character position at which packing is to start. The left most location of the bottom line corresponds to setting IY tc) 0. The next location corresponds to IY equal to 1 etc.
2) Call HEXPCK. Characters are packed until a character other that 0-9 or A-F is encountered; an exit then occurs.
3) Continue into the user code where the values of HXPKL and HXPKH will be read.

For example, packing 1 CR gives HXPKL = 1 and HXPKH = 0. Packing FEDC CR gives HXPKL = DC and HXPKH = FE. Packing FEDCBA CR gives HXPKL = BA and HXPKH = DC, i.e. if more than four hexadecimal characters in succession are encountered then the last four are packed. Additionally, two flags in the processor status word (PSW) are used to indicate exit conditions. The zero flag Z is clear if the terminating character is the cursor (ASCII code FF), set otherwise. The overflow flag V is set if there w as one or more hex characters, clear if the first character encountered by the subroutine was not a hexadecimal character.
Notes: Address of subroutine HEXPCK is FF28. Address of HXPKL is

is 0013 and HXPKH is 0014. Registers IX, IY and A are all corrupted and must be saved if necessary.

INTERRUPTS

TANBUG uses both the maskable and non-maskable interrupts. How-ever, means have been provided tc) access the interrupts via both hardware and software. Of necessity user interrupts may, in some cases, place restrictions on certain monitor commands.

The maskable interrupt

When TANBUG is initialised by a reset, certain RAM locations are set up to link through the interrupts for monitor use. These locations are labelled INTFS1, INTFS2, INTFS3 and INTSL1. When a maskable interrupt occurs, the following sequence of events is obeyed (assuming the RAM locations mentioned above have not been modified).

a) The program jumps to INTFS1 in RAM.
b) The locations INTFS1, INTFS2 and INTFS3 contain

the instruction JMP KBINT. The program therefore jumps to KBINT which resides in the monitor ROM.

c The monitor software looks to see what caused the interrupt. If a BRK instruction, then the break-point code is executed. If a keyboard interrupt, location ICHAR is updated with the new ASCII character which is read from the keyboard I/O port.

d) If the interrupt is caused by anything other than a BRK instruction then the monitor jumps to location INTSL1.

e) Normally INTSLL contains an RTI instruction - the program would then return to where it was interrupted.

It can therefore be seen that the user can implement his/her own interrupt service routines in two ways.

1) A fast interrupt response by modifying the locations INTFS1, INTFS2 and- INTFS3 to jump to the user interrupt service code. In this case bre ak-points and the ESC command cannot be used unless the u--er program jumps back to the monitor service

routine after executing its own code.

2) A slower interrupt response by modifying INTSL1, INTSL2 and INTSL3 to jump to user service routine, after executing the monitor service routine. The RAM locations INTSL1, INTSL2 and INTSL3 would be modified to contain the instruction JMP USER. This method places no restrictions on monitor commands.

A number of things should be noted when using interrupts:

a) An RTI instruction must always occur at the end of user code to return the program to the point at which it was interrupted, unless the user code jumps back to the monitor service routine.

b) If a reset it issued, the INTFS and INTSL locations are set back to their monitor values by TANBUG, and the user has to reset them.

c) If any microprocessor internal registers are used in the user interrupt service routine, they must be saved before modification and restored before the RTI instruction, i.e. on return to the monitor the registers IX, IY and A must contain the same values as they had on entry to the user routines.

d) The interrupt jump locations should be modified by instructions in the user program at run time and not by the use of the M command. This is because TANBUG softwar\-- uses keyboard interrupts. If using an alternative link at INTFS1, no break-points c an be set.

e Addresses of RAM locations are; INTFS1 = OW4, INTFS2 = OW5, INTFS3 = ON6, INTSLI 0010, INTSL2 = 0011, INTSL3 = 0012.

The non-maskable interrupt

The non-maskable interrupt vector is accessed in the same way as explained for the maskable interrupt. The user can obtain access

by modifying locations NMIJP, NMIJPL and NMIJP2. Note that single instruction mode will be inoperative and that breakpoints will be destructive, i.e. they are destroyed when they have been executed once and replaced with the original code. Addresses of RAM locations are; NMIJP = OW7, NMIJPL and NMIJP2 = W09.

ERROR LINKING

It will be noted that TANBUG displays a question mark whenever an illegal command is typed. In order to allow future expansion of the monitor, an error link to memory external to the monitor ROM's is incorporated.

When an error occurs the following sequence of events is initiated:

a) The program jumps to F7F7.
b) With no expansion board (TANEX) present the address F7F7 (outside TANBUG space) is decoded as address FFF7 (inside TANBUG space).
c) A question mark is printed.

With TANEX present, a special link is incorporated to return the program to the monitor. The user may remove this link and insert an EPROM in the position which includes the address F7F7 containing the code JMP USERCODE at address F7F7, where USERCODE may contain software to deal with any extra commands the user wishes to add to the monitor. Note that this facility will be used by future TANGERINE software.

There are two methods of returning to the monitor from external code:

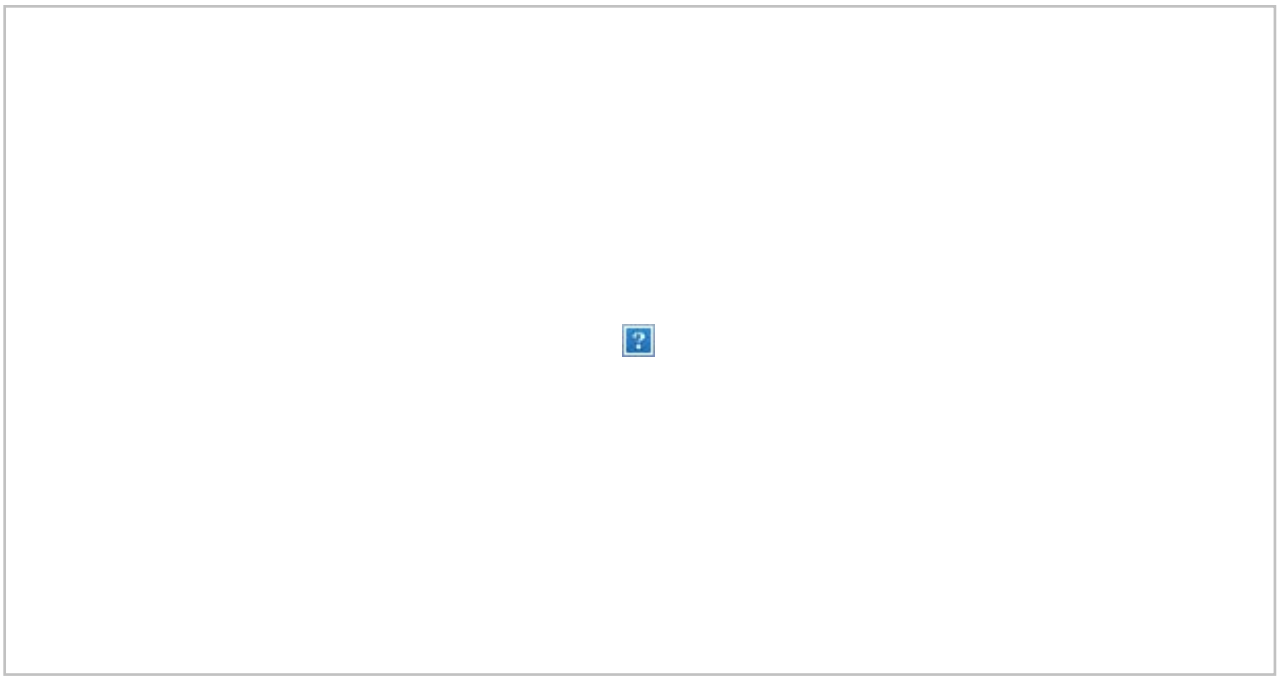
1) The instruction RTS at the end of the user code returns to the monitor, gives a carriage return then continues looking for commands.
2) The instruction JMP FFF7 returns tc) the monitor, giving a question mark on the display.

EXAMPLE OF TANBUG's USE

The following, simple example program clears the screen by calling OUTPCR F times, then slowly fill the screen with asterisks. It is used as an example to demonstrate the use of some of TANBUG's commands. Deliberate errors are later writben into the program to demonstrate TANBUG's fault finding capabilities.

The first step in writing a program is to produce a flowchart of program execution. The second step is to write the program in assembly language code using the instruction mnemonics. The third step is to look up and write the op-codes and arguments for each instruction. At this stage the branch code arguments will be left blank and TANBUG's 0 command used.

The flowchart and program listing now follows.



