CHAPTER 23. MULTITASKER

The source code of the multitasker is in CPU8086.BLK, screens 22-23, and in UTILITY.BLK, screens 52-54.

23.1. MULTITASKING

Multitasking is the technique to use one computer to do several things at the same time. Most of the microcomputers run rather inefficiently in the single user, interactive mode, because the computer wastes most of its time in waiting the user to type in commands. This waiting time can be utilized to perform useful work, like printing a long file, keeping a timer clock, watching over the heater or the air conditioner and other instruments, etc. If properly scheduled, all these activities can be handled by a single computer, allocating each task sufficient time to do its work and still satisfies the programming needs of the user.

Most mainframe computers and minicomputer operating systems have the multitasking function and can support many users and tasks to run at the same time, using rather complicated hardware and software to schedule and run the tasks, and also manage a host of peripheral devices like disk drives, tape drives, printers, plotters, etc. Scheduling and resource allocation are big headaches in these operating systems, contributing a fair share to the complexity in the operating system.

People generally conceive Forth as a toy language only suitable for single user microcomputers. This is probably due to the limited capability presented in the public domain fig-Forth model, which has become the most widely distributed Forth dialect. However, in many more expensive commercial Forth implementations, especially those developed by Charles Moore himself and later marketed by Forth, Inc. under the trade name poly-Forth, multitasking was a standard component using the very simple but effective round-robin scheduling technique.

F83 also includes the elementary operators to implement multi- tasking. The basic system design takes the task switching into consideration, so that tasks can be easily added to the system when needed. Task switching is very fast because of the brevity of code involved. Here we will go through the entire system to describe the multitasker in great details.

23.2. USER VARIABLES AND THE USER AREA

Special words for managing a multitasking or multiuser Forth system are collected in a special vocabulary USER. Some of them have the same names as other regular Forth words, but different functions. They have to be used with care. They allocate space for user variables in the user area which is a unique memory area for every task in the system.

VARIABLE #USER	Count of the number of user variables allocated in a user area.
VOCABULARY USER	Declare the user vocabulary.
USER DEFINITIONS	Put all subsequent words in the USER vocabulary.

```
: ALLOT             ( n --- )       Allocate space in the user area for a task.
        #USER +!                    Move the user area pointer forward for n bytes.
        ;
```

```
: CREATE        ( --- )     A special header builder for user variables.
    CREATE                  Build a regular header.
    #USER @ ,               Compile the current user area pointer in the parameter field,
                            to be used as the offset of the user variable from origin of the
                            user area.
    ;USES           Get the code field address of the new user variable.  DOUSER-
VARIABLE ,  Patch the code field using DOUSER-VARIABLE as the
    runtime interpreter for user variables.

: VARIABLE      ( --- )     New defining word for user variables.
    CREATE                  This is the newly defined CREATE.
    2 ALLOT                 Allocate two bytes in the user area, not on top of dictionary.;

: DEFER         ( --- )     New defining word for deferred words in the user area.
    VARIABLE                Create a new user variable.
    ;USES           Patch code field with
    DOUSER-DEFER ,          address of the runtime routine DOUSER-DEFER.
```

When tasks are switched, the environment of the task currently under execution must be preserved before the task is put to sleep, so that when the task is waken up the next time around it will be able to pick the execution sequence where was left off and continue the task until finished or put to sleep again. What defines the environment of a task is a set of parameters stored in a set of 'user variables' and an area where the data stack and the return stack used by the task are allocated. Each task must have its own copy of these user variables and stacks. As these essential bits of information are stored independently for each task, task switching becomes very easy because only a minimal amount of information has to be preserved explicitly during task switching.

