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CP/M 2 INTERFACE GUIDE

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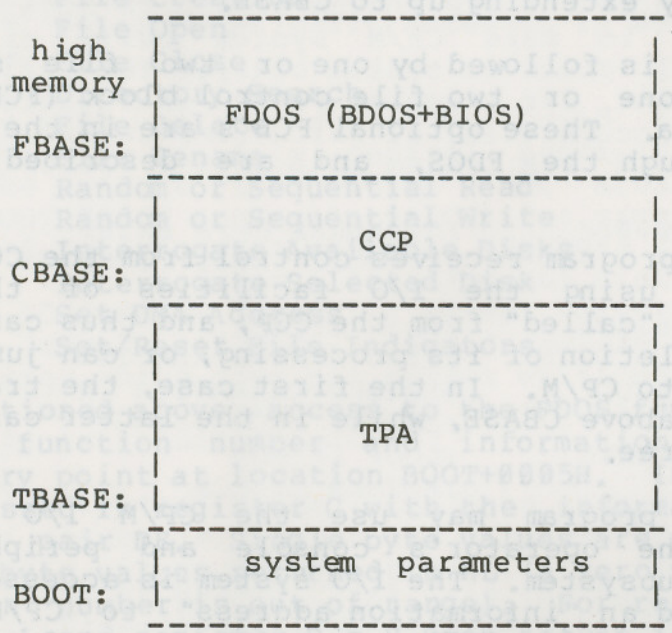
CP/M 2 INTERFACE GUIDE

1. INTRODUCTION.

This manual describes CP/M, release 2, system organization including the structure of memory and system entry points. The intention is to provide the necessary information required to write programs which operate under CP/M, and which use the peripheral and disk I/O facilities of the system.

CP/M is logically divided into four parts, called the Basic I/O System (BIOS), the Basic Disk Operating System (BDOS), the Console command processor (CCP), and the Transient Program Area (TPA). The BIOS is a hardware-dependent module which defines the exact low level interface to a particular computer system which is necessary for peripheral device I/O. Although a standard BIOS is supplied by Digital Research, explicit instructions are provided for field reconfiguration of the BIOS to match nearly any hardware environment (see the Digital Research manual entitled "CP/M Alteration Guide"). The BIOS and BDOS are logically combined into a single module with a common entry point, and referred to as the FDOS. The CCP is a distinct program which uses the FDOS to provide a human-oriented interface to the information which is cataloged on the backup storage device. The TPA is an area of memory (i.e., the portion which is not used by the FDOS and CCP) where various non-resident operating system commands and user programs are executed. The lower portion of memory is reserved for system information and is detailed later sections. Memory organization of the CP/M system in shown below:



The exact memory addresses corresponding to BOOT, TBASE, CBASE, and FBASE vary from version to version, and are described fully in the "CP/M Alteration Guide." All standard CP/M versions, however, assume BOOT = 0000H, which is the base of random access memory. The machine code found at location BOOT performs a system "warm start" which loads and initializes the programs and variables necessary to return control to the CCP. Thus, transient programs need only jump to location BOOT

to return control to CP/M at the command level. Further, the standard versions assume TBASE = BOOT+Ø1ØØH which is normally location Ø1ØØH. The principal entry point to the FDOS is at location BOOT+ØØØ5H (normally ØØØ5H) where a jump to FBASE is found. The address field at BOOT+ØØØ6H (normally ØØØ6H) contains the value of FBASE and can be used to determine the size of available memory, assuming the CCP is being overlayed by a transient program.

Transient programs are loaded into the TPA and executed as follows. The operator communicates with the CCP by typing command lines following each prompt. Each command line takes one of the forms:

```
command
command file1
command file1 file2
```

where "command" is either a built-in function such as DIR or TYPE, or the name of a transient command or program. If the command is a built-in function of CP/M, it is executed immediately. Otherwise, the CCP searches the currently addressed disk for a file by the name

```
command.COM
```

If the file is found, it is assumed to be a memory image of a program which executes in the TPA, and thus implicitly originates at TBASE in memory. The CCP loads the COM file from the disk into memory starting at TBASE and possibly extending up to CBASE.

If the command is followed by one or two file specifications, the CCP prepares one or two file control block (FCB) names in the system parameter area. These optional FCB's are in the form necessary to access files through the FDOS, and are described in the next section.

The transient program receives control from the CCP and begins execution, perhaps using the I/O facilities of the FDOS. The transient program is "called" from the CCP, and thus can simply return to the CCP upon completion of its processing, or can jump to BOOT to pass control back to CP/M. In the first case, the transient program must not use memory above CBASE, while in the latter case, memory up through FBASE-1 is free.

The transient program may use the CP/M I/O facilities to communicate with the operator's console and peripheral devices, including the disk subsystem. The I/O system is accessed by passing a "function number" and an "information address" to CP/M through the FDOS entry point at BOOT+ØØØ5H. In the case of a disk read, for example, the transient program sends the number corresponding to a disk read, along with the address of an FCB to the CP/M FDOS. The FDOS, in turn, performs the operation and returns with either a disk read completion indication or an error number indicating that the disk read was unsuccessful. The function numbers and error indicators are given in below.

2. OPERATING SYSTEM CALL CONVENTIONS.

The purpose of this section is to provide detailed information for performing direct operating system calls from user programs. Many of the functions listed below, however, are more simply accessed through the I/O macro library provided with the MAC macro assembler, and listed in the Digital Research manual entitled "MAC Macro Assembler: Language Manual and Applications Guide."

CP/M facilities which are available for access by transient programs fall into two general categories: simple device I/O, and disk file I/O. The simple device operations include:

Read a Console Character
Write a Console Character
Read a Sequential Tape Character
Write a Sequential Tape Character
Write a List Device Character
Get or Set I/O Status
Print Console Buffer
Read Console Buffer
Interrogate Console Ready

The FDOS operations which perform disk Input/Output are

Disk System Reset
Drive Selection
File Creation
File Open
File Close
Directory Search
File Delete
File Rename
Random or Sequential Read
Random or Sequential Write
Interrogate Available Disks
Interrogate Selected Disk
Set DMA Address
Set/Reset File Indicators

As mentioned above, access to the FDOS functions is accomplished by passing a function number and information address through the primary entry point at location BOOT+0005H. In general, the function number is passed in register C with the information address in the double byte pair DE. Single byte values are returned in register A, with double byte values returned in HL (a zero value is returned when the function number is out of range). For reasons of compatibility, register A = L and register B = H upon return in all cases. Note that the register passing conventions of CP/M agree with those of Intel's PL/M systems programming language. The list of CP/M function numbers is given below.

0	System Reset	19	Delete File
1	Console Input	20	Read Sequential
2	Console Output	21	Write Sequential
3	Reader Input	22	Make File
4	Punch Output	23	Rename File
5	List Output	24	Return Login Vector
6	Direct Console I/O	25	Return Current Disk
7	Get I/O Byte	26	Set DMA Address
8	Set I/O Byte	27	Get Addr(Alloc)
9	Print String	28	Write Protect Disk
10	Read Console Buffer	29	Get R/O Vector
11	Get Console Status	30	Set File Attributes
12	Return Version Number	31	Get Addr(Disk Parms)
13	Reset Disk System	32	Set/Get User Code
14	Select Disk	33	Read Random
15	Open File	34	Write Random
16	Close File	35	Compute File Size
17	Search for First	36	Set Random Record
18	Search for Next		

(Functions 28 and 32 should be avoided in application programs to maintain upward compatibility with MP/M.)

Upon entry to a transient program, the CCP leaves the stack pointer set to an eight level stack area with the CCP return address pushed onto the stack, leaving seven levels before overflow occurs. Although this stack is usually not used by a transient program (i.e., most transients return to the CCP though a jump to location 0000H), it is sufficiently large to make CP/M system calls since the FDOS switches to a local stack at system entry. The following assembly language program segment, for example, reads characters continuously until an asterisk is encountered, at which time control returns to the CCP (assuming a standard CP/M system with BOOT = 0000H):

```
BDOS    EQU     0005H       ;STANDARD CP/M ENTRY
CONIN   EQU     1           ;CONSOLE INPUT FUNCTION
;
        ORG     0100H       ;BASE OF TPA
NEXTC:  MVI     C,CONIN     ;READ NEXT CHARACTER
        CALL    BDOS        ;RETURN CHARACTER IN <A>
        CPI     '*'         ;END OF PROCESSING?
        JNZ     NEXTC       ;LOOP IF NOT
        RET                 ;RETURN TO CCP
        END
```

CP/M implements a named file structure on each disk, providing a logical organization which allows any particular file to contain any number of records from completely empty, to the full capacity of the drive. Each drive is logically distinct with a disk directory and file data area. The disk file names are in three parts: the drive select code, the file name consisting of one to eight non-blank characters, and the file type consisting of zero to three non-blank characters. The file type names the generic category of a particular file, while the file name distinguishes individual files in each category. The file types listed below name a few generic categories

which have been established, although they are generally arbitrary:

ASM	Assembler Source	PLI	PL/I Source File
PRN	Printer Listing	REL	Relocatable Module
HEX	Hex Machine Code	TEX	TEX Formatter Source
BAS	Basic Source File	BAK	ED Source Backup
INT	Intermediate Code	SYM	SID Symbol File
COM	CCP Command File	$$$	Temporary File

Source files are treated as a sequence of ASCII characters, where each "line" of the source file is followed by a carriage-return line-feed sequence (ØDH followed by ØAH). Thus one 128 byte CP/M record could contain several lines of source text. The end of an ASCII file is denoted by a control-Z character (1AH) or a real end of file, returned by the CP/M read operation. Control-Z characters embedded within machine code files (e.g., COM files) are ignored, however, and the end of file condition returned by CP/M is used to terminate read operations.