Example program listing

```
0050   00   00       VDUIND: 0                  ; display index
 0052   AO   OF         START:    LDY# F          ;set Y index
 0054   20   73 FE     SCRAG:    JSR   OUTPCR    ;carriage return
 0057   88                       DEY             ;do E times
 0058   10   (arg 1)             BPL   SCRAG
 005A   A9   20                   LDA#  20        ;load A ascii space
 005C   8D   EO   03              STA   3EO       ;obliterate cursor
 005F , A9   00                   LDA#  0         ;set display index
 0061   85   50                   STA   VDUIND
 0063   A9   02                   LDA#  2
 0065   85   51                   STA   VDUIND+L
 0067   AO   00             CONT: LDY#  0         ;clear Y index
 0069   A9   2A                   LDA#  2A        ;set ascii
 006B   91   50                   STA  (VDUIND),y
 006D   A2   OF                   LDX# F          ; delay loop
 006F   AO   FF                   LDY#  FF
 0071   88              DECIT:    DEY
 0072   DO   (arg 2)             BNE   DECIT
 0074   CA                       DEX
 0075   DO   (arg 3)             BNE   DECIT
 0077   18                       CLC             ;inc display index
 0078   E6   50                   INC   VDUIND
 007A   Do   (arg 4)             BNE   NOMSB
 007C   E6   51                   INC   VDUIND+L
 007E   A5   51          NOMSB:   LDA   VDUIND+L ;top of display?
 0080   C9   03                   CMP#  3
 0082   Do   (arg 5)             BNE   CONT      ; no - continue
 0084   A5   50                   LDA   VDUIND
 0086   C9   FF                   CMP#  FF
 0088   DO   (arg 6)             BNE   CONT      ; double prec. cmp.
 008A   00                       BRK             ;return to monitor
```

Program entry is performed using the M command. For the time being set the branch arguments (arg I - arg 6) to 00, these c an be altered when calculated, using the 0 command.

Once the program is entered the branch offsets are calculated. The first is arg 1 which has an opcode address of 0058 and branches to the label SCRAG at location 0054. By typing 058,54<CR> TANBUG print3 out the value of arg 1 as FA. This may now be placed in location 0059 using the M command. By repeating the exercise for the other five arguments it will be found that location 0073 should contain FD, 0076 should contain FA, 007B should contain 02, 0083 should contain E3 and 0089 should contain DD.

The program will now run if it has been entered correctly. To start the program type G52<CR> since the first instruction of the program is at location 0052. When the screen is full of asterisks the program exits to the monitor. Alternatively, if an alphanumeric keyboard is being used, depression of the ESC key causes an exit to the monitor. If the program does not run correctly then it may be necessary to issue a reset in order to regain control. The program can be listed by typing L50,8<CR> yielding a display of

```
L50,8
0050  00  00  AO  OF  20  73  FE  88
0058  10  FA  A9  20  8D  EO  03  A9
0060  00  85  50  A9  02  85  51  AO
0068  00  A9  2A  91  50  A2  OF  AO
0070  FF  88  DO  FD  CA  DO  FA  18
0078  E6  50  DO  02  E6  51  A5  51
0080  C9  03  DO  E3  A5  50  C9  FF
0088  DO  DD  00  XX  XX  XX  XX  XX
I
```

providing the program has been correctly entered (XX indicates any value as these locations are not part of the program). If the program failed to run carefully check the listing from the L command with the program listing and correct any errors with the M command.

Having got the program working it is now possible to introduce a deliberate error to demonstrate the use of breakpoints and the single instruction mode. The error to be introduced is to put the wron value for the branch argument on the first occurrence of the

instruction BNE DECIT; instead of location 73 containing FD change it to F B. Now the register IY will never be zero and the program will loop here. If the program is started now only one asterisk will be printed and then nothing else will happen. Debugging steps are as follows:

a) Regain control to the monitor by issuing a reset.
b) The first part of the program is being executed correctly as the display scrolls. Furthermore, it is at least getting to location 6B because an asterisk is printed. It would be very tedious to single instruction this far from the beginning because the OUTPCR routine is called sixteen times. Therefore set a breakpoint at location 6D by typing B6D,O<CR>.
c) Start the program again by typing G52<CR>. The

display scrolls and the status message
006f 31 F F OF 00 2 A
0 D

is displayed. Control is now back in the monitor.

d) Set single instruction mode by typing S<CR>.

e) Repeatedly typing P<CR> causes single instructions to be executed followed by a status print-out. The following sequence of instructions will be, observed.
006F 21 FF OF 00 2A
0071 Al FF OF FF 2A
0072 Al FF OF FE 2A
006F Al FF OF FE 2A
Now if the code were correct the program could not go back to location 6F. In fact, since IY is shown to be FE, the program should have jumped back to location 71. The branch instruction is probably at fault, therefore examine it and its argument using the M command.
M72, Do,
M0073,FB,m
The value in location 73 should be FD, therefore change it by typing FD<CR>.

f) Remove single instruction mode and breakpoints by typing N<CR> then B<CR>.

g) Restart the program by typing G52<CR>. The program should now run correctly.

Note that when using an alphanumeric keyboard, debugging is slightly easier. When the program stlcks in a loop ESC can be used to return to the monitor (provided interrupts have not been disabled). Single instruction mode can then be set to determine the loop in which the program was running.

TABLE OF HEX ASCII CODES

00	NUL	
01	Control A	Home
02	Control B	
03	Control C	
04	Control D	
05	Control E	
06	Control F	
07	Control G	Bel 1
08	Control H	Backspace
09	Control I	Horizontal Tab - Cursor Right
OA	Control J	Line Fee d
OB	Control K	
oc	Control L	P age Cle ar - Form Fee d
OD	Control M	Carriage Return
OE	Control N	
OF	Control 0	
10	Control P	
11	Control Q	

12	Control	R		
13	Control	S		
14	Control	T		
15	Control	U		
16	Control	V		
17	Control	W		
18	Control	X		
19	Control	Y		
1A	Control	Z	Vertic al Tab	Cursor Up
1B	Si			
ic	S2			
1D	S3			
1E	S4			
1F	S5			

Note that the codes 00 - 1F produce special symbols when used in display memory.

TABLE OF HEX ASCII CODES (CONTINUED)

20	Space	40	@	60	
21		41	A	61	a
22		42	B	62	b
23	f- or	43	c	63	c
24	$	44	D	64	d
25	%	45	E	65	e
26	&	46	F	66	f
27		47	G	67	9
28		48	H	68	h
29		49	I	69	i
2A		4A	i	6A	
2B		4B	K	6B	k
2C		4C	L	6C	1
2D		4D	m	6D	m
2E		4E	N	6E	n
2F		4F	0	6F	0
30	0	50	p	70	p
31	1	51	Q	71	q
32	2	52	R	72	r
33	3	53	s	73	s
34	4	54	T	74	t
35	5	55	u	75	u
36	6	56	v	76	v
37	7	57	w	77	w
38	8	58	x	78	x
39	9	59	y	79	y
3A		5A	z	7A	z
3B		5B		7B	
3C	<	5C		7C	
3D		5D		7D	
3E	>	5E	A	7E	
3F	?	5F		7F	or Rubout