Following is the list of user variables needed in every task:

TABLE 23.1. USER VARIABLES

```
    TOS             Top of data stack.
    ENTRY           Entry point to be jumped to when the task is activated.     LINK
                Point to next task in the round- robin circle.
    SP0             Origin of the data stack.
    RP0             Origin of the return stack.
    DP              Top of dictionary.
    #OUT            Number of characters emitted.
    #LINE       Number of lines typed.
    OFFSET          Block offset from block 0 in the current file.
    BASE            Numeric base for I/O conversion.
    HLD             Point to the last character converted in the PAD buffer.    FILE
                Point to FCB (file control block) of currently opened file.  IN-FILE
            Point to the FCB of the input file.
    PRINTING        A flag.  True if printer is active.
    EMIT            Send a character to the output device currently active.
```

One should note that these user variables have their names in the main dictionary while the parameters are stored in the user area. Only one copy of the names needs to be defined. Every user or task will have its own copy of the user variables. The functions of these user variables will become apparent in the following sections.

23.3. PAUSE AND RESTART

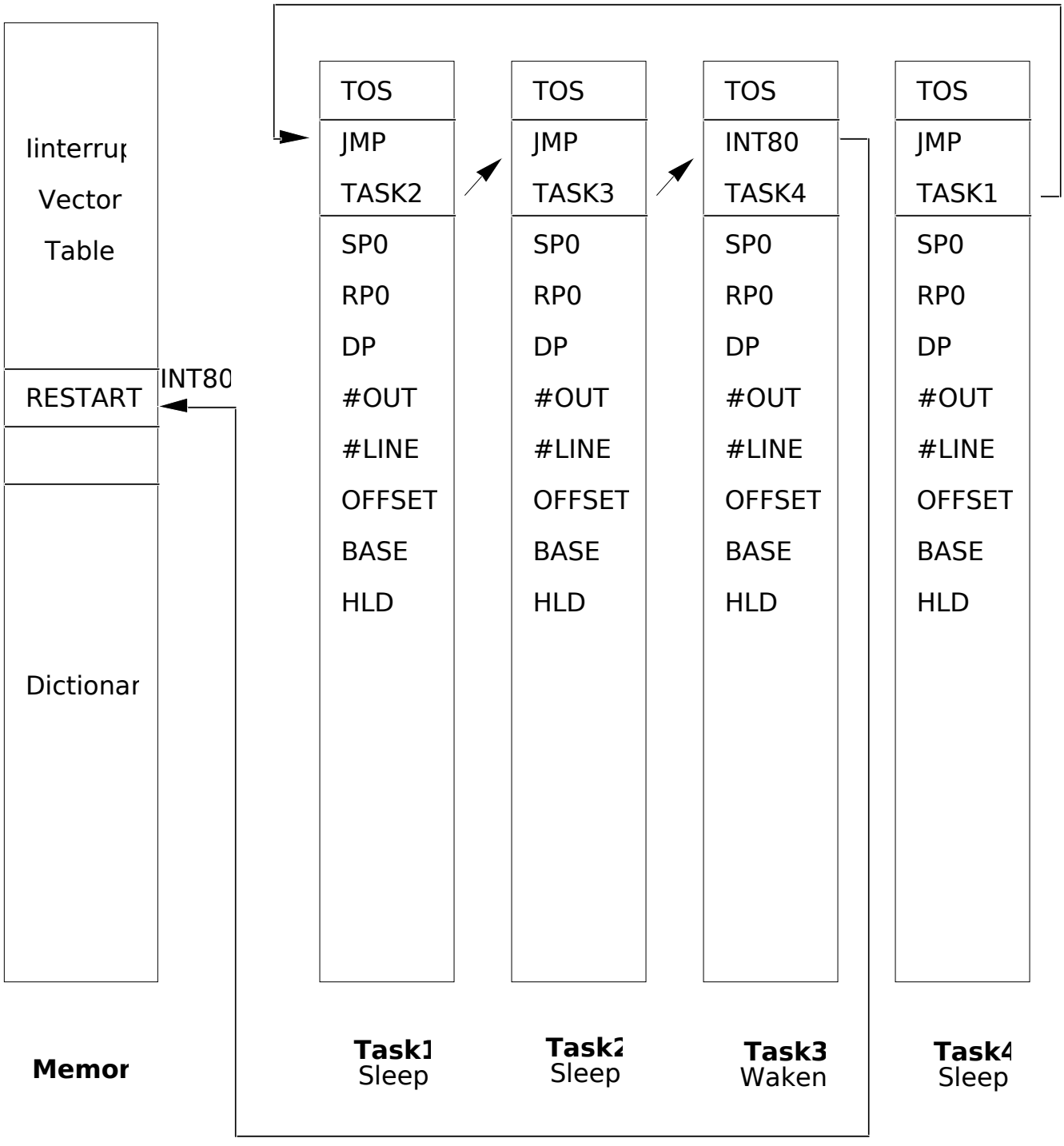
PAUSE and RESTART are the two most crucial operators to effect the task switching process. (PAUSE) stops the current task and passes control of the CPU to the next task in the round-robin loop. It saves the necessary information in the user area so that the task can continue the next time it gains the control of the CPU.

```
CODE  (PAUSE)              Stop executing the current task and pass control to the next
                           task.
        IP  PUSH           Save the Interpretive pointer on the data stack.
        RP  PUSH           Save the return stack pointer.
        UP #) BX MOV       Fetch the user area pointer into BX register.
        SP 0 [BX] MOV      Save the data stack pointer in user variable TOS.
        BX INC   BX INC
        BX INC   BX INC    Increment BX and point it at the user variable LINK.
        0 [BX] BX ADD      Calculate the address of the user area from the offset in
                           LINK.
        BX INC   BX INC    Now point to the ENTRY user variable of the next task.
        BX JMP             Execute the next task. END-CODE

CODE  RESTART              The reverse of (PAUSE). Retrieve the stored information
                           and start executing the task left asleep during the last pass.
        -4 # AX MOV        Store -4 in the AX register for later use.
        BX POP             Pop the LINK address of the next task to be waked up.   AX
BX ADD                     Point BX to the TOS user variable.
        BX UP #) MOV       Copy this address into UP as the user pointer for the next
                           task.
        AX POP   AX POP    Discard two items from the stack. They were pushed on the
                           stack by the interrupt routine waking up this task.
        0 [BX] SP MOV      Restore the data stack pointer.
        RP POP             Restore the return stack pointer.
        IP POP             Restore the interpretive pointer.
        NEXT               IP contains the pointer pointing to the next word to be
                      executed in this task. NEXT will continue the execution left
                      off last time.
        END-CODE

CODE PAUSE                 A dummy word allowing multitasker to be switched on and
                           off.
        NEXT               In the single user mode, PAUSE returns immediately
                      without doing anything.
        END-CODE           However, its code field will be patched so that the word
                           (PAUSE) will be invoked in the multitasking mode of
                      operation.
```