Files in CP/M can be thought of as a sequence of up to 65536 records of 128 bytes each, numbered from Ø through 65535, thus allowing a maximum of 8 megabytes per file. Note, however, that although the records may be considered logically contiguous, they may not be physically contiguous in the disk data area. Internally, all files are broken into 16K byte segments called logical extents, so that counters are easily maintained as 8-bit values. Although the decomposition into extents is discussed in the paragraphs which follow, they are of no particular consequence to the programmer since each extent is automatically accessed in both sequential and random access modes.

In the file operations starting with function number 15, DE usually addresses a file control block (FCB). Transient programs often use the default file control block area reserved by CP/M at location BOOT+ØØ5CH (normally ØØ5CH) for simple file operations. The basic unit of file information is a 128 byte record used for all file operations, thus a default location for disk I/O is provided by CP/M at location BOOT+ØØ8ØH (normally ØØ8ØH) which is the initial default DMA address (see function 26). All directory operations take place in a reserved area which does not affect write buffers as was the case in release 1, with the exception of Search First and Search Next, where compatibility is required.

The File Control Block (FCB) data area consists of a sequence of 33 bytes for sequential access and a series of 36 bytes in the case that the file is accessed randomly. The default file control block normally located at ØØ5CH can be used for random access files, since the three bytes starting at BOOT+ØØ7DH are available for this purpose. The FCB format is shown with the following fields:

```
|dr|f1|f2|/ /|f8|t1|t2|t3|ex|s1|s2|rc|d0|/ /|dn|cr|r0|r1|r2|
 00 01 02 ... 08 09 10 11 12 13 14 15 16 ... 31 32 33 34 35
```

where

dr — drive code (0 - 16)
0 => use default drive for file
1 => auto disk select drive A,
2 => auto disk select drive B,
...
16=> auto disk select drive P.

f1...f8 — contain the file name in ASCII upper case, with high bit = 0

t1,t2,t3 — contain the file type in ASCII upper case, with high bit = 0
t1', t2', and t3' denote the bit of these positions,
t1' = 1 => Read/Only file,
t2' = 1 => SYS file, no DIR list

ex — contains the current extent number, normally set to 00 by the user, but in range 0 - 31 during file I/O

s1 — reserved for internal system use

s2 — reserved for internal system use, set to zero on call to OPEN, MAKE, SEARCH

rc — record count for extent "ex," takes on values from 0 - 128

d0...dn — filled-in by CP/M, reserved for system use

cr — current record to read or write in a sequential file operation, normally set to zero by user

r0,r1,r2 — optional random record number in the range 0-65535, with overflow to r2, r0,r1 constitute a 16-bit value with low byte r0, and high byte r1

Each file being accessed through CP/M must have a corresponding FCB which provides the name and allocation information for all subsequent file operations. When accessing files, it is the programmer's responsibility to fill the lower sixteen bytes of the FCB and initialize the "cr" field. Normally, bytes 1 through 11 are set to the ASCII character values for the file name and file type, while all other fields are zero.

FCB's are stored in a directory area of the disk, and are brought into central memory before proceeding with file operations (see the OPEN and MAKE functions). The memory copy of the FCB is updated as file operations take place and later recorded permanently on disk at the termination of the file operation (see the CLOSE command).

The CCP constructs the first sixteen bytes of two optional FCB's for a transient by scanning the remainder of the line following the transient name, denoted by "file1" and "file2" in the prototype command line described above, with unspecified fields set to ASCII blanks. The first FCB is constructed at location BOOT+005CH, and can be used as-is for subsequent file operations. The second FCB occupies the d0 ... dn portion of the first FCB, and must be moved to another area of memory before use. If, for example, the operator types

```
PROGNAME B:X.ZOT Y.ZAP
```

the file PROGNAME.COM is loaded into the TPA, and the default FCB at BOOT+005CH is initialized to drive code 2, file name "X" and file type "ZOT". The second drive code takes the default value 0, which is placed at BOOT+006CH, with the file name "Y" placed into location BOOT+006DH and file type "ZAP" located 8 bytes later at BOOT+0075H. All remaining fields through "cr" are set to zero. Note again that it is the programmer's responsibility to move this second file name and type to another area, usually a separate file control block, before opening the file which begins at BOOT+005CH, due to the fact that the open operation will overwrite the second name and type.

If no file names are specified in the original command, then the fields beginning at BOOT+005DH and BOOT+006DH contain blanks. In all cases, the CCP translates lower case alphabetics to upper case to be consistent with the CP/M file naming conventions.

As an added convenience, the default buffer area at location BOOT+0080H is initialized to the command line tail typed by the operator following the program name. The first position contains the number of characters, with the characters themselves following the character count. Given the above command line, the area beginning at BOOT+0080H is initialized as follows:

```
BOOT+0080H:
+00 +01 +02 +03 +04 +05 +06 +07 +08 +09 +10 +11 +12 +13 +14
 14  " " "B" ":" "X" "." "Z" "O" "T" " " "Y" "." "Z" "A" "P"
```

where the characters are translated to upper case ASCII with uninitialized memory following the last valid character. Again, it is the responsibility of the programmer to extract the information from this buffer before any file operations are performed, unless the default DMA address is explicitly changed.

The individual functions are described in detail in the pages which follow.

```
****************************************
*                                      *
*  FUNCTION Ø:  System Reset           *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  ØØH              *
****************************************
```

The system reset function returns control to the CP/M operating system at the CCP level. The CCP re-initializes the disk subsystem by selecting and logging-in disk drive A. This function has exactly the same effect as a jump to location BOOT.

```
****************************************
*                                      *
*  FUNCTION 1:  CONSOLE INPUT          *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  Ø1H              *
*                                      *
*  Returned   Value:                   *
*      Register   A:  ASCII Character  *
****************************************
```

The console input function reads the next console character to register A. Graphic characters, along with carriage return, line feed, and backspace (ctl-H) are echoed to the console. Tab characters (ctl-I) are expanded in columns of eight characters. A check is made for start/stop scroll (ctl-S) and start/stop printer echo (ctl-P). The FDOS does not return to the calling program until a character has been typed, thus suspending execution if a character is not ready.

```
****************************************
*                                      *
*  FUNCTION 2:  CONSOLE OUTPUT         *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  Ø2H              *
*      Register   E:  ASCII Character  *
*                                      *
****************************************
```

The ASCII character from register E is sent to the console device. Similar to function 1, tabs are expanded and checks are made for start/stop scroll and printer echo.

```
****************************************
*                                      *
*  FUNCTION 3:  READER INPUT           *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  Ø3H              *
*                                      *
*  Returned   Value:                   *
*      Register   A:  ASCII Character  *
****************************************
```

The Reader Input function reads the next character from the logical reader into register A (see the IOBYTE definition in the "CP/M Alteration Guide"). Control does not return until the character has been read.

```
****************************************
*                                      *
*  FUNCTION 4:  PUNCH OUTPUT           *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  Ø4H              *
*      Register   E:  ASCII Character  *
*                                      *
****************************************
```

The Punch Output function sends the character from register E to the logical punch device.

```
****************************************
*                                      *
*  FUNCTION 5:  LIST OUTPUT            *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  Ø5H              *
*      Register   E:  ASCII Character  *
*                                      *
****************************************
```

The List Output function sends the ASCII character in register E to the logical listing device.

```
**************************************
*                                    *
*  FUNCTION 6:  DIRECT CONSOLE I/O   *
*                                    *
**************************************
*  Entry Parameters:                 *
*      Register   C:  Ø6H            *
*      Register   E:  ØFFH (input) or *
*                     char (output)  *
*                                    *
*  Returned   Value:                 *
*      Register   A:  char or status  *
*                     (no value)     *
**************************************
```

Direct console I/O is supported under CP/M for those specialized applications where unadorned console input and output is required. Use of this function should, in general, be avoided since it bypasses all of CP/M's normal control character functions (e.g., control-S and control-P). Programs which perform direct I/O through the BIOS under previous releases of CP/M, however, should be changed to use direct I/O under BDOS so that they can be fully supported under future releases of MP/M and CP/M.