TANBUG LISTING

```
Om                  NULL: 00                    ;reserved for bpt use
Owl                ICHAR:   00                  ; asci-i character
ON2                OCHAR:   00                  ;temp char store
W03               VDUIND:   00                  ; display index
OW4               INTFS1:   00                  ;fast int link
OW5               INTFS2:   00
                  INTFS3:   00
OW7                NMIJP:   00                  ;nmi link
OW8               NMIJP1:   00
W09               NMIJP2:   00
OMA                ICURS:   00                  ;cursor index
OMB               ICURSH:   00                  ;cursor index high
moc               RUNIND:   00                  ; zero if in user
OND               SINGLE:   00                  ; nonzero if sing int3
OOOE              PROCED:   00                  ; proceed count
OMF               SIMCOM:   00                  ;simple/complex  kb
0010              INTSL1:   00                  ; slow int i nk
0011              INTSL2:   00
0012              INTSL3:   00
0013               HXPKL:   00                  ;hexpack low byte
0014               HXPKH:   00
0015              PCLBCK:   00                  ;pseudo reg PCL
0016              PCHBCK:   00                  PCH
0017              PSWBCK:   00                  ; PSW
0018               SPBCK:   00                  ;SP
0019                 XBCK:  00                  ;IX
001A                 YBCK:  00                  ;IY
001B                 ABCK:  00                  ; A
ooic              MODADL:   00                  ;temp store
001D              MODADH:   00
001E                 COPL:  00                  ; copy store
001F                 COPH:  00
0020               BPTLO:   00                  ; bpt status table
0021                        00
0022                        00
0023               BPTHL:   00
```



```
0024                    00
0025                    00
0026                    00
0027                    00
0028                    00
0029                    00
002A                    00
002B                    00
002 C                   00
002D                    00
002E                    00
002 F                   00
```

```
0030              BPTCOD:   00                    bpt code store
0031                        00
0032                        00
0033                        00
0034                        00
0035                        00
0036                        00
0037                        00
0038                        00
0039                        00
003A                        00
003B                        00
003C                        00
003D                        00
003E                        00
003F                        00
0100              STKBSE:   00                    ;stack base address
0200              VDUSTT:   00                    ;display scroll labels
0220              VDUFST:   00
0300              VDUMID:   00
0320              VDUTOP:   00
03EO              LINBOT:   00
BFFO              SGRAPH:   00                    ;I/O ports
                  KBINCL:   00                    ;alt. tc) SGRAPH
BFF1                  SNMI: 00
BFF2              KBWRIT:   00
BFF3              KBREAD:   00
                     STEXT: 00                    ;alt. to KBREAD
F7 lF7            INPERR:   00                    ;error exit link

                       ;start of main program       init. sequence
                       ;program starts here on a reset

   FCOO A2FF            START: LDX #FF                 ;set stack pointer
   FC02 9A                     TXS                     ;to top of the stack
   F C03 EN,                   INX                     ;enable interrupts in
   FC04 8617                   STX  PSWBCK              user prog on a go

                       ;clear breakpoint store as their values will be
                       ;indeterminate on power up.

   FC06 2OB7FF                 JSR BPTCLR              ;clear breakpoints.
   FC09 8DF3BF                 STA STEXT               ;set text mode.

                       now use   table to initiate parameters
                       ;note order of table must correspond with the
                       ;order of INTFS1 to ICURSH in ram definitions.

   FCOC    A20E                LDX #E                  ;set index.
   FCOE    BDDFFF      SETUPL: LDA SETUPX              ; get value.
   FC11    9504                STA INTFS1, X           ; store in ram.
   FC13    CA                  DEX
   FC14    10FO                BPL  SETUP1             ; do till all done
                       ;
                       ; determine keyboard type and set flag
                       ; note IX=FF.
                       ;
   FC16 EO                     INX
   FC17    8E90FO        TSFIV: STX KBWRIT             ;clear kb write latch.
   FCLA    8DFOBF              STA  KBINCL             ;clear kbint. flag.
```

```
FCLD    CA                  DEX
FCLE    8EF2BF              STX  KBWRIT          ; write to kb lines.
FC21    EO                  INX                 ;reset IX.
FC22    ADF3BF              LDA  KBREAD         ;read it back.
FC25    1002                BPL  KPCPLX         ;if plus not set-alpha.
FC27    E60F                INC  SIMCOM         ;if set then keypad.
FC29    8DFOBF      KPCPLX: STA  KBINCL         ;clear kbint.
FC2C    BDECFF         TBMS: LDA  HDR, X        ; print TANBUG.
FC2F    F006                BEQ  MONTOR
FC31    2075FE              JSR  OPCHR          ;o/p chars until a 0.
FC34    E8                  INX

FC35 DOF5                   BNE TBMS
                    ;
                    ; monitor  at present part of main program.
                    ;
FC37    D8          MONTOR: CLD                 ;set binary mode.
FC38    58                  CLI
FC39    20FAEO              JS R POLLKB         ; look at kb.
FC3C    A501                LDA ICHAR           ;get char.
FC3E    C921                CMP #21             ;LT or EQ space-term.
FC40    3006                BMI  MONCH1         ;else o/p char.
FC42    2075FE      ISTERM: JSR  OPCHR
FC45    4C37FC              JM P MONTOR
FC48    204FFC      M ONCHL: JSR  M ONEN2       ;call string process.
FC4B    A90D             RCl: LDA #D            ;set up CR.
FC4D    DOF3                BNE  ISTERM         ;uncond. branch loop.
FC4F    Aooo        M ONEN2: LDY  #0            ; set IY to zero.
FC51    B10A                LDA  (ICURS), Y     ;pick up command.
FC53    AA                  TAX                 ; store in X.
FC54    Co                  INY                 ; pee k at ne xt c h ar.
FC55    B10A                LDA  (ICURS), Y     ;get it in A.
FC57    1036                BPL  MULTI          ;if -ve was curs   or.
FC59    A900                LDA  #0             ;else set A to zero.
FC5B    E053          TRYS: CPX  #53            ; was it S?
FC5D    D003                BNE  TRYM           ; yes-set GT 0 else skip.
FC5F    860D                STX  SINGLE
FC61    60                  RTS
FC62    E04E          TRYN: CPX  #4E            ; was it N?
FC64    D003                BNE  TRYP           ; no-try P.
FC66    850D                STA  SINGLE         ;else clr single mode.
FC68    60                  RTS
FC69    E050          TRYP: CPX  #50            ; P with no ar g?
FC6B    D004                BNE  TRYR           ; no-try for R.
FC6D    850E                STA  PROCED         ;else clr P count.
FC6F    F056                BEQ  PROC1          ;uncond. branch proc.
FC71    E052          TRYR: CPX  #52            ;command R?
FC73    D009                BNE  TRYB           ;no-try for no bpts.
                                                ;note A=o
FC75    851D                STA  MODADH
FC77    A915                LDA  #15            ;else set pseudo reg.
FC79    851C                STA  MODADL
FC7B    4CE5FD              JMP  REOPEN         ;jmp mod memory.

    FC7E E042           TRYB: CPX #42             ;remove bpts?
    FC80 D004                 BNE ERRQ            ;no-error.
    FC82 2OB7FF               JSR BPTCLR          ;else clear.
    FC85 60                   RTS
```

```
                        ;
                        ; with no TANEX FFF7 will respond to F7F7.
                        ;with TANEX monitor can be expanded.
                        ;FFF7 jumps back to here.
                        ;
FC86 4CF7F7               ERRQ: JMP !NPERR
FC89 A93F               RETERR: LDA #3F                 ;load question mark.
FC8B 2075FE                     JSR OPCHR               ;print it.
FC8E 60                 PRERC:  RTS

                        ;if we get here command expects data too.

FC8F    88              MULTI:  DEY                     ;readjust IY.
FC90    8A                      TXA                     ;save cmd on stack.
FC91    48                      PHA
FC92    202OFF                  JSR  HEXPCK             ; pack its arg.
FC95    D054                    BNE MOREY               ; more data?
FC97    68                      PLA                     ;else is cmd G.
FC98    50EC                    BVC  ERRQ               ;error if no arg.
FC9A    C947                    CMP  #47                ;is it a G?
FC9C    D021                    BNE  TRYPL              ; no-s kip.
FC9E    A200                    LDX  #0
FCAO    860E                    STX  PROCED             ;clr proceed count.
FCA2    CA                      DEX                     ;set IX to FF.

                        ;if G stack pointer initialised
                        ;and pseudo registers loaded.

FCA3    9A              GOEND:  TXS                     ;reload it.
FCA4    A514                    LDA  HXPKH               push PC high.
FCA6    48                      PHA
FCA7                            LDA  HXPKL               push PC low.
        A513
FCA9    48                      PHA
FCAA    A517                    LDA  PSWBCK
FCAC    48                      PHA
FCAD    C60C                    DEC  RUNIND             ;cl-r run flag.
FCAF    A920                    LDA  #20                ;obliterate cursor.


FCB1   A403                  LDY VDUIND
FCB3   910A                  STA  (ICURS), Y
FCB5   A619                  LDX  XBCK
FCB7   A41A                  LDY  YBCK
FCB9   A51B          SRET:   LDA  ABCK              ; set users A.
FCBB   8DFlBF                STA  SNMI             ;set NMI for next.
FCBE   40                    RTI                   ; get to user prog.
FCBF   C950          TRYPL:  CMP  #50              ;is cmd P with arg?
FCC1   DOll                  BNE  TRYM             ; no-try M.
FCC3   A513                  LDA  HXPKL            ; else set P count.
FCC5   850E                  STA  PROCED
FCC7   A516          PROCL:  LDA  PCHBCK           ;restore users PC.
                     PNOARG:
FCC9   8514                  STA  HXPKH
FCCB   A515                  LDA  PCLBCK
FCCD   8513                  STA  HXPKL
FCCF   A618                  LDX  SPBCK            ;set IX tc) users SP.
FCD1   4CA3FC                JMP  GOEND            ;then back ti) user.
FCD4   C94D            TRYM: CMP  #4D              ; is it M address?
```

```
FCD6   DOAE                  BNE  ERRQ            ; no-error popping S.
FCD8   A92C          EQPT:   LDA  #2C
FCDA   2075FE                JSR  OPCHR
FCDD   AWO                   LDY #0              ; pick up value
FCDF   B113                  LDA (HXPKL), Y
FCE1   20OBFF                JSR  HEXPNT         ;and print it.
FCE4   68                    PLA                 ; pop stack return.
FCE5   68                    PLA
FCE6   A92C                  LDA  #2C            ;load comma.
FCE8   4C42FC                JMP  ISTERM         ;back to monitor.
FCEB   E02C          MOREY:  CPX  #2C            ;was term a comma?
FCED   F004                  BEQ  GETPT2         ;yes-continue.
FCEF   68            LINKPH: PLA                 ;else pull command
FCFO   4C86FC        LINKR:  JMP  ERRQ           ;and give error.
FCF3   A513          GETPT2: LDA  HXPKL          ; no-stc)re previous
FCF5   851C                  STA  MODADL         ;in MODADL&MODADH.
FCF7   A514                  LDA  HXPKH
FCF9   851D                  STA  MODADH
FCFB   2028FF                JSR  HEXPCK         ; p ac k ne xt v alue.
FCFE   D07C                  BNE MOREY1          ; not curs-more yet.
FDOO   68                    PLA                 ;else pull command.
FDO1   50ED                  BVC  LINKR          ; no arg? - error.

     FDO3   C94C                CMP #4C             ;is it L?
     FDO5   F042                BEQ  LISTIT         ; yes-list it.
     FDO7   C94F                CMP  #4F            ; is it offset O?
     FDO9   D027                BNE  TRYBPT         ; no-skip.
     FDOB   A513                LDA  HXPKL          ;else get branch dest.