A few operators are defined to manipulate data stored in the user variables to control the tasks:

```
HEX 80 CONSTANT INT#          8086 software interrupt number, used to wake up a task.
```

Figure 23.1 The round-robin task scheduler.



```
: LOCAL     ( base addr --- addr1 ) Get the address of a user variable in another task's
                user area.
        UP @                    The origin of current user area.
        -                       Offset of current user variable from its origin.
        +                       Add offset to the origin of the other user area (base),
                        returning the address of the same user variable in the other
                task.
        ;

: @LINK         ( --- addr )    Return a pointer to the entry point in the next task.  LINK
                        Address of LINK in this task.
        DUP @ +                 Get the ENTRY in the next task.
        2+                      LINK field in the next task.   ;

: !LINK         ( addr --- )    Set the LINK field of the current task, given the origin of the
                                user area of the next task.
        LINK -          The relative distance from LINK to the other task.
        2+                      Relative distance from this LINK to the other LINK.     LINK !
                Store it in the current LINK.
        ;

: SLEEP         ( addr --- )    Make the addressed task pause indefinitely.
        E990                    90 is NOP and E9 is JMP in 8086 machine instruction.  JMP
                                (link) passes CPU to the next task whose address is in the
                        LINK field right after the ENTRY field.
        SWAP            Get the task address to top.
        ENTRY LOCAL             Get the address of the ENTRY field in the target task.     !
                        Store the sleep code in its ENTRY field and force that task to
                        pass control immediately to its next task.
        ;

: WAKE          ( addr --- )    Wake up a task so that it will execute in its next turn.     80CD
                        Machine instruction INT 80H which wakes up this task by a
                        software interrupt with vector number 80H.
        SWAP            Get the task's user area address.
        ENTRY LOCAL !           Store that wake code in the ENTRY field of the target task
                        and make it an active member in the round-robin loop.
        ;

: STOP      ( --- )     Make the current task pause indefinitely.
        UP @                    Get the address of the current task.
        SLEEP           Put it to sleep.
        PAUSE                   Stop right now.
        ;
```