Upon entry to function 6, register E either contains hexadecimal FF, denoting a console input request, or register E contains an ASCII character. If the input value is FF, then function 6 returns A = ØØ if no character is ready, otherwise A contains the next console input character.

If the input value in E is not FF, then function 6 assumes that E contains a valid ASCII character which is sent to the console.

```
****************************************
*                                      *
*  FUNCTION 7:  GET I/O BYTE           *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  07H              *
*                                      *
*  Returned   Value:                   *
*      Register   A:  I/O Byte Value   *
****************************************
```

The Get I/O Byte function returns the current value of IOBYTE in register A. See the "CP/M Alteration Guide" for IOBYTE definition.

```
****************************************
*                                      *
*  FUNCTION 8:  SET I/O BYTE           *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  08H              *
*      Register   E:  I/O Byte Value   *
*                                      *
****************************************
```

The Set I/O Byte function changes the system IOBYTE value to that given in register E.

```
****************************************
*                                      *
*  FUNCTION 9:  PRINT STRING           *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  09H              *
*      Registers DE:  String Address   *
*                                      *
****************************************
```

The Print String function sends the character string stored in memory at the location given by DE to the console device, until a "$" is encountered in the string. Tabs are expanded as in function 2, and checks are made for start/stop scroll and printer echo.

```
**************************************
*                                    *
*  FUNCTION 1Ø: READ CONSOLE BUFFER  *
*                                    *
**************************************
*  Entry Parameters:                 *
*     Register  C: ØAH               *
*     Registers DE: Buffer Address   *
*                                    *
*  Returned   Value:                 *
*     Console Characters in Buffer   *
**************************************
```

The Read Buffer function reads a line of edited console input into a buffer addressed by registers DE. Console input is terminated when either the input buffer overflows. The Read Buffer takes the form:

```
DE: +Ø +1 +2 +3 +4 +5 +6 +7 +8    . . .   +n
    ---------------------------------------
    |mx|nc|c1|c2|c3|c4|c5|c6|c7|   . . .  |??|
    ---------------------------------------
```

where "mx" is the maximum number of characters which the buffer will hold (1 to 255), "nc" is the number of characters read (set by FDOS upon return), followed by the characters read from the console. if nc < mx, then uninitialized positions follow the last character, denoted by "??" in the above figure. A number of control functions are recognized during line editing:

```
rub/del removes and echoes the last character
 ctl-C  reboots when at the beginning of line
 ctl-E  causes physical end of line
 ctl-H  backspaces one character position
 ctl-J  (line feed) terminates input line
 ctl-M  (return) terminates input line
 ctl-R  retypes the current line after new line
 ctl-U  removes currnt line after new line
 ctl-X  backspaces to beginning of current line
```

Note also that certain functions which return the carriage to the leftmost position (e.g., ctl-X) do so only to the column position where the prompt ended (in earlier releases, the carriage returned to the extreme left margin). This convention makes operator data input and line correction more legible.

```
****************************************
*                                      *
*  FUNCTION 11: GET CONSOLE STATUS     *
*                                      *
****************************************
*  Entry Parameters:                   *
*     Register   C:  0BH               *
*                                      *
*  Returned   Value:                   *
*     Register   A:  Console Status    *
****************************************
```

The Console Status function checks to see if a character has been typed at the console. If a character is ready, the value 0FFH is returned in register A. Otherwise a 00H value is returned.

```
****************************************
*                                      *
*  FUNCTION 12: RETURN VERSION NUMBER  *
*                                      *
****************************************
*  Entry Parameters:                   *
*     Register   C:  0CH               *
*                                      *
*  Returned   Value:                   *
*     Registers HL:  Version Number    *
****************************************
```

Function 12 provides information which allows version independent programming. A two-byte value is returned, with H = 00 designating the CP/M release (H = 01 for MP/M), and L = 00 for all releases previous to 2.0. CP/M 2.0 returns a hexadecimal 20 in register L, with subsequent version 2 releases in the hexadecimal range 21, 22, through 2F. Using function 12, for example, you can write application programs which provide both sequential and random access functions, with random access disabled when operating under early releases of CP/M.

```
****************************************
*                                      *
*  FUNCTION 13: RESET DISK SYSTEM      *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  ØDH              *
*                                      *
****************************************
```

The Reset Disk Function is used to programmatically restore the file system to a reset state where all disks are set to read/write (see functions 28 and 29), only disk drive A is selected, and the default DMA address is reset to BOOT+ØØ8ØH. This function can be used, for example, by an application program which requires a disk change without a system reboot.

```
****************************************
*                                      *
*  FUNCTION 14: SELECT DISK            *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  ØEH              *
*      Register   E:  Selected Disk    *
*                                      *
****************************************
```

The Select Disk function designates the disk drive named in register E as the default disk for subsequent file operations, with E = Ø for drive A, 1 for drive B, and so-forth through 15 corresponding to drive P in a full sixteen drive system. The drive is placed in an "on-line" status which, in particular, activates its directory until the next cold start, warm start, or disk system reset operation. If the disk media is changed while it is on-line, the drive automatically goes to a read/only status in a standard CP/M environment (see function 28). FCB's which specify drive code zero (dr = ØØH) automatically reference the currently selected default drive. Drive code values between 1 and 16, however, ignore the selected default drive and directly reference drives A through P.

```
****************************************
*                                      *
*  FUNCTION 15: OPEN FILE              *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  ØFH              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Directory Code   *
****************************************
```

The Open File operation is used to activate a file which currently exists in the disk directory for the currently active user number. The FDOS scans the referenced disk directory for a match in positions 1 through 14 of the FCB referenced by DE (byte s1 is automatically zeroed), where an ASCII question mark (3FH) matches any directory character in any of these positions. Normally, no question marks are included and, further, bytes "ex" and "s2" of the FCB are zero.

If a directory element is matched, the relevant directory information is copied into bytes dØ through dn of the FCB, thus allowing access to the files through subsequent read and write operations. Note that an existing file must not be accessed until a sucessful open operation is completed. Upon return, the open function returns a "directory code" with the value Ø through 3 if the open was successful, or ØFFH (255 decimal) if the file cannot be found. If question marks occur in the FCB then the first matching FCB is activated. Note that the current record ("cr") must be zeroed by the program if the file is to be accessed sequentially from the first record.

```
****************************************
*                                      *
*  FUNCTION 16: CLOSE FILE             *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  1ØH              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Directory Code   *
****************************************
```

The Close File function performs the inverse of the open file function. Given that the FCB addressed by DE has been previously activated through an open or make function (see functions 15 and 22), the close function permanently records the new FCB in the referenced disk directory. The FCB matching process for the close is identical to the open function. The directory code returned for a successful close operation is Ø, 1, 2, or 3, while a ØFFH (255 decimal) is returned if the file name cannot be found in the directory. A file need not be closed if only read operations have taken place. If write operations have occurred, however, the close operation is necessary to permanently record the new directory information.

```
****************************************
*                                      *
*  FUNCTION 17: SEARCH FOR FIRST       *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  11H              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Directory Code   *
****************************************
```

Search First scans the directory for a match with the file given by the FCB addressed by DE. The value 255 (hexadecimal FF) is returned if the file is not found, otherwise Ø, 1, 2, or 3 is returned indicating the file is present. In the case that the file is found, the current DMA address is filled with the record containing the directory entry, and the relative starting position is A * 32 (i.e., rotate the A register left 5 bits, or ADD A five times). Although not normally required for application programs, the directory information can be extracted from the buffer at this position.

An ASCII question mark (63 decimal, 3F hexadecimal) in any position from "f1" through "ex" matches the corresponding field of any directory entry on the default or auto-selected disk drive. If the "dr" field contains an ASCII question mark, then the auto disk select function is disabled, the default disk is searched, with the search function returning any matched entry, allocated or free, belonging to any user number. This latter function is not normally used by application programs, but does allow complete flexibility to scan all current directory values. If the "dr" field is not a question mark, the "s2" byte is automatically zeroed.

```
****************************************
*                                      *
*  FUNCTION 18: SEARCH FOR NEXT        *
*                                      *
****************************************
*  Entry Parameters:                   *
*     Register   C:  12H               *
*                                      *
*  Returned   Value:                   *
*     Register   A:  Directory Code    *
****************************************
```

The Search Next function is similar to the Search First function, except that the directory scan continues from the last matched entry. Similar to function 17, function 18 returns the decimal value 255 in A when no more directory items match.

```
****************************************
*                                      *
*  FUNCTION 19: DELETE FILE            *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  13H              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Directory Code   *
****************************************
```

The Delete File function removes files which match the FCB addressed by DE. The filename and type may contain ambiguous references (i.e., question marks in various positions), but the drive select code cannot be ambiguous, as in the Search and Search Next functions.