     FDOD   38                  SEC
     FDOE   E902                SBC  #2             ;adj for branch code.
     FDlo   B002                BCS  NOTOPO
     FD12   3OA0                DEC  HXPKH
     FD14   38          NOTOPO: SEC
     FD15   E51 C               SBC  MODADL         ; subtract source.
     FD17   AA                  TAX                 ; hold result in IX.
     FD18   A514                LDA  HXPKH          ; subtract high byte.
     FDLA   E51D                SBC  MODADH
     FDLC   A8                  TAY                 ; store in I Y.
     FDLD   8A                  TXA                 ; get low byte.
     FDLE   3005                BMI  RNGNG          ; if -ve branch.
     FD20   98                  TYA                 ; if +ve look at high.
     FD21   DOCD                BNE  LINKR          ;not O-error.
     FD23   F003                BEQ  PNTITO         if ok continue.
     FD25   C8            RNGNG: INY                 if -ve high is   FF.
     FD26   DOC8                BNE  LINKR
     FD28   A93D        PNTITO: LDA  #3D            ;ok-print equals
     FD2A   2075FE              JSR  OPCHR
     FD2D   8A                  TXA
     FD2E   20OBFF              JSR  HEXPNT         ;and the value.
     FD31   60                  RTS
     FD32   C942        TRYBPT: CMP  #42            ;is it B?
     FD34   DOBA          LINK1: BNE  LINKR         ;no-error.
     FD36   2898                LDA  HXPKL          ;max bpt  code is 7.
     FD38   3OB6                BMI  LINKR
     FD3A   C908                CMP  #8             ; if greater-error.
     FD3C   1OB2                BPL  LINKR
     FD3E   OA                  ASL  A              ; double A.
     FD3F   AA                  TAX                 ;set X for mode X.
```

```
FD40   A51C                LDA  MODADL          ;store bpt address.
FD42   9520                STA  BPTLO,  X
FD44   A51D                LDA  MODADH
FD46   9521                STA  BPTH, X
FD48   60          JPRTRN: RTS
FD49   2073FE      LISTIT: JSR  OUTPCR          ;o/p carriage return.


                    NXLI:
FD4C    AOM                LDY #0              ;set IY to zero.
FD4E    A51D               LDA MODADH          ; print address.
FD50    2009FF             JSR HEXPNT
FD53    A51C               LDA MODADL
FD55    2009 F F   NXLIST: JSR HEXPNT          ;o/p low byte.
FD58    A920               LDA #20             -load a space.
FD5A    2075FO             JSR (PDCHR          ;o/p 8 mem locations.
FD5D    B11C               LDA (MODADL), Y     ;get character.
FD5F    C8                 INY
FD60    C009               CPY  #9             ; is IY GT 7?
FD62    3OF1               BMI  NXLIST         ; no-more yet.
FD64    C613               DEC  HXPKL          ;dec line count.
                ;
                ;note that requesting 0 lines   gives 256!
                ;
FD66    FOEO               BEQ JPRTRN          ;O? RTS via CR.
FD68    88          DELX1: DEY
FD69    DOFD               BNE DELXL
FD6B    CA                 DEX
FD6C    DOFA               BNE DELXL
                ;
                ;now adjust the address.
                ;
FD6E    A51C               LDA MODADL          ;get low bybe.
FD70    18                 CLC
FD71    6908               ADC  #8             ;add 8.
FD73    851C               STA  MODADL          store it.
FD75    9OD2               BCC  NXLI            more if C set.
FD77    E61D               INC  MODADH          inc high byte.
FD79    4C49FD             JMP  NXLI
                ;
                ; if we get here there  is a third parameter.'
                ;
FD7C    E02C       M OREYL: CPX #2C            ;term a comma?
FD7E    F018               BEQ  TERMOK         ;no-error..
FD80    4CEFFC     ERJUM2:  JMP  LINKPH
FD83    A513       TERMOK:  LDA  HXPKL         ;else store parameter.
FD85    851E                STA  COPL
FD87    A514                LDA  HXPKH
FD89    851F                STA  COPH           ;then pack new para.


      FD8B    2028FF              JSR HEXPCK
      FD8E    DOFO                BNE ERJUM2            ; error not term I d.
      FD90    68                  PLA                   ;is command M?
      FD91    C94D                CMP   #4D
      FD93    F027                BEQ   MEM100          ; yes-mod memory.
      FD95    C943                CMP   #43             ; is it C?
      FD97    D09B                BNE   LINK1           ;no-error.
```

```
                        ;
                        ; if copy command, start address is held in MODADL.
                        ;end address in COPL.
                        ;destination address in HXPKL.
                        ;
FD99    5099                    BVC LINK1               ;arg? error if not.
FD9B    AOM                     LDY   #0
FD9D    B11C        NXCOP:      LDA   (MODADL), Y       ;get instruction.
FD9F    9113                    STA   (HXPKL), Y        ; store it.
FDAL    A51F                    LDA   COPH              ;is it done?
FDA3    28E8                    CMP   MODADH
FDA5    D006                    BNE   ICMCOP
FDA7    A51E                    LDA   COPL
FDA9    C51C                    CMP   MODADL
FDAB    F05B                    BEQ   ENDLS
FDAD    E61C        ICMCOP:     INC   MODADL            increment source.
FDAF    D002                    BNE   NOHIH1
FDBL    E61D                    INC   MODADH
FDB3    E613        NOHIH1:     INC   HXPKL             ;increment dest.
FDB5    DOE6                    BNE   NXCOP
FDB7    E614                    INC   HXPKH
FDB9    DOE2                    BNE   HXCOP

                        ;destination can not roll over top of memory.

FDBB 60                         RTS                     ;return if end.
FDBC A601           MEM100:     LDX   ICHAR             ; get term char in IX.

FDBE    E020                    CPX   #20               ;was it a space?
FDCO    F023                    BEQ   REOPEN            ; yes-reopen.
FDC2    5006                    BVC   NOENT             ; branch if nothing.
FDC4    A513                    LDA   HXPKL             ;else enter data.
FDC6    PM                      LDY   #0
FDC8    911C                    STA   (MODADL), Y
FDCA    EOOA        NOENT:      CPX   #A                ;was LF typed?

FDCC   FOll                 BEQ WASLF           ; yes-process it.
FDCE   E018                 CPX #lB,            ; was it ES C?
FDDO   D036                 ENDLS               ;no-return.
FDD2   C61C          ESCIT: DEC MODADL          ; dec mem mod address
FDD4   A51C                 LDA  MODADL
FDD6   C9FF                 CMP  #FF
FDD8   D009                 BNE  REOPEN
FDDA   C61D                 DEC  MODADH
FDDC   4CE5FD               JMP  REOPEN
FDDF   E61C          WASLF: INC  MODADL         ; inc mem address.
FDE1   D002                 BNE  REOPEN        ;also high byte.
FDE3   E61D                 INC  MODADH
FDE5   2073FE       REOPEN: JSR  OUTPQR        ;o/p carriage return.
FDE8   A94D                 LDA  #4D
FDEA   2075FE               JSR  OPCHR         ;print M.
FDED   A51D                 LDA MODADH         ; print address.
FDEF   20OBFF               JSR  HEXPNT
FDF2   A51C,                LDA MODADL
FDF4   20OBFF               JSR  HEXPNT
FDF7   4C4FFC               JMP  MONEN2         go to cm d bit.
                    ;
                    ;POLLKB   subroutine.
                    ; note all addresses are page zero.
```

```
                    ;
FDFA   A900         POLLKB:   LDA #0
FDFC   48                     PHA                    ; push 0-shift ind.
FDFD   8501          PLKB1:   STA  ICHAR             ;set ICHAR to zero.
FDFF   C50F                   CMP  simcom           ;is it,keypad?
FE01   D006                   BNE  SIMPLE
FE03   C501          WAIT1:   CMP  ICHAR            ;else wait for int.
FE05   FOFC                   BEQ  WAIT1
FE07   68           PLKEND:   PLA                     pop in dic atc)r.
FE08   60            ENDLS:   RTS

                    ;simple keypad routine.

FE09   A90F         SIMPLE:   LDA #F                ;enable all kb lines.
FEOB   8DF2BF                 STA KBWRIT
FEOE   ADF3BF                 LDA KBREAD            look at kb     nes.
FEll   DOF6                   BNE SIMPLE            ;key down?-wait ti-li up.
FE13   A240                   LDX #40               ; debounce it.

 FE15 88             DEBOUN: DEY
 FE16 DOE8                     BNE DEBOUN
 FE18 CA                       DEX
 FE19 DOFA                     BNE DEBOUN

                     ;now poll the keypad properly.
                     ;note IY  is zero.

 FELB    AOFF          PLK1:   LDY #FF               ;set up Y index.
 FELD    68                    PLA                   ; peep at shift ind.
 FELE    48                    PHA
 FELF    F002                  BEQ  NOSHIF           ;if shift set mod IY.
 FE21    A013                  LDY  #13
 FE23    A208         NOSHIF:  LDX  #8               ;set IX-kb drive.
 FE25    8EF2BF         PLK2:  STX  KBWRIT           ;drive kb lines.
 FE28    ADF3BF                LDA  KBREAD           ;get result in A.
 FE2B    DOOC                  BNE  ACHAR            ;not 0-a char-skip.
 FE2D    C8                    INY                   ;else adjust IY.
 FE2E    C8                    INY
 FE2F    C8                    INY
 FE30    C8                    INY
 FE31    C8                    INY
 FE32    8A                    TXA                   ;shift IX right.
 FE33   4A                     LSR  A
 FE34 AA                       TAX
 FE35    FOE4                  BEQ  PLK1             ;if zero repeat.
 FE37    DOEC                  BNE  PLK2             ;else next line.

                      if we get here a   key has been pressed.

 FE39    C8            ACHAR: INY
 FE3A    4A                    LSR  A                ;which key of 5?
 FE3B    90FC                  BCC  ACHAR            ; C set'? thats key.
 FE3D    B94BFE                LDA  CHRTBL, Y        ; get asc ii e quiv.
 FE40    8501                  STA  ICHAR             put it in IACHR.
 FE42    DOC3                  BNE  PLKEND           ; if zero-shift.
 FE44    68                    PLA                   ; pull shift.
 FE45    49FF                  EOR  #FF              ;change shift state.
 FE47    48                    PHA                   ; push shift.
 FE48    4CO9FE                JMP  SIMPLE           ; continue.

                    ;character look up table for ascii equivalent.
```

```
FE4B   333742     CHRTBL:
FE4E   463F32
FE51   364145
FE54   OD
FE55   313539
FE58   44 OA
FE5A   303438
FE5D   4300
FE5F   2C524C
FE62   4E3F32
FE65   434953
FE68   20314F
FE6B   lB477F
FE6E   303450
FE71   4DOO

                  ;output character routine.
                  ;on entry character is stor\--d in A.
                  I X an d I Y are s ave d.

FE73   A90D         OUTPCR:  LDA #D                ; load CR.
FE75   8502          OPCHR:  STA  OCHAR            ;save the  character.
FE77   8A                    TXA                  ;save IX and IY.
FE78   48                    PHA
FE79   98                    TYA
FE7A   48                    PHA
FE7B   A403                  LDY  VDUIND          ;get curs position.
FE7D   A920                  LDA  #20             ;obliterate cursor.
FE7F   910A                  STA  (ICURS), Y
FE81   A602                  LDX  OCHAR           ;get char in IX.
FE83   E07F                  CPX  #7F             ; is it delete?
FE85   D010                  BNE  TRYCR           ;no-skip.
FE87   88                    DEY                  ;else dec vdu index.
FE88   1002                  BPL  DODEL           ;if neg set zero.
FE8A   AOM          ZERCUR:  LDY  #0
FE8C   A9FF          DODEL:  LDA  #FF             ; print cursor.
FE8E   910A                  STA  (ICURS), Y
FE90   8403                  STY  VDUIND          ;save index.
FE92   68                    PLA                  ;restore regs and rtn.

    FE93   40                  TAY
    FE94   68                  PLA
    FE95   AA                  TAX
    FE96   60                  RTS
    FE97   EOOD       TRYCR:   CPX  #D              ; is it a C R?
    FE99   F008                BEQ  DOCR          ;yes-process it.
    FE9B   8A                  TXA                ;else o/p character.
    FE9C   910A                STA  (ICURS), Y
    FEGE   C8                  INY                ;inc vdu index.
    FE9F   C020                CPY  #20           ; end of line?
    FEAL   3OE9                BMI  DODEL         ; no-tidy up-exit.
    FEA3   A200        DOCR:   LDX  #0            ;else scroll.
    FEA5   BD2002     LOWBLK:  LDA  VDUFST, X     ; do in two blocks.
    FEA8   9@2                 STA  VDUSTT,    X
    FEAB   E8                  INX
    FEAC   DOF7                BNE  LOWBLK