23.4. THE MULTITASKER

The Forth multitasking is implemented using a round-robin scheduler and dispatcher technique. All tasks are linked into a loop. A task must use the PAUSE command explicitly to relinquish CPU control to the next task. If a task does not need the CPU service, it will pass the CPU control directly to the next task. When a task needs CPU, it will put a wake code in the ENTRY field in its user area. Next time when the control of CPU is passed to it, it will be able to grab the CPU and restart or continue on the execution left off last time. Each task therefore must include PAUSEs at

suitable intervals to let other tasks have a piece of the action. Otherwise a task can hold onto the CPU indefinitely and no other task can use the CPU. The cooperative nature of this scheme thus requires that each task be designed to pause regularly. The advantage is that each task can stop and restart at known points and the code to do the multitasking is simple and fast.

```
CODE MULTI          ( --- )          Install the multitasker's schedule/ dispatcher loop by
                                          patching the appropriate interrupt vector and enabling
                                     PAUSE.
        ' (PAUSE) @ # BX MOV         Copy the contents of code field of (PAUSE) to BX register.
                                          It is the starting address of the (PAUSE) code routine.
        BX ' PAUSE #) MOV Patch the code field of PAUSE with code of (PAUSE) so
                                     that the task will pause at PAUSE.
        ' RESTART @ # BX MOV         Get the RESTART code address.
        DS AX MOV
        AX PUSH                      Save DS register on data stack.
        AX AX SUB                    Clear AX register.
        AX DS MOV                    Clear DS register.
        CS AX MOV                    Copy code segment into AX.
        AX INT# 4 * 2+ #) MOV        Store the code segment in the second cell of the interrupt
                                          vector for this task.
        BX INT# 4 * #) MOV Store the RESTART address in the first cell of the interrupt
                                     vector. Hereafter, INT 80H will activate this task.
        AX POP
        AX DS MOV                    Restore the data segment register.
        NEXT
        END-CODE

: SINGLE            ( --- )          Remove the multitasker's scheduler/dispatcher loop.
        ['] PAUSE >BODY              Get the parameter field address of PAUSE, which points to a
                                          simple NEXT routine.
        ['] PAUSE !                  Restore the code field of PAUSE so that PAUSE will return
                                          immediately rather than go through (PAUSE) for the
                                          multitasker.
        ;
```

23.5. TASK DEFINITION

A task must be first defined as a word in the dictionary. At the same time, user area and space for two stacks must also be allocated for the task. The new task must then be installed in the round-robin loop. When functions must be performed by this task, the word to be executed by this task must be passed to the multitasker and the task must be waken. The tools to create and activate new tasks are discussed in this section.

```
: TASK:             ( size --- )     Create a new named task and initialize its user variables.
        CREATE                       Build an header for the task.
        TOS                          Address of the user area for the current task.
        HERE                         The user area of the new task.
```