Function 19 returns a decimal 255 if the referenced file or files cannot be found, otherwise a value in the range Ø to 3 is returned.

```
****************************************
*                                      *
*  FUNCTION 2Ø: READ SEQUENTIAL        *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  14H              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Directory Code   *
****************************************
```

Given that the FCB addressed by DE has been activated through an open or make function (numbers 15 and 22), the Read Sequential function reads the next 128 byte record from the file into memory at the current DMA address. the record is read from position "cr" of the extent, and the "cr" field is automatically incremented to the next record position. If the "cr" field overflows then the next logical extent is automatically opened and the "cr" field is reset to zero in preparation for the next read operation. The value ØØH is returned in the A register if the read operation was successful, while a non-zero value is returned if no data exists at the next record position (e.g., end of file occurs).

```
****************************************
*                                      *
*  FUNCTION 21: WRITE SEQUENTIAL       *
*                                      *
****************************************
*  Entry Parameters:                   *
*     Register  C:  15H                *
*     Registers DE:  FCB Address       *
*                                      *
*  Returned  Value:                    *
*     Register  A:  Directory Code     *
****************************************
```

Given that the FCb addressed by DE has been activated through an open or make function (numbers 15 and 22), the Write Sequential function writes the 128 byte data record at the current DMA address to the file named by the FCB. the record is placed at position "cr" of the file, and the "cr" field is automatically incremented to the next record position. If the "cr" field overflows then the next logical extent is automatically opened and the "cr" field is reset to zero in preparation for the next write operation. Write operations can take place into an existing file, in which case newly written records overlay those which already exist in the file. Register A = ØØH upon return from a successful write operation, while a non-zero value indicates an unsuccessful write due to a full disk.

```
****************************************
*                                      *
*  FUNCTION 22: MAKE FILE              *
*                                      *
****************************************
*  Entry Parameters:                   *
*     Register  C:  16H                *
*     Registers DE:  FCB Address       *
*                                      *
*  Returned  Value:                    *
*     Register  A:  Directory Code     *
****************************************
```

The Make File operation is similar to the open file operation except that the FCB must name a file which does not exist in the currently referenced disk directory (i.e., the one named explicitly by a non-zero "dr" code, or the default disk if "dr" is zero). The FDOS creates the file and initializes both the directory and main memory value to an empty file. The programmer must ensure that no duplicate file names occur, and a preceding delete operation is sufficient if there is any possibility of duplication. Upon return, register A = Ø, 1, 2, or 3 if the operation was successful and ØFFH (255 decimal) if no more directory space is available. The make function has the side-effect of activating the FCB and thus a subsequent open is not necessary.

```
****************************************
*                                      *
*  FUNCTION 23: RENAME FILE            *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  17H              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Directory Code   *
****************************************
```

The Rename function uses the FCB addressed by DE to change all occurrences of the file named in the first 16 bytes to the file named in the second 16 bytes. The drive code "dr" at position Ø is used to select the drive, while the drive code for the new file name at position 16 of the FCB is assumed to be zero. Upon return, register A is set to a value between Ø and 3 if the rename was successful, and ØFFH (255 decimal) if the first file name could not be found in the directory scan.

```
****************************************
*                                      *
*  FUNCTION 24: RETURN LOGIN VECTOR    *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  18H              *
*                                      *
*  Returned   Value:                   *
*      Registers HL:  Login Vector     *
****************************************
```

The login vector value returned by CP/M is a 16-bit value in HL, where the least significant bit of L corresponds to the first drive A, and the high order bit of H corresponds to the sixteenth drive, labelled P. A "Ø" bit indicates that the drive is not on-line, while a "1" bit marks an drive that is actively on-line due to an explicit disk drive selection, or an implicit drive select caused by a file operation which specified a non-zero "dr" field. Note that compatibility is maintained with earlier releases, since registers A and L contain the same values upon return.

```
****************************************
*                                      *
*  FUNCTION 25: RETURN CURRENT DISK    *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  19H              *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Current Disk     *
****************************************
```

Function 25 returns the currently selected default disk number in register A. The disk numbers range from 0 through 15 corresponding to drives A through P.

```
****************************************
*                                      *
*  FUNCTION 26: SET DMA ADDRESS        *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  1AH              *
*      Registers DE:  DMA Address      *
*                                      *
****************************************
```

"DMA" is an acronym for Direct Memory Address, which is often used in connection with disk controllers which directly access the memory of the mainframe computer to transfer data to and from the disk subsystem. Although many computer systems use non-DMA access (i.e., the data is transfered through programmed I/O operations), the DMA address has, in CP/M, come to mean the address at which the 128 byte data record resides before a disk write and after a disk read. Upon cold start, warm start, or disk system reset, the DMA address is automatically set to BOOT+0080H. The Set DMA function, however, can be used to change this default value to address another area of memory where the data records reside. Thus, the DMA address becomes the value specified by DE until it is changed by a subsequent Set DMA function, cold start, warm start, or disk system reset.

```
****************************************
*                                      *
*  FUNCTION 27: GET ADDR(ALLOC)        *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  1BH              *
*                                      *
*  Returned   Value:                   *
*      Registers HL:  ALLOC Address    *
****************************************
```

An "allocation vector" is maintained in main memory for each on-line disk drive. Various system programs use the information provided by the allocation vector to determine the amount of remaining storage (see the STAT program). Function 27 returns the base address of the allocation vector for the currently selected disk drive. The allocation information may, however, be invalid if the selected disk has been marked read/only. Although this function is not normally used by application programs, additional details of the allocation vector are found in the "CP/M Alteration Guide."

```
****************************************
*                                      *
*  FUNCTION 28: WRITE PROTECT DISK     *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  1CH              *
*                                      *
****************************************
```

The disk write protect function provides temporary write protection for the currently selected disk. Any attempt to write to the disk, before the next cold or warm start operation produces the message

```
Bdos Err on d: R/O
```

```
****************************************
*                                      *
*  FUNCTION 29: GET READ/ONLY VECTOR   *
*                                      *
****************************************
*  Entry Parameters:                   *
*     Register   C:  1DH               *
*                                      *
*  Returned   Value:                   *
*        Registers HL:  R/O Vector Value*
****************************************
```

Function 29 returns a bit vector in register pair HL which indicates drives which have the temporary read/only bit set. Similar to function 24, the least significant bit corresponds to drive A, while the most significant bit corresponds to drive P. The R/O bit is set either by an explicit call to function 28, or by the automatic software mechanisms within CP/M which detect changed disks.

```
****************************************
*                                      *
*  FUNCTION 30: SET FILE ATTRIBUTES    *
*                                      *
****************************************
*  Entry Parameters:                   *
*     Register   C:  1EH               *
*     Registers DE:  FCB Address       *
*                                      *
*  Returned   Value:                   *
*     Register   A:  Directory Code    *
****************************************
```

The Set File Attributes function allows programmatic manipulation of permanent indicators attached to files. In particular, the R/O and System attributes (t1' and t2') can be set or reset. The DE pair addresses an unambiguous file name with the appropriate attributes set or reset. Function 30 searches for a match, and changes the matched directory entry to contain the selected indicators. Indicators f1' through f4' are not presently used, but may be useful for applications programs, since they are not involved in the matching process during file open and close operations. Indicators f5' through f8' and t3' are reserved for future system expansion.

```
*****************************************
*                                       *
*  FUNCTION 31: GET ADDR(DISK PARMS)    *
*                                       *
*****************************************
*  Entry Parameters:                    *
*      Register   C:  1FH               *
*                                       *
*  Returned   Value:                    *
*      Registers HL:  DPB Address       *
*****************************************
```

The address of the BIOS resident disk parameter block is returned in HL as a result of this function call. This address can be used for either of two purposes. First, the disk parameter values can be extracted for display and space computation purposes, or transient programs can dynamically change the values of current disk parameters when the disk environment changes, if required. Normally, application programs will not require this facility.

```
*****************************************
*                                       *
*  FUNCTION 32: SET/GET USER CODE       *
*                                       *
*****************************************
*  Entry Parameters:                    *
*      Register   C:  20H               *
*      Register   E:  0FFH (get) or     *
*                     User Code (set)   *
*                                       *
*  Returned   Value:                    *
*      Register   A:  Current Code or   *
*                     (no value)        *
*****************************************
```

An application program can change or interrogate the currently active user number by calling function 32. If register E = 0FFH, then the value of the current user number is returned in register A, where the value is in the range 0 to 31. If register E is not 0FFH, then the current user number is changed to the value of E (modulo 32).

```
****************************************
*                                      *
*  FUNCTION 33: READ RANDOM            *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  21H              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Return Code      *
****************************************
```

The Read Random function is similar to the sequential file read operation of previous releases, except that the read operation takes place at a particular record number, selected by the 24-bit value constructed from the three byte field following the FCB (byte positions r0 at 33, r1 at 34, and r2 at 35). Note that the sequence of 24 bits is stored with least significant byte first (r0), middle byte next (r1), and high byte last (r2). CP/M does not reference byte r2, except in computing the size of a file (function 35). Byte r2 must be zero, however, since a non-zero value indicates overflow past the end of file.