    FEAE   BD2003      HIBLK:  LDA  VDUTOP,    X
    FEB1   9WW3                STA  VDUMID,    X
    FEB4   E8                  INX
```

```
FEB5   EOEO                CPX  #Eo              ; see if done.
FEB7   DOF5                BNE  HIBLK
FEB9   A920                LDA  #20              ;fi.-ll line spaces.
FEBB   A8                  TAY
FEBC   88          M ORSP: DEY                   ; set IX as count.
FEBD   910A                STA  (ICURS), Y
FEBF   DOF'B               BNE  MORSP            ;do for whole line
FEC1   FOC7                BEQ  ZERCUR           ;when done tidy up.

                   ;keyboard interrupt subroutine.
                   ;note this is entered via jump instruction
                   ;stored in RAM location labelled INTF'SL
                   ;so that user can access interrupts quickly.
                   ;a reset will always initiahse INTFS1.

FEC3   48          KBINT:  PHA                   ;save accumulator.
FEC4   D8                  CLD                   ;set binary mode.
FEC5   8A                  TXA                   ;save IX.
FEC6   48                  PHA
FEC7   BA                  TSX                   ; get SP in IX.
FECB   E8                  INX                   ; IX tc) add old PSW.
FEC9   E8                  INX

FECA   E8                      INX
FECB   BDO001                  LDA  STKBSE, X        ;get the PSW.
FECE   2910                    AND  #10              w as it a bre ak?
FEDO   DOLE                    BNE  BRKP             yes-process it.
FED2   68                      PLA                   ;else pull IX.
FED3   AA                      TAX                   ;restz)re and continue.
FED4   ADF3BF                  LDA  KBREAD           ;read keyboard.
FED7   3004                    BMI  WASKB            if -ve w as kb.
FED9   68           USER:      PLA                   else restore A.
FEDA   4ClWo                   JM P INTSLL

                   ;note that INTSLL normally holds an RTI
                   ;unless the user has modified it.

FEDD   297F        WASKB: AND #7F                   ; mask top bit.
FEDF   8501                STA  ICHAR            ; put it in ICHAR.
FEE1   8DFOBF              STA  KBINCL           ;clr kb int flip-flop.
FEE4   C91B                CMP  #lB              ; w as it ES C?
FEE6   DOF1                BNE  USER             ; no-norm al return.
FEE8   A50C                LDA  RUNIND           ;user prog running?
FEEA   DOED                BNE  USER             ; no-norm a-1.
FEEC   850E                STA  PROCED           ;else clr pr-oc count.
FEEE   F012                BEQ  ACTBP            ;uncond br to break.

                   ;break processing code-break     was encountered.
                   ; note the user should not set    a break at own break
                   ;or in this interrupt routine else crashes.
                   ;now adjust PC to return to instr must subtract 3.

FEFO   E8            BRKP: INX                   ; address PC L.
FEF1   38                  SEC                   ;set C.
FEF2   BDOW1               LDA  STKBSE, X        ; get PCL.
FEF5   E902                SBC  #2               ; subtract 3.
FEF7   9DOW1               STA  STKBSE,  X       ;put it back.
FEFA   B004                BCS  NOROLL           ; C set? NOHI byte.
FEFC   E8                  INX                   ;else address PCH.
FEFD   DEN08               DEC  STKBSE, X        ; dec PCH.
```

```
FFOO   68          NOROLL:   PLA                    ;pull IX.
FF01   AA                    TAX                    ; restore it.
FF02   68           ACTBP:   PLA                    ;pull accumulator.
FF03   851B                  STA  ABCK              ;back it up.

    FF05 2OClFF                   JSR BPTREM            ;restore user code.
    FF08 4C75FF          NOROL:   JMP NMNT1              service break.

                      ;HEXPNT   takes a hex value stored in accumulator
                      ;ie a two character number and displays it.
                      ;registers are not saved.  IX is corrupted.

    FFOB   48         HEXPNT: PHA                      ;save value of char.
    FFOC   A201               LDX   #1               ;load IX with 1.
    FFOE   4A                 LSR   A                ; get top part
    FFOF   4A                 LSR   A                ;by multiple shifts.
    FF10   4A                 I-SR  A
    FF11   4A                 LSR   A
    FF12   18              PNT2: CLC
    FF13   6930               ADC   #30              ;add hex 30.
    FF15   C93A               CMP   #3A               more than 9?
    FF17   3003               BMI   PNT1              no- print it.
    FF19   18                 CLC
    FFLA   6907               ADC   #7
    FFLC   2075FE          PNT1:  JSR   OPCHR        ;print it.
    FFLF   CA                 DEX
    FF20   lool               BPL   MOR1             ;-ve?-end else low bit.
    FF22   60                 RTS
    FF23   68              MORL:  PLA                ;recover low bits.
    FF24   29OF               AND   #F               ;clr unwanted bits.
    FF26   10EA               BPL   PNT2             ;uncond branch.

                      ;HEXPCK   uses  values in TXTP   to store hex values
                      ;of characters indexed by IY     from display RAM.
                      ;on exit, caused by any non-hex character,these
                      ;contain a two byte number.  HEXENT contains
                      ;the number of characters entered.
                      ;registers are not saved.
                      ;on exit IY points tc) the last character.
                      ;the zero flag is clear if the terminating
                      ;character was the cursor, else set.
                      ;the overflow flag is set if this subroutine
                      ;encountered some hex data.

    FE28 A900         HEXPCK: LDA #0                   ;clr accumulator.
    FF2A 48                   PHA                    ;push as PSW.

      FF2B    8513                STA HXPKL               ;clr parameters.
      FF2D    8514                STA  HXPKH
      FF2F    CB            NXHX:   INY
      FF30    B10A                LDA  (ICURS), Y         ;get character.
      FF32    AA                  TAX                     ; store in I X
      FF33    38                  SEC                     ;subtract hex 30.
      FF34    E930                SBC  #30                ; tc) give 0 to 9.
      FF36    3010                BMI  ENDTS
      FF38    C90A           HX1:   CMP  #A               ; is it 0 tc) 9?
      FF3A    3010                BMI  HX2                ;yes-pack it.
      FF3C    38                  SEC                     ;else sub hex 11.
      FF3D    E911                SBC  #11
```

```
FF3F    3007                    BMI  ENDTS              ;goto carry setup.
FF41    18              HX3:    CLC                     ;else add 9.
FF42    690A                    ADC  #A
FF44    C910                    CMP  #10                ;more than 15? exit.
FF46    3004                    BMI  HX2
FF48    28              ENDTS:  PLP                     ;deal with V flag.
FF49    EOFF                    CPX  #FF                ; c ursor.
FF4B    60                      RTS

                        note character is in     IX on exit
                       ;return does not affect zero flag.

FF4C    A204            HX2:    LDX #4                  ; its he x s ave it.
FF4E    0614            HX5:    ASL  HXPKH              ; shift left 4 times.
FF50    0613                    ASL  HXPKL              ;add new one.
FF52    9002                    BCC  HX4
FF54    E614                    INC  HXPKH              ; replicate.
FF56    CA              HX4:    DEX                     ; dec IX until zero.
FF57    DOF5                    BNE  HXS
FF59    18                      CLC                     ; add in char.
FF5A    6513                    ADC  HXPKL
FF5C    8513                    STA  HXPKL              ; store it.
FF5E    68                      PLA                     ; get pseudo PSW.
FF5F    A940                    LDA  #40                ; set V bit.
FF61    48                      PHA                     ;and push it.
FF62    DOCB                    BNE  NXHX               ; do next.

                       ;non-maskable interrupt routine for single instr.


FF64   851 B         NMNT: STA ABCK                    ;save accumulator.
FF66   D8                    CLD                       ;set binary mode.
FF67   A50D                  LDA  SINGLE               ;test single inst.
FF69   DOOA                  BNE  NMNT1
FF6B   8A                    TXA                       ; if not save I X.
FF6C   48                    PHA
FF6D   20DOFF                JSR  BPSET                ;set breakpoints.
FF70   68                    PLA                       ;restore IX.
FF71   AA                    TAX
FF72   A51B                  LDA  ABCK                 ;restore accumulator.
FF74   40                    RTI
FF75   A50E          NMNT1:  LDA  PROCED               ;get proc count.
FF77   F005                  BEQ  ZERBCK               ;if zero break.
FF79   C60E                  DEC  PROCED               ;else dec count.
FF7B   4CB9FC                JMP  SRET                 ;rts via single test.
FF7E   E60C         ZERBCK:  INC  RUNIND               ;set not running.
FF80   68                    PLA                       ; pop bpt PSW to acc.
FF81   8517                  STA  PSWBCK               ;back it up.
FF83   68                    PLA
FF84   8515                  STA  PCLBCK               ; ditto PC L.
FF86   68                    PLA
FF87   8516                  STA  PCHBCK               ; ditto PC H.
FF89   8619                  STX  XBCK
FF8B   841A                  STY  YBCK
FF8D   BA                    TSX                       ;operators  SP.
FF8E   8618                  STX  SPBCK
FF90   2073FE        PSEUD:  JSR  OUTPCR
FF93   A516                  LDA PCHBCK
FF95   20OBFF                JSR  HEXPNT
```

```
   FF98   A515                LDA PCLBCK
   FF9A   20OBFF              JSR  HEXPNT
   FF9D   AWO                 LDY #0                ;clear IY.
   FF9F   A920          PSNX: LDA #20               ;print two spaces.
   FFAL   48                  PHA
   FFA2   2075FE              JSR  OPCHR
   FFA5   68                  PLA
   FFA6   2075FE              JSR  OPCHR
   FFA9   B91700              LDA PSWBCK, Y
   FFAC   20OBFF              JSR  HEXPNT
   FFAF   C8                  INY                   ;do all registers.
   FFBO   C005                CPY  #5

FFB2 30EB                  BMI PSNX
FFB4 4C4BFC                JMP RC1

                  ;breakpoint clearing routine uses IX and A.

FFB7   A21F        BPTCLR:  LDX #lF               ; set count for 8 bpt3.
FFB9   A900                 LDA  #0
FFBB   9520        BPTCL1:  STA  BPTLO, X         ; c le ar a loc atio n.
FFBD   CA                   DEX                   ; dec count.
FFBE   10FB                 BPL  BPTCL1           ; do for all loc atio ns.
FFCO   60                   RTS

                  ;this subroutine removes breakpoints by
                  ;writing back the users original code.
                  ;IX and IY are used.

FFC1   8A          BPTREM: TXA
FFC2   48                  PHA
FFC3   A20E                LDX  #E                ; set for 8 bpts.
FFC5   B530        BPTRML:  LDA  BPTCOD, X        ;load old instruction.
FFC7   8120                 STA  (BPTLO, X)       ;write tc) prog mem.
FFC9   CA                   DEX
FFCA   CA                   DEX                   ;decrement it.
FFCB   10                   BPL  BPTRM1           ;do for all bpts.
FFCD   68                   PLA
FFCE   AA                   TAX
FFCF   60                   RTS

                  ;subroutine BPSET looks at the entered breakpoint
                  ;addresses, stores the present instruction
                  ;and writes brk to program memory.

FFDO   A20E          BPSET: LDX #E                 ; set for 8 bpts.
FFD2   A120           BPS1: LDA  (BPTLO, X)        ;get users instr.
FFD4   9530                 STA  BPTCOD, X        ; store it.
FFD6   A900                 LDA  #0               ;set brk..
FFD8   8120                 STA  (BPTLO, X)
FFDA   CA                   DEX
FFDB   CA                   DEX
FFDC   1OF4                 BPL  BPS1             ;do tlll done.
FFDE   60                   RTS



                ;setup table for initial values.
                ;order is same as RAM locations.

FFDF   4CC3FE     SETUP:
```

```
FFE2   4C64FF
FFE5   E00301
FFE8
FFEB   40

                ;header message "TANBUG"

FFEC   OD
FFED   54414E
FFFO   425547
FFF3   ODOO
FFF7   4C89FC            JMP RETERR
FFFA   070M
FFFD   FC0400
```