#USER @	Size of the user area.
CMOVE	Copy the current user variables into the new user area for the new task.
@LINK	New user area.
UP @ -ROT	Save the current user area pointer at the bottom of the data stack.

```
        HERE UP !               Put new user area address in the user area pointer UP.
        !LINK           Store address of current user area in the LINK field of the
                        new task.
        DUP HERE +      Address of the space after the new user area and dictionary
                        space.
        DUP RP0 !               Initialize the return stack pointer of the new task.
        100 - SP0 !             Initialize the data stack pointer of the new task.
        SWAP UP !               Restore the user area pointer to the current user area.
        HERE ENTRY LOCAL !LINK  Store the address of the new task in the LINK field
                                of the current task.
        HERE #USER @ +          Starting address of the dictionary for the new task.
        HERE DP LOCAL !         Initialize the dictionary pointer of the new task.
        HERE SLEEP      Put the new task to sleep first.
        ALLOT                   Allocate space for the new task according to the size
                                parameter given on the stack initially.
        ;

: SET-TASK      ( ip task --- )  Assign an existing task to execute the code pointed to by ip
                                on stack.
        DUP SP0 LOCAL @         Get the top of data stack of the task to be used.
        2-                      Decrement stack pointer preparing a push.
        ROT OVER !              Push ip on data stack.
        2-                      Prepare another push.
        OVER RP0 LOCAL @        Get the new task's return stack pointer.
        OVER !                  Push it on the data stack.
        SWAP TOS LOCAL ! Store the data stack pointer in the TOS field of the new task.
                                These actions simulate (PAUSE) in a way that when the new
                                task is wakened the code pointed to by ip will be executed.  ;

: ACTIVATE      ( task --- )    Assign the invoked task to execute the following code, and
                                wake the task making it ready to execute these code.
        R>                      Address of the next code to be executed.
        OVER SET-TASK           Assign this code to the task.
        WAKE            wake the task.
        ;
```

23.6. BACKGROUND TASKS

A background task is some functions the computer does while still allowing the user to use the computer interactively doing programming and executing other programs. F83 allows the user to create many such tasks to run concurrently, using the task defining and control words. Here are some examples illustrating the command sequence to create background tasks and activate them.

```
: BACKGROUND:   ( --- )         Create a new task with 400 bytes of dictionary space.
                                Initialize this task to execute the following code.
        400 TASK:               Define a new task with the name following.
        HERE                    IP for code to be compiled so that it can be executed by the
```

	new task.
@LINK 2-	Address of the new task.
SET-TASK	Initialize the new task.
!CSP	Compiler error checking initial- ization.

```
    ]                       Turn on the compiler to compile following code to be
                        executed by the new task.
    ;
```

Now we will create the first background task, called SPOOLER:

```
BACKGROUND:  SPOOLER        ( --- )  Create a new task named spooler which will print the
                                     current file.
        1                           First screen to be listed.
        CAPACITY                    Last screen in the current file.
        SHOW                List the entire file.
        STOP                        Stop the task here.  STOP is needed at the end of a task.
        ;
```

Executing SPOOLER will print out the entire current file on the printer while the user can still user the terminal for normal activities. Low level input/output codes in SHOW contain enough PAUSE commands to alternate the spooling task with the terminal task to allow the user seemingly full control over the computer while it is also printing a long file.

SPOOLER can also be assigned a different function by the following definition:

```
: SPOOL-THIS        ( --- )         Assign new functions to an existing task.
        SPOOLER ACTIVATE            Force the task SPOOLER to execute the following code:     3 15
        [ SHADOW ]  SHOWInvoke the special SHOW command in the SHADOW
                            vocabulary to print shadow screens along twith he source
                    screens.
        STOP                        Terminate the task.
        ;
```

Another example is to use the computer to keep a counter which keeps the number of circles the multitasker running around the round-robin loop:

```
VARIABLE COUNTS

BACKGROUND:  COUNTER        Define a new background task.
        BEGIN               Beginning of an infinite loop.
                PAUSE               Allow other tasks to run once.
                1 COUNTS +! Increment the counter.
        AGAIN       ;
```

The task COUNTER executes an infinite loop, so STOP is not required at the end of the definition. However, note that you must use PAUSE in the loop, or no other task will be executed. PAUSE is built in all the input/output words, so that tasks which do I/O like SPOOLER do not have to use PAUSE explicitly.