Thus, the r0,r1 byte pair is treated as a double-byte, or "word" value, which contains the record to read. This value ranges from 0 to 65535, providing access to any particular record of the 8 megabyte file. In order to process a file using random access, the base extent (extent 0) must first be opened. Although the base extent may or may not contain any allocated data, this ensures that the file is properly recorded in the directory, and is visible in DIR requests. The selected record number is then stored into the random record field (r0,r1), and the BDOS is called to read the record. Upon return from the call, register A either contains an error code, as listed below, or the value 00 indicating the operation was successful. In the latter case, the current DMA address contains the randomly accessed record. Note that contrary to the sequential read operation, the record number is not advanced. Thus, subsequent random read operations continue to read the same record.

Upon each random read operation, the logical extent and current record values are automatically set. Thus, the file can be sequentially read or written, starting from the current randomly accessed position. Note, however, that in this case, the last randomly read record will be re-read as you switch from random mode to sequential read, and the last record will be re-written as you switch to a sequential write operation. You can, of course, simply advance the random record position following each random read or write to obtain the effect of a sequential I/O operation.

Error codes returned in register A following a random read are listed below.

```
Ø1  reading unwritten data
Ø2  (not returned in random mode)
Ø3  cannot close current extent
Ø4  seek to unwritten extent
Ø5  (not returned in read mode)
Ø6  seek past physical end of disk
```

Error code Ø1 and Ø4 occur when a random read operation accesses a data block which has not been previously written, or an extent which has not been created, which are equivalent conditions. Error 3 does not normally occur under proper system operation, but can be cleared by simply re-reading, or re-opening extent zero as long as the disk is not physically write protected. Error code Ø6 occurs whenever byte r2 is non-zero under the current 2.Ø release. Normally, non-zero return codes can be treated as missing data, with zero return codes indicating operation complete.

```
****************************************
*                                      *
*  FUNCTION 34: WRITE RANDOM           *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  22H              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Register   A:  Return Code      *
****************************************
```

The Write Random operation is initiated similar to the Read Random call, except that data is written to the disk from the current DMA address. Further, if the disk extent or data block which is the target of the write has not yet been allocated, the allocation is performed before the write operation continues. As in the Read Random operation, the random record number is not changed as a result of the write. The logical extent number and current record positions of the file control block are set to correspond to the random record which is being written. Again, sequential read or write operations can commence following a random write, with the notation that the currently addressed record is either read or rewritten again as the sequential operation begins. You can also simply advance the random record position following each write to get the effect of a sequential write operation. Note that in particular, reading or writing the last record of an extent in random mode does not cause an automatic extent switch as it does in sequential mode.

The error codes returned by a random write are identical to the random read operation with the addition of error code Ø5, which indicates that a new extent cannot be created due to directory overflow.

```
****************************************
*                                      *
*  FUNCTION 35: COMPUTE FILE SIZE      *
*                                      *
****************************************
*  Entry Parameters:                   *
*      Register   C:  23H              *
*      Registers DE:  FCB Address      *
*                                      *
*  Returned   Value:                   *
*      Random Record Field Set         *
****************************************
```

When computing the size of a file, the DE register pair addresses an FCB in random mode format (bytes r0, r1, and r2 are present). The FCB contains an unambiguous file name which is used in the directory scan. Upon return, the random record bytes contain the "virtual" file size which is, in effect, the record address of the record following the end of the file. if, following a call to function 35, the high record byte r2 is 01, then the file contains the maximum record count 65536. Otherwise, bytes r0 and r1 constitute a 16-bit value (r0 is the least significant byte, as before) which is the file size.

Data can be appended to the end of an existing file by simply calling function 35 to set the random record position to the end of file, then performing a sequence of random writes starting at the preset record address.

The virtual size of a file corresponds to the physical size when the file is written sequentially. If, instead, the file was created in random mode and "holes" exist in the allocation, then the file may in fact contain fewer records than the size indicates. If, for example, only the last record of an eight megabyte file is written in random mode (i.e., record number 65535), then the virtual size is 65536 records, although only one block of data is actually allocated.

```
****************************************
*                                      *
*  FUNCTION 36: SET RANDOM RECORD      *
*                                      *
****************************************
*  Entry Parameters:                   *
*        Register   C:  24H            *
*        Registers DE:  FCB Address    *
*                                      *
*  Returned   Value:                   *
*        Random Record Field Set       *
****************************************
```

The Set Random Record function causes the BDOS to automatically produce the random record position from a file which has been read or written sequentially to a particular point. The function can be useful in two ways.

First, it is often necessary to initially read and scan a sequential file to extract the positions of various "key" fields. As each key is encountered, function 36 is called to compute the random record position for the data corresponding to this key. If the data unit size is 128 bytes, the resulting record position is placed into a table with the key for later retrieval. After scanning the entire file and tabularizing the keys and their record numbers, you can move instantly to a particular keyed record by performing a random read using the corresponding random record number which was saved earlier. The scheme is easily generalized when variable record lengths are involved since the program need only store the buffer-relative byte position along with the key and record number in order to find the exact starting position of the keyed data at a later time.

A second use of function 36 occurs when switching from a sequential read or write over to random read or write. A file is sequentially accessed to a particular point in the file, function 36 is called which sets the record number, and subsequent random read and write operations continue from the selected point in the file.