CHAPTER 7 : SOME GAMES PROGRAMS

[I haven't typed this chapter, but instead OCR'ed it, so there are some glitches...]

LIFE PROGRAM

Start Address: B0
No options required.

Life is a program which simulates a colony of living organisms which can grow, move and die out. "Life" is run in two stages.

1) Seeding the cells. On starting the program, the display is cleared and the cursor is placed in the middle of the screen. Four single letber commands are avail-able to move the cursor about the lower half of the display.
   L moves it to the left.
   R moves it to the right.
   D moves it down.
   M moves it up.
   A fifth command, A, whenever typed replaces the cursor with an asterisk, which then remains on the display when the cursor is moved again. By using these five commands any patbern of asterisks can be built up on the lower half of the display.
2) Evolution. Typing "GI' causes the program to jump from the seeding mode and into the evolution mode. Every two seconds the display is scanned and a new "generation" of cells produced from the old according to the following rules.
   a) If a cell space is surrounded by exactly three other asterisks, this cell will contain an asterisk in the next generation.
   b) If an asterisk is surrounded by two or three others, it will remain as an asterisk in the next generation.
   c) All- other arterisks will become spaces.

Eventually a stable patbern will occur which will either be an immobile patbern, a blinking pattern or a blank screen. At this point the monitor can be entered by issuing a reset or, if using an alphanumeric keyboard, by depressing ESC and a new game started. Note that asterisks placed on the bottom line of the display do not change; they act as a permanent seeding set.

life pro gr am

```
             Om                        LIN1:
             0060                      LIN2:
             0080                      LIN3:
             OOAO                     VDULO:                              ; vdu position.
             0OAl                     VDUHI:
             0OA2                      YIND:                              ; y i-idex.
             OOBO      Aolo                    LDY #10                    ;clear screen.
             0OB2      2073FE          NXSR:   JSR   OUTPCR
             0OB5      88                      DEY
             0OB6      DOFA                    BNE   NXSR
             0OB8      A920                    LDA   #20                  ;obliterate
cursor.
             OOBA      8@E003                  STA   CUR
             OOBD      AOW                     LDY   #0                   ; put curs in
mid      vdu.
             OOBF      84AO                    STY   VDULO
             00cl                              LDY   #3
             0OC3      84Al                    STY   VDUHI
             0OC5      AOOF                    LDY   #F
             0OC7      84A2              NXC:  STY   YIND
             0OC9      A9FF                    L-DA  #FF
             OOCB      91 AO          P LKI T: STA   (VDULO), Y
             OOCD      20FAFD                  JSR   POLLKB
             OODO      A4A2                    LDY YIND                   ;char--cursor?
             OOD2      BlAo                    LDA   (VDULO), Y
             OOD4      C9FF                    CMP   #FF
             OOD6      D008                    BNE   NODL                 ; no-skip.
             OOD8      A920                    LDA   #20                  ;else delete.
             OODA      91 AO                   STA   (VDULO), Y
             OODC      4CEOW                   JMP   NODL                 ;skip for
expansion.
             OODF      00
             OOEO      A601            NODL:   LDX   ICHAR                ;pick up input
char.
             OOE2      E04C                    CPX   #4C                  ; L for left?
             OOE4      D006                    BNE   NOL                  ;no-skip.
             OOE6      88                      DEY
             OOE7      DODE                    BNE   NXC                  ;look for 'next
command.
             OOE9      C8              INGO:   INY                        ; else inc it.
             OOEA      DODB                    BNE   NXC                  ; unconditional
branch.
             OOEC      E052              NOL:  CPX   #52                  ; R for right?
             OOEE      D006                    BNE   NOLL                 ; no-skip.
             OOFO      COLE                    CPY   #lE                  ;else shift right.



                  0OF2   FOD3                    BEQ NXC                 ; next char.
                  0OF4   DOF3                    BNE  INGO
                  0OF6   E041             NOLL:  CPX  #41                ; A for asterisk?
                  0OF8   D004                    BNE  NOL2               ; no-skip.
                  OOFA   A92A                    LDA  #2A                ; e lse o utp ut a
                  OOFC   DOCD                    BNE  PLKIT              ; unconditional
branch.
                  OOFE   E@               NOL2:  CPX  #44                ; D for down?
                  0100   DOOA                    BNE  NOL3               ; no-skip.
                  0102   18                      CLC                     ;else inc line
pointer.
```

```
0103   A5AO                LDA  VDULO
0105   6920                ADC  #20
0107   85AO                STA  VDULO
0109   4CC700              JMP  NXC
010C   E04D          NOL3: CPX  #4D              ; M for up?
010E   DOOA                BNE  NOL4             ; no-s kip.
0110   38                  SEC                   ;else sub a line.
0111   A5AO                LDA  VDULO
0113   E920                SBC  #20
0115   85AO                STA  VDULO
0117   4CC700        LKAG: JMP  NXC
01 1 A @Z047         NOLA: CPX  #47              ; G for go?
011C   DOF9                BNE  LKAG             ; no-skip.
011E   AOW             GO: LDY  #0
0120   84AO                STY  VDULO
0122   A002                  LDY  #2
0124   84Al                STY  VDUHI
0126   A900        GOTW 0:   LDA  #0             determine number
0128   85A2                STA  YIND             ;of cell neighbours.
012A   A920                LDA  #20
012C   A207                LDX  #7
012E   BC3COl         NXX:  LDY  INDEX, X
0131   DlAo                CMP  (VDULO), Y
0133   F002                BEQ  DCT
0135   E6A2                INC  YIND
0137   CA             DCT:  DEX
0138   1OF4                BPL  NXX              ;YIND holds number.
013A   3008                BMI  CNT
013C   000102       INDEX:
013F   202240
0142   4142
0144   18             CNT: CLC                   ;clear carry.


0145   A5A2                LDA YIND
0147   C903                CMP  #3               ; if 3 go set carry.
0149   FOOC                BEQ  CST
014B   C902                CMP  #2               ;if not 2 clear carry.
014D   D058                BNE  CNS1
014F   A021                LDY  #21               if 2 look at this.
0151   BLAO                LDA  (VDULO), Y
0153   C920                CMP  #20
0155   F050                BEQ  CNS1
0157   38              CST: SEC                   ; c arry set if in ne xt.
0158   A250            CNS: LDX  #50              ; store it shift prev.
015A   3640          NXPL: ROL  LIN1, X
015C   CA                  DEX
015D   10FB                BPL  NXPL
015F   E6AO                INC  VDULO             do for whole page.
0161   D002                BNE  NHI
0163   E6Al                INC  VDUHI
0165   A5Al           NHI: LDA  VDUHI
0167   C903                CMP  #3
0169   D006                BNE  TPJP
016B   A5AO                LDA  VDULO
016D   C9BE                CMP  #BE
016F   F03A                BEQ  PATCH1
0171   4C2601        TPJP: JMP  GOTWO
```

```
0174   38          DNUPD:   SEC                  ;empty store tD vdu.
0175   E901                 SBC  #1
0177   85AO                 STA  VDULO
0179   A5Al                 LDA  VDUHI
017B   E900                 SBC  #0
017D   85Al                 STA  VDUHI
017F   4CB001               JMP  PATCH2
0182   EA                   NOP
0183   A220         DLYIT:  LDX  #20              ;delay.
0185   88              DLDY: DEY
0186   DOFD                 BNE  DLDY
0188   CA                   DEX
0189   DOFA                 BNE  DLDY
018B   4ClEol               JMP  GO
018E   A200         MOROP:  LDX  #0
0190   A050                 LDY  #50
0192   7640         NXROR:  ROR  LIN1, X
          I

 0194     E8                      INX
 0195     88                      DEY
 0196     10FA                    BPL   NXROR
 0198     A920                    LDA   #20
 019A     9002                    BCC   CHROP
 019C     A92A                    LDA   #2A
 019E     ANO             CHROP:  LDY   #0
 OLAO     91AO                    STA   (VDULO), Y
 OlA2     A5AO                    LDA   VDULO
 OlA4     4C7401                  JMP   DNUPD
 OlA7     18               CNS1:  CLC
 OlA8     4C5801                  JMP   CNS
 01AB     A9DF          PATCHL:   LDA   #DF
 01AD     4C7401                  JMP   DNUPD
 01 BO    C902          PATCH2:   CMP   #2
 OIB2     DODA                    BNE   MOROP
 01 B4    A5AO                    LDA   VDULO
 01 B6    C920                    CMP   #20
 01 B8    DOD4                    BNE   M OROP
 01BA     FOC7                    BEQ   DLYIT
```

SHOOTDOWN

Start Address: 0045
No options required.

A row of "aircraft" fly across the screen fiom left to right. A "gun" is positioned at the bottom of the display. Typing any key causes the gun to shoot at the aircraft. Number of shots and number of hits are recorded. The object of the game is tc) shoot all the aircraft down with the minimum number of shots.

When all aircraft are shot down, the game is automatically re-started after a delay.