3. A SAMPLE FILE-TO-FILE COPY PROGRAM.

The program shown below provides a relatively simple example of file operations. The program source file is created as COPY.ASM using the CP/M ED program and then assembled using ASM or MAC, resulting in a "HEX" file. The LOAD program is the used to produce a COPY.COM file which executes directly under the CCP. The program begins by setting the stack pointer to a local area, and then proceeds to move the second name from the default area at 006CH to a 33-byte file control block called DFCB. The DFCB is then prepared for file operations by clearing the current record field. At this point, the source and destination FCB's are ready for processing since the SFCB at 005CH is properly set-up by the CCP upon entry to the COPY program. That is, the first name is placed into the default fcb, with the proper fields zeroed, including the current record field at 007CH. The program continues by opening the source file, deleting any exising destination file, and then creating the destination file. If all this is successful, the program loops at the label COPY until each record has been read from the source file and placed into the destination file. Upon completion of the data transfer, the destination file is closed and the program returns to the CCP command level by jumping to BOOT.

```
                ;       sample file-to-file copy program
                ;
                ;       at the ccp level, the command
                ;
                ;               copy a:x.y b:u.v
                ;
                ;       copies the file named x.y from drive
                ;       a to a file named u.v on drive b.
                ;
0000 =          boot    equ     0000h   ; system reboot
0005 =          bdos    equ     0005h   ; bdos entry point
005c =          fcb1    equ     005ch   ; first file name
005c =          sfcb    equ     fcb1    ; source fcb
006c =          fcb2    equ     006ch   ; second file name
0080 =          dbuff   equ     0080h   ; default buffer
0100 =          tpa     equ     0100h   ; beginning of tpa
                ;
0009 =          printf  equ     9       ; print buffer func#
000f =          openf   equ     15      ; open file func#
0010 =          closef  equ     16      ; close file func#
0013 =          deletef equ     19      ; delete file func#
0014 =          readf   equ     20      ; sequential read
0015 =          writef  equ     21      ; sequential write
0016 =          makef   equ     22      ; make file func#
                ;
0100            org     tpa     ; beginning of tpa
0100 311b02             lxi     sp,stack; local stack
                ;
                ;       move second file name to dfcb
0103 0e10               mvi     c,16    ; half an fcb
```

```
0105 116c00          lxi     d,fcb2  ; source of move
0108 21da01          lxi     h,dfcb  ; destination fcb
010b 1a      mfcb:   ldax    d       ; source fcb
010c 13              inx     d       ; ready next
010d 77              mov     m,a     ; dest fcb
010e 23              inx     h       ; ready next
010f 0d              dcr     c       ; count 16...0
0110 c20b01          jnz     mfcb    ; loop 16 times
                ;
                ;       name has been moved, zero cr
0113 af              xra     a       ; a = 00h
0114 32fa01          sta     dfcbcr  ; current rec = 0
                ;
                ;       source and destination fcb's ready
                ;
0117 115c00          lxi     d,sfcb  ; source file
011a cd6901          call    open    ; error if 255
011d 118701          lxi     d,nofile; ready message
0120 3c              inr     a       ; 255 becomes 0
0121 cc6101          cz      finis   ; done if no file
                ;
                ;       source file open, prep destination
0124 11da01          lxi     d,dfcb  ; destination
0127 cd7301          call    delete  ; remove if present
                ;
012a 11da01          lxi     d,dfcb  ; destination
012d cd8201          call    make    ; create the file
0130 119601          lxi     d,nodir ; ready message
0133 3c              inr     a       ; 255 becomes 0
0134 cc6101          cz      finis   ; done if no dir space
                ;
                ;       source file open, dest file open
                ;       copy until end of file on source
                ;
0137 115c00  copy:   lxi     d,sfcb  ; source
013a cd7801          call    read    ; read next record
013d b7              ora     a       ; end of file?
013e c25101          jnz     eofile  ; skip write if so
                ;
                ;       not end of file, write the record
0141 11da01          lxi     d,dfcb  ; destination
0144 cd7d01          call    write   ; write record
0147 11a901          lxi     d,space ; ready message
014a b7              ora     a       ; 00 if write ok
014b c46101          cnz     finis   ; end if so
014e c33701          jmp     copy    ; loop until eof
                ;
               eofile: ; end of file, close destination
0151 11da01          lxi     d,dfcb  ; destination
0154 cd6e01          call    close   ; 255 if error
0157 21bb01          lxi     h,wrprot; ready message
015a 3c              inr     a       ; 255 becomes 00
015b cc6101          cz      finis   ; shouldn't happen
                ;
                ;       copy operation complete, end
```

```
015e 11cc01          lxi     d,normal; ready message
                ;
                finis:  ; write message given by de, reboot
0161 0e09            mvi     c,printf
0163 cd0500          call    bdos    ; write message
0166 c30000          jmp     boot    ; reboot system
                ;
                ;       system interface subroutines
                ;       (all return directly from bdos)
                ;
0169 0e0f       open:   mvi     c,openf
016b c30500          jmp     bdos
                ;
016e 0e10       close:  mvi     c,closef
0170 c30500          jmp     bdos
                ;
0173 0e13       delete: mvi     c,deletef
0175 c30500          jmp     bdos
                ;
0178 0e14       read:   mvi     c,readf
017a c30500          jmp     bdos
                ;
017d 0e15       write:  mvi     c,writef
017f c30500          jmp     bdos
                ;
0182 0e16       make:   mvi     c,makef
0184 c30500          jmp     bdos
                ;
                ;       console messages
0187 6e6f20fnofile: db  'no source file$'
0196 6e6f209nodir:  db  'no directory space$'
01a9 6f7574fspace:  db  'out of data space$'
01bb 7772695wrprot: db  'write protected?$'
01cc 636f700normal: db  'copy complete$'
                ;
                ;       data areas
01da            dfcb:   ds      33      ; destination fcb
01fa =          dfcbcr  equ     dfcb+32 ; current record
                ;
01fb                    ds      32      ; 16 level stack
                stack:
021b                    end
```

Note that there are several simplifications in this particular program. First, there are no checks for invalid file names which could, for example, contain ambiguous references. This situation could be detected by scanning the 32 byte default area starting at location 005CH for ASCII question marks. A check should also be made to ensure that the file names have, in fact, been included (check locations 005DH and 006DH for non-blank ASCII characters). Finally, a check should be made to ensure that the source and destination file names are different. A speed improvement could be made by buffering more data on each read operation. One could, for example, determine

the size of memory by fetching FBASE from location 0006H and use the entire remaining portion of memory for a data buffer. In this case, the programmer simply resets the DMA address to the next successive 128 byte area before each read. Upon writing to the destination file, the DMA address is reset to the beginning of the buffer and incremented by 128 bytes to the end as each record is transferred to the destination file.

4. A SAMPLE FILE DUMP UTILITY.

The file dump program shown below is slightly more complex than the simple copy program given in the previous section. The dump program reads an input file, specified in the CCP command line, and displays the content of each record in hexadecimal format at the console. Note that the dump program saves the CCP's stack upon entry, resets the stack to a local area, and restores the CCP's stack before returning directly to the CCP. Thus, the dump program does not perform and warm start at the end of processing.

```
                ; DUMP program reads input file and displays hex data
                ;
0100                    org     100h
0005 =          bdos    equ     0005h   ;dos entry point
0001 =          cons    equ     1       ;read console
0002 =          typef   equ     2       ;type function
0009 =          printf  equ     9       ;buffer print entry
000b =          brkf    equ     11      ;break key function (true if char
000f =          openf   equ     15      ;file open
0014 =          readf   equ     20      ;read function
                ;
005c =          fcb     equ     5ch     ;file control block address
0080 =          buff    equ     80h     ;input disk buffer address
                ;
                ;       non graphic characters
000d =          cr      equ     0dh     ;carriage return
000a =          lf      equ     0ah     ;line feed
                ;
                ;       file control block definitions
005c =          fcbdn   equ     fcb+0   ;disk name
005d =          fcbfn   equ     fcb+1   ;file name
0065 =          fcbft   equ     fcb+9   ;disk file type (3 characters)
0068 =          fcbrl   equ     fcb+12  ;file's current reel number
006b =          fcbrc   equ     fcb+15  ;file's record count (0 to 128)
007c =          fcbcr   equ     fcb+32  ;current (next) record number (0
007d =          fcbln   equ     fcb+33  ;fcb length
                ;
                ;       set up stack
0100 210000             lxi     h,0
0103 39                 dad     sp
                ;       entry stack pointer in hl from the ccp
0104 221502             shld    oldsp
                ;       set sp to local stack area (restored at finis)
0107 315702             lxi     sp,stktop
                ;       read and print successive buffers
010a cdc101             call    setup   ;set up input file
010d feff               cpi     255     ;255 if file not present
010f c21b01             jnz     openok  ;skip if open is ok
                ;
                ;       file not there, give error message and return
0112 11f301             lxi     d,opnmsg
0115 cd9c01             call    err
0118 c35101             jmp     finis   ;to return
                ;
```

```
                openok: ;open operation ok, set buffer index to end
011b 3e80               mvi     a,80h
011d 321302             sta     ibp     ;set buffer pointer to 80h
                ;       hl contains next address to print
0120 210000             lxi     h,0     ;start with 0000
                ;
                gloop:
0123 e5                 push    h       ;save line position
0124 cda201             call    gnb
0127 e1                 pop     h       ;recall line position
0128 da5101             jc      finis   ;carry set by gnb if end file
012b 47                 mov     b,a
                ;       print hex values
                ;       check for line fold
012c 7d                 mov     a,l
012d e60f               ani     0fh     ;check low 4 bits
012f c24401             jnz     nonum
                ;       print line number
0132 cd7201             call    crlf
                ;
                ;       check for break key
0135 cd5901             call    break
                ;       accum lsb = 1 if character ready
0138 0f                 rrc             ;into carry
0139 da5101             jc      finis   ;don't print any more
                ;
013c 7c                 mov     a,h
013d cd8f01             call    phex
0140 7d                 mov     a,l
0141 cd8f01             call    phex
                nonum:
0144 23                 inx     h       ;to next line number
0145 3e20               mvi     a,' '
0147 cd6501             call    pchar
014a 78                 mov     a,b
014b cd8f01             call    phex
014e c32301             jmp     gloop
                ;
                finis:
                ;       end of dump, return to ccp
                ;       (note that a jmp to 0000h reboots)
0151 cd7201             call    crlf
0154 2a1502             lhld    oldsp
0157 f9                 sphl
                ;       stack pointer contains ccp's stack location
0158 c9                 ret             ;to the ccp
                ;
                ;
                ;       subroutines
                ;
                break:  ;check break key (actually any key will do)
0159 e5d5c5             push h! push d! push b; environment saved
015c 0e0b               mvi     c,brkf
015e cd0500             call    bdos
0161 c1d1e1             pop b! pop d! pop h; environment restored
```

```
0164 c9             ret
                    ;
                    pchar:  ;print a character
0165 e5d5c5         push h! push d! push b; saved
0168 0e02           mvi     c,typef
016a 5f             mov     e,a
016b cd0500         call    bdos
016e c1d1e1         pop b! pop d! pop h; restored
0171 c9             ret
                    ;
                    crlf:
0172 3e0d           mvi     a,cr
0174 cd6501         call    pchar
0177 3e0a           mvi     a,lf
0179 cd6501         call    pchar
017c c9             ret
                    ;
                    ;
                    pnib:   ;print nibble in reg a
017d e60f           ani     0fh     ;low 4 bits
017f fe0a           cpi     10
0181 d28901         jnc     pl0
                    ;       less than or equal to 9
0184 c630           adi     '0'
0186 c38b01         jmp     prn
                    ;
                    ;       greater or equal to 10
0189 c637   pl0:    adi     'a' - 10
018b cd6501 prn:    call    pchar
018e c9             ret
                    ;
                    phex:   ;print hex char in reg a
018f f5             push    psw
0190 0f             rrc
0191 0f             rrc
0192 0f             rrc
0193 0f             rrc
0194 cd7d01         call    pnib    ;print nibble
0197 f1             pop     psw
0198 cd7d01         call    pnib
019b c9             ret
                    ;
                    err:    ;print error message
                    ;       d,e addresses message ending with "$"
019c 0e09           mvi     c,printf        ;print buffer function
019e cd0500         call    bdos
01a1 c9             ret
                    ;
                    ;
                    gnb:    ;get next byte
01a2 3a1302         lda     ibp
01a5 fe80           cpi     80h
01a7 c2b301         jnz     g0
                    ;       read another buffer
                    ;
```

```
                ;
01aa cdce01             call    diskr
01ad b7                 ora     a       ;zero value if read ok
01ae cab301             jz      g0      ;for another byte
                ;       end of data, return with carry set for eof
01b1 37                 stc
01b2 c9                 ret
                ;
                g0:     ;read the byte at buff+reg a
01b3 5f                 mov     e,a     ;ls byte of buffer index
01b4 1600               mvi     d,0     ;double precision index to de
01b6 3c                 inr     a       ;index=index+1
01b7 321302             sta     ibp     ;back to memory
                ;       pointer is incremented
                ;       save the current file address
01ba 218000             lxi     h,buff
01bd 19                 dad     d
                ;       absolute character address is in hl
01be 7e                 mov     a,m
                ;       byte is in the accumulator
01bf b7                 ora     a       ;reset carry bit
01c0 c9                 ret
                ;
                setup:  ;set up file
                ;       open the file for input
01c1 af                 xra     a       ;zero to accum
01c2 327c00             sta     fcbcr   ;clear current record
                ;
01c5 115c00             lxi     d,fcb
01c8 0e0f               mvi     c,openf
01ca cd0500             call    bdos
                ;       255 in accum if open error
01cd c9                 ret
                ;
                diskr:  ;read disk file record
01ce e5d5c5             push h! push d! push b
01d1 115c00             lxi     d,fcb
01d4 0e14               mvi     c,readf
01d6 cd0500             call    bdos
01d9 c1d1e1             pop b! pop d! pop h
01dc c9                 ret
                ;
                ;       fixed message area
01dd 46494c0signon: db      'file dump version 2.0$'
01f3 0d0a4e0opnmsg: db      cr,lf,'no input file present on disk$'

                ;       variable area
0213            ibp:    ds      2       ;input buffer pointer
0215            oldsp:  ds      2       ;entry sp value from ccp
                ;
                ;       stack area
0217                    ds      64      ;reserve 32 level stack
                stktop:
                ;
0257                    end
```

5. A SAMPLE RANDOM ACCESS PROGRAM.

This manual is concluded with a rather extensive, but complete example of random access operation. The program listed below performs the simple function of reading or writing random records upon command from the terminal. Given that the program has been created, assembled, and placed into a file labelled RANDOM.COM, the CCP level command:

```
RANDOM X.DAT
```

starts the test program. The program looks for a file by the name X.DAT (in this particular case) and, if found, proceeds to prompt the console for input. If not found, the file is created before the prompt is given. Each prompt takes the form

```
next command?
```

and is followed by operator input, terminated by a carriage return. The input commands take the form

```
nW   nR   Q
```

where n is an integer value in the range Ø to 65535, and W, R, and Q are simple command characters corresponding to random write, random read, and quit processing, respectively. If the W command is issued, the RANDOM program issues the prompt

```
type data:
```

The operator then responds by typing up to 127 characters, followed by a carriage return. RANDOM then writes the character string into the X.DAT file at record n. If the R command is issued, RANDOM reads record number n and displays the string value at the console. If the Q command is issued, the X.DAT file is closed, and the program returns to the console command processor. In the interest of brevity, the only error message is

```
error, try again
```

The program begins with an initialization section where the input file is opened or created, followed by a continuous loop at the label "ready" where the individual commands are interpreted. The default file control block at ØØ5CH and the default buffer at ØØ8ØH are used in all disk operations. The utility subroutines then follow, which contain the principal input line processor, called "readc." This particular program shows the elements of random access processing, and can be used as the basis for further program development.

```
                ;*****************************************************
                ;*                                                   *
                ;* sample random access program for cp/m 2.0         *
                ;*                                                   *
                ;*****************************************************
0100                    org     100h    ;base of tpa
                ;
0000 =          reboot  equ     0000h   ;system reboot
0005 =          bdos    equ     0005h   ;bdos entry point
                ;
0001 =          coninp  equ     1       ;console input function
0002 =          conout  equ     2       ;console output function
0009 =          pstring equ     9       ;print string until '$'
000a =          rstring equ     10      ;read console buffer
000c =          version equ     12      ;return version number
000f =          openf   equ     15      ;file open function
0010 =          closef  equ     16      ;close function
0016 =          makef   equ     22      ;make file function
0021 =          readr   equ     33      ;read random
0022 =          writer  equ     34      ;write random
                ;
005c =          fcb     equ     005ch   ;default file control block
007d =          ranrec  equ     fcb+33  ;random record position
007f =          ranovf  equ     fcb+35  ;high order (overflow) byte
0080 =          buff    equ     0080h   ;buffer address
                ;
000d =          cr      equ     0dh     ;carriage return
000a =          lf      equ     0ah     ;line feed
                ;
                ;*****************************************************
                ;*                                                   *
                ;* load SP, set-up file for random access            *
                ;*                                                   *
                ;*****************************************************
0100 31bc0              lxi     sp,stack
                ;
                ;       version 2.0?
0103 0e0c               mvi     c,version
0105 cd050              call    bdos
0108 fe20               cpi     20h     ;version 2.0 or better?
010a d2160              jnc     versok
                ;       bad version, message and go back
010d 111b0              lxi     d,badver
0110 cdda0              call    print
0113 c3000              jmp     reboot
                ;
                versok:
                ;       correct version for random access
0116 0e0f               mvi     c,openf ;open default fcb
0118 115c0              lxi     d,fcb
011b cd050              call    bdos
011e 3c                 inr     a       ;err 255 becomes zero
011f c2370              jnz     ready
                ;
                ;       cannot open file, so create it
```

```
0122 0e16           mvi     c,makef
0124 115c0          lxi     d,fcb
0127 cd050          call    bdos
012a 3c             inr     a       ;err 255 becomes zero
012b c2370          jnz     ready
             ;
             ;      cannot create file, directory full
012e 113a0          lxi     d,nospace
0131 cdda0          call    print
0134 c3000          jmp     reboot  ;back to ccp
             ;
             ;*****************************************************
             ;*                                                   *
             ;*  loop back to "ready" after each command          *
             ;*                                                   *
             ;*****************************************************
             ;
             ready:
             ;      file is ready for processing
             ;
0137 cde50          call    readcom ;read next command
013a 227d0          shld    ranrec  ;store input record#
013d 217f0          lxi     h,ranovf
0140 3600           mvi     m,0     ;clear high byte if set
0142 fe51           cpi     'Q'     ;quit?
0144 c2560          jnz     notq
             ;
             ;      quit processing, close file
0147 0e10           mvi     c,closef
0149 115c0          lxi     d,fcb
014c cd050          call    bdos
014f 3c             inr     a       ;err 255 becomes 0
0150 cab90          jz      error   ;error message, retry
0153 c3000          jmp     reboot  ;back to ccp
             ;
             ;*****************************************************
             ;*                                                   *
             ;* end of quit command, process write                *
             ;*                                                   *
             ;*****************************************************
             notq:
             ;      not the quit command, random write?
0156 fe57           cpi     'W'
0158 c2890          jnz     notw
             ;
             ;      this is a random write, fill buffer until cr
015b 114d0          lxi     d,datmsg
015e cdda0          call    print   ;data prompt
0161 0e7f           mvi     c,127   ;up to 127 characters
0163 21800          lxi     h,buff  ;destination
             rloop: ;read next character to buff
0166 c5             push    b       ;save counter
0167 e5             push    h       ;next destination
0168 cdc20          call    getchr  ;character to a
016b e1             pop     h       ;restore counter
```

```
016c c1          pop     b       ;restore next to fill
016d fe0d        cpi     cr      ;end of line?
016f ca780       jz      erloop
                 ;       not end, store character
0172 77          mov     m,a
0173 23          inx     h       ;next to fill
0174 0d          dcr     c       ;counter goes down
0175 c2660       jnz     rloop   ;end of buffer?
                 erloop:
                 ;       end of read loop, store 00
0178 3600        mvi     m,0
                 ;
                 ;       write the record to selected record number
017a 0e22        mvi     c,writer
017c 115c0       lxi     d,fcb
017f cd050       call    bdos
0182 b7          ora     a       ;error code zero?
0183 c2b90       jnz     error   ;message if not
0186 c3370       jmp     ready   ;for another record
                 ;
                 ;*************************************************
                 ;*                                               *
                 ;* end of write command, process read            *
                 ;*                                               *
                 ;*************************************************
                 notw:
                 ;       not a write command, read record?
0189 fe52        cpi     'R'
018b c2b90       jnz     error   ;skip if not
                 ;
                 ;       read random record
018e 0e21        mvi     c,readr
0190 115c0       lxi     d,fcb
0193 cd050       call    bdos
0196 b7          ora     a       ;return code 00?
0197 c2b90       jnz     error
                 ;
                 ;       read was successful, write to console
019a cdcf0       call    crlf    ;new line
019d 0e80        mvi     c,128   ;max 128 characters
019f 21800       lxi     h,buff  ;next to get
                 wloop:
01a2 7e          mov     a,m     ;next character
01a3 23          inx     h       ;next to get
01a4 e67f        ani     7fh     ;mask parity
01a6 ca370       jz      ready   ;for another command if 00