shootdown.

```
0040              LINDL:                        ;aircraft line delay.
0041              GUNDL:                        ; gun delay.
0042              SHOOT:                        ; shoot flag.
0043             GNPOSL:                        ; gun position.
                 GNPOSH:
0045   AOOF       START:   LDY #F               ;clear screen.
0047   2073FE    INITCR:   JSR  OUTCR
004A   88                  DEY
004B   IOFA                BPL  INITCR
004D   A920                LDA  #20
004F   8DE003              STA  SCRTP
0052   A01A                LDA  #lA            ;write aircraft to line
2.
0054   A9FF                LDA  #FF
0056   994002       NXAC:  STA  AC,  Y
0059   88                  DEY
005A   88                  DEY
005B   88                  DEY
005C   1OF8                BPL  NXAC           ; set up delay.
005E   8540                STA  LINDL
0060   A930                LDA  #30            ; zero the scale.
0062   8D2002              STA  VDUT
0065   8D2102              STA  VDUT1
0068   Aool      RESGUN:   LDY  #1             ;reset gun delay.
006A   8441                STY  GUNDL
006C   88                  DEY                 ;clear ICHAR.
006D   8401                STY  ICHAR
006 F  A50F                LDA  SIMCOM         ; if full kb skip.
0071   FOOA                BEQ  FULLK
0073   A90F                LDA  #F             ;if keypad wait no key.
0075   8DF2BF              STA  KBWRIT
0078   ADF3BF         W T:  LDA  KBREAD
007B   DOFB                BNE  W T
007D   8442       FULLK:   STY  SHOOT           ;clear shoot flag.
007F   AOEF                LDY  #EF            ;set gun position.
0081   8443                STY  GNPOSL
0083   A003                LDY  #3
0085   8444                STY  GNPOSH
0087   ANO        ACDLY:   LDY  #0             ;actually put it out.
0089   A95E                LDA  #5E
```

```
OOBB   9143                STA  (GNPOSL), Y
008D   AOFF         MSDLY: LDY  #FF            ; master delay.
008F   88            GMDL: DEY
0090   DOFD                BNE  GMDL
0092   C640                DEC  LINDL          ; dec aircraft delay.
0094   D015                BNE  ROTEND         ; not O go test shoot.
0096   A960                LDA  #60            ;else reset delay.
0098   4C3101              JM P PATCH1         ; rotate ne.
009B   48            BACK:  PHA
009C   A01 E               LDY  #lE
009E   B94002       ROTRT: LDA  SRTLIN, Y
0OAl   994102              STA  SRPLUS, Y
0OA4   88                  DEY
0OA5   1OF7                BPL  ROTRT
0OA7   68                  PLA
```

```
0OA8   8D4002              STA  LINBT
OOAB   A542@       ROTEND: LDA  SHOOT          ; shoot in progress?
OOAD   D023                BNE  GOSHOT         ;yes-deal with it.
OOAF   A50F                LDA  SIMCOM         ;else keypad?
0OB1   D006                BNE  SIMKBL         ; yes-branch.
0OB3   A501                LDA  ICHAR          ;else full kb hit?
0OB5   FOD8                BEQ  GMDL           ; no-w ait.
0OB7   D005                BNE  INSHT          ; else go and shoot.
0OB9   ADF3BF      SIMKB1: LDA  KBREAD         ; look at kb.
OOBC   FOD1                BEQ  GMDL
OOBE   E642         INSHT: INC  SHOOT          ; hit-inc in dic atc)r.
OOCO   EE2102              INC  VDUT1          ; adjust shots @d.
0OC3   AD2102              LDA  VDUT1
0OC6   C93A                CMP  #3A
0OC8   3008                BMI  GOSHOT
OOCA   A930                LDA  #30
OOCC   8D2102              STA  VDUT1
OOCF   EE2002              INC  VDUT
OOD2   C641        GOSHOT: DEC  GUNDL          ; dec gun delay.
OOD4   DOB7                BNE  MSDLY          ; not O then more delay.
OOD6   A91 F               LDA  #lF            ;else reset gun delay.
OOD8   8541                STA  GUNDL
OODA   PM                  LDY  #0             ;obliterate gun.
OODC                       JMP  NXLL           ;skip for expansion.
OODF   00
OOEO   A920          NXLL: LDA  #20

OOE2   9143                STA (GNPOSL), Y
OOE4   38                  SEC
OOE5   A543                LDA  GNPOSL         ;adjust gun position.
OOE7   E920                SBC  #20
OOE9   8543                STA  GNPOSL
OOEB   B002                BCS  NOHIH
OOED   C644                DEC  GNPOSH
OOEF   A902         NOHIH: LDA  #2             ;gun in aircraft rank?

0OF1   C544                CMP  GNPOSH
0OF3   D092                BNE  ACDLY          no-continue.
0OF5   A94F                LDA  #4F
0OF7   C543                CMP  GNPOSL
0OF9   D08C                BNE  ACDLY          else we are.
OOFB   AD4FO2              LDA  GNLN           ;have we scored?
OOFE   C9FF                CMP  #FF
0100   F003                BEQ  AHIT           ;a hit-deal with it.
0102   4C6800              JMP  RESGUN         ;else reset gun.
0105   A920          AHIT: LDA  #20            ;obliterate aircraft.
0107   8D4FO2              STA  GNLN
010A   AD2502              LDA  ACSCO          ;setup the score.
Olot D C920                CMP  #20
01OF   D008                BNE  INCSC
0111   A931                LDA  #31
0113   8D2502              STA  ACSCO
0116   4C6800        RSJP: JMP  RESGUN
0119   EE2502       INCSC: INC  ACSCO
011C   C938                CMP  #38            ; game over test.
011E   DOF6                BNE  RSJP
0120   A909                LDA  #9             ; delay, then restart.
```

```
                0122   8543                STA  GNPOSL
                0124   CA            DLY:  DEX
                0125   DOFD                BNE  DLY
                0127   88                  DEY
                0128   DOFA                BNE  DLY
                012A   C643                DEC  GNPOSL
                012C   DOF6                BNE  DLY

It              012E   4C4500              JMP  START
                0131   8540       PATCHL:  STA  T.TNDL
                0133   AD5FO2              LDA  ENDLN
                0136   4C9BOO              JMP  BACK
```

GRAPHICS SUBROUTINE

Calling Address: OW (not relocatable)
Variables: XCOORD O"
YCOORD 0041
Requirements: Graphics option.

The graphics subroutine uses the VDU as a 64 x 64 pixel graphics display. When called it picks up the values of X and Y co-ordinates (set up by the calling program) and turns the relevant pixel on. The bottom left hand side of the screen is point (0,O).

Note that this subroutine does not turn any pixel off - it is therefore necessary to zero the screen before using this subroutine to output a graph.

Notes on use of graphics subroutine.

1) Initially with the monitor in "TANBUG", all unused areas of the screen are filled with spaces (HEX 20). Before attempting to draw a graph using the subroutine shown, the screen must be filled with hex O's with graphics mode set.
2) If using TANBUG and graphics mode, test mode is not reset on entering TANBUG. Care must therefore be taken that the program resets text mode before exit.
3) The OPCHR subroutine should not be used if graphics mode is in use anywhere on the screen.
4) It is possible to display both alphanumerics and graphics characters simultaneously, e.g. an annotated graph. The procedure is as follows:- a) set graphics mode, b) fill screen with hexadecimal O's, c) draw axes and graph, d) set text mode, e) write text.

Note that any use of the OPCHR subroutine, e.g. by the monitor, corrupts the graphics display.

To demonstrate this subroutine this example program also contains a main program which utllises it. The program repeatedly draws X and Y axes and the function y = Y2x.

Start address: FD

Graphics Subroutine Listing.

```
Om      00          XCOORD:
0041    00          YCOORD:
0042    00           VDULO:
```

```
                00          VDUHI:
          OW    ADFOBF      GRAPH:  LDA GON              ;set graphics mode.
          0047  A93 F               LDA   #3F            ;check coord size.
          0049  C540                CMP   XCOORD
          004B  302E                BMI   EXIT
          004D  EA                  NOP
          004E  38                  SEC
          004F  E541                SBC   YCOORD
          0051  EA                  NOP
          0052  48                  PHA
          0053  2903                AND   #3             ; m ask tc) 2 lsbs.
          0055  AA                  TAX                  ; store in I X.
          0056  68                  PLA
          0057  EA                  NOP
          0058  293C                AND   #3C            ; mask two lsbs.
          005A  OA                  ASL   A              ; shift 1 3 times.
          005B  OA                  ASL   A
          005C  OA                  ASL   A
          005D  8542                STA   VDULO
          005F  A902                LDA   92             ; set up VDULO and
          0061  8543                STA   VDUHI          ; VDUHI with y axis
          0063  9002                BCC   NOINC          ; address.
          0065  E643                INC   VDUHI
          0067  A54 0       NOINC:  LDA   XCOORD         ; get xcoordinate.
          0069  4A                  LSR   A
          006A  A8                  TAY                  ; adjust, store in I Y
          006B  A901                LDA   #1             ; determine which
          006D  9001                BCC   NOSF2          ;bit to set in the
          006F  OA                  ASL   A              ; graphics'word
          0070  'CA         NOSF2:  DEX                  ; held in acc.
          0071  3004                BMI   ENDOP
          0073  OA                  ASL   A
          0074  OA                  ASL   A
          0075 DOF9                 BNE   NOSF2           jm p to re pe at.

     0077 1142          ENDOP: ORA (VDULO)      Y      ;or with present.
     0079 9142                   STA (VDULO), Y        ;write it back out.
     007B 60            ;EXIT:
RTS                                                    fig
                        ;this program repeatedly draws X and Y axes
                        ;and the function y=?/2x to demonstrate the
                        ;operation of the 'graphics subroutine and the
                        ; graphics hardware.
                        ;first save regs, o/p graph subroutine and delay.
                        ;
     0084   48          SAVOP:   PHA
     0085   98                   TYA
     0086   48                   PHA
     0087   8A                   TXA
     0088   48                   PHA                   ;save registers.
     0089   A220                 LDX  #20              ;set delays.
     008B   AOW                  LDY  #0
     008D   88           DECM:   DEY
     008E   DOFD                 BNE  DECM
     0090   CA                   DEX
     0091   DOFA                 BNE  DECM
     0093   2@                   JSR GRAPIA            ;output char.
     0096   68                   PLA                   restor-e.
```

```
0097   AA                  TAX
0098   68                  PLA
0099   A8                  TAY
009A   68                  PLA
009B   60                  RTS
                  ;
                  ;main program.
                  ;
OOFD   ADFOBF              LDA GON              ;set graphics mode.
0100   A900        GTEST:  LDA  #0              ;clear display.
0102   AA                  TAX
0103   9DWO2       NXSTO:  STA  VDUL, X
0106   9DWO3               STA  VDUM, X
0109   CA                  DEX
010A   DOF7                BNE  NXSTO
010C   EA                  NOP
010D   A03F                LDY  #3F             ;set IY decimal 63.
01OF   A900                LDA  #0              ;clear x co-ord.

      0111   8540                STA XCOORD
      0113   8441           NEX: STY  YCOORD          ;load IY to y co-ord.
      0115   208400              JSR  SAVOP          ;o/p char with delay.
      0118   88                  DEY                  do for y axis    ne.
      0119   1OF8                BPL NEX
      011B   A03F                LDY  #3F             now do for x axis.
      011D   8541                STA  YCOORD
      011F   8440          NEX1: STY  XCOORD
      0121   208400              JSR  SAVOP
      0124   88                  DEY
      0125   1OF8                BPL  NEX1
      0127   A200                LDX  #0              now draw graph.
      0129   8640           NXT: STX  XCOORD
      012B   8A                  TXA
      012C   4A                  LSR  A
      012D   8541                STA  YCOORD
      012F   208400              JSR  SAVOP
      0132   E8                  INX
      0133   E040                CPX #40
      0135   DOF2                BNE  NXT
      0137   4CWOl               JMP  GTEST
      0200               VDUL:
      0300               VDUM:
```