01a9 c5          push    b       ;save counter
01aa e5          push    h       ;save next to get
01ab fe20        cpi     ' '     ;graphic?
01ad d4c80       cnc     putchr  ;skip output if not
01b0 e1          pop     h
01b1 c1          pop     b
01b2 0d          dcr     c       ;count=count-1
01b3 c2a20       jnz     wloop
01b6 c3370       jmp     ready
```

```
                ;
                ;*****************************************************
                ;*                                                   *
                ;* end of read command, all errors end-up here       *
                ;*                                                   *
                ;*****************************************************
                ;
                error:
01b9 11590              lxi     d,errmsg
01bc cdda0              call    print
01bf c3370              jmp     ready
                ;
                ;*****************************************************
                ;*                                                   *
                ;* utility subroutines for console i/o               *
                ;*                                                   *
                ;*****************************************************
                getchr:
                        ;read next console character to a
01c2 0e01               mvi     c,coninp
01c4 cd050              call    bdos
01c7 c9                 ret
                ;
                putchr:
                        ;write character from a to console
01c8 0e02               mvi     c,conout
01ca 5f                 mov     e,a     ;character to send
01cb cd050              call    bdos    ;send character
01ce c9                 ret
                ;
                crlf:
                        ;send carriage return line feed
01cf 3e0d               mvi     a,cr    ;carriage return
01d1 cdc80              call    putchr
01d4 3e0a               mvi     a,lf    ;line feed
01d6 cdc80              call    putchr
01d9 c9                 ret
                ;
                print:
                        ;print the buffer addressed by de until $
01da d5                 push    d
01db cdcf0              call    crlf
01de d1                 pop     d       ;new line
01df 0e09               mvi     c,pstring
01e1 cd050              call    bdos    ;print the string
01e4 c9                 ret
                ;
                readcom:
                        ;read the next command line to the conbuf
01e5 116b0              lxi     d,prompt
01e8 cdda0              call    print   ;command?
01eb 0e0a               mvi     c,rstring
01ed 117a0              lxi     d,conbuf
01f0 cd050              call    bdos    ;read command line
                ;       command line is present, scan it
```

```
01f3 21000          lxi     h,0     ;start with 0000
01f6 117c0          lxi     d,conlin;command line
01f9 1a     readc:  ldax    d       ;next command character
01fa 13             inx     d       ;to next command position
01fb b7             ora     a       ;cannot be end of command
01fc c8             rz
                ;   not zero, numeric?
01fd d630           sui     '0'
01ff fe0a           cpi     10      ;carry if numeric
0201 d2130          jnc     endrd
                ;   add-in next digit
0204 29             dad     h       ;*2
0205 4d             mov     c,l
0206 44             mov     b,h     ;bc = value * 2
0207 29             dad     h       ;*4
0208 29             dad     h       ;*8
0209 09             dad     b       ;*2 + *8 = *10
020a 85             add     l       ;+digit
020b 6f             mov     l,a
020c d2f90          jnc     readc   ;for another char
020f 24             inr     h       ;overflow
0210 c3f90          jmp     readc   ;for another char
                endrd:
                ;   end of read, restore value in a
0213 c630           adi     '0'     ;command
0215 fe61           cpi     'a'     ;translate case?
0217 d8             rc
                ;   lower case, mask lower case bits
0218 e65f           ani     10l$1111b
021a c9             ret
                ;
                ;***************************************************
                ;*                                                 *
                ;* string data area for console messages           *
                ;*                                                 *
                ;***************************************************
                badver:
021b 536f79         db      'sorry, you need cp/m version 2$'
                nospace:
023a 4e6f29         db      'no directory space$'
                datmsg:
024d 547970         db      'type data: $'
                errmsg:
0259 457272         db      'error, try again.$'
                prompt:
026b 4e6570         db      'next command? $'
                ;
```

```
                ;*************************************************
                ;*                                               *
                ;* fixed and variable data area                  *
                ;*                                               *
                ;*************************************************
027a 21     conbuf: db      conlen  ;length of console buffer
027b        consiz: ds      1       ;resulting size after read
027c        conlin: ds      32      ;length 32 buffer
0021 =      conlen  equ     $-consiz
                ;
029c                ds      32      ;16 level stack
            stack:
02bc                end
```

Again, major improvements could be made to this particular program to enhance its operation. In fact, with some work, this program could evolve into a simple data base management system. One could, for example, assume a standard record size of 128 bytes, consisting of arbitrary fields within the record. A program, called GETKEY, could be developed which first reads a sequential file and extracts a specific field defined by the operator. For example, the command

GETKEY NAMES.DAT LASTNAME 10 20

would cause GETKEY to read the data base file NAMES.DAT and extract the "LASTNAME" field from each record, starting at position 10 and ending at character 20. GETKEY builds a table in memory consisting of each particular LASTNAME field, along with its 16-bit record number location within the file. The GETKEY program then sorts this list, and writes a new file, called LASTNAME.KEY, which is an alphabetical list of LASTNAME fields with their corresponding record numbers. (This list is called an "inverted index" in information retrieval parlance.)

Rename the program shown above as QUERY, and massage it a bit so that it reads a sorted key file into memory. The command line might appear as:

QUERY NAMES.DAT LASTNAME.KEY

Instead of reading a number, the QUERY program reads an alphanumeric string which is a particular key to find in the NAMES.DAT data base. Since the LASTNAME.KEY list is sorted, you can find a particular entry quite rapidly by performing a "binary search," similar to looking up a name in the telephone book. That is, starting at both ends of the list, you examine the entry halfway in between and, if not matched, split either the upper half or the lower half for the next search. You'll quickly reach the item you're looking for (in log2(n) steps) where you'll find the corresponding record number. Fetch and display this record at the console, just as we have done in the program shown above.

At this point you're just getting started. With a little more work, you can allow a fixed grouping size which differs from the 128 byte record shown above. This is accomplished by keeping track of the record number as well as the byte offset within the record. Knowing the group size, you randomly access the record containing the proper group, offset to the beginning of the group within the record read sequentially until the group size has been exhausted.

Finally, you can improve QUERY considerably by allowing boolean expressions which compute the set of records which satisfy several relationships, such as a LASTNAME between HARDY and LAUREL, and an AGE less than 45. Display all the records which fit this description. Finally, if your lists are getting too big to fit into memory, randomly access your key files from the disk as well. One note of consolation after all this work: if you make it through the project, you'll have no more need for this manual!

6. SYSTEM FUNCTION SUMMARY.

FUNC	FUNCTION NAME	INPUT PARAMETERS	OUTPUT RESULTS
Ø	System Reset	none	none
1	Console Input	none	A = char
2	Console Output	E = char	none
3	Reader Input	none	A = char
4	Punch Output	E = char	none
5	List Output	E = char	none
6	Direct Console I/O	see def	see def
7	Get I/O Byte	none	A = IOBYTE
8	Set I/O Byte	E = IOBYTE	none
9	Print String	DE = .Buffer	none
1Ø	Read Console Buffer	DE = .Buffer	see def
11	Get Console Status	none	A = ØØ/FF
12	Return Version Number	none	HL= Version*
13	Reset Disk System	none	see def
14	Select Disk	E = Disk Number	see def
15	Open File	DE = .FCB	A = Dir Code
16	Close File	DE = .FCB	A = Dir Code
17	Search for First	DE = .FCB	A = Dir Code
18	Search for Next	none	A = Dir Code
19	Delete File	DE = .FCB	A = Dir Code
2Ø	Read Sequential	DE = .FCB	A = Err Code
21	Write Sequential	DE = .FCB	A = Err Code
22	Make File	DE = .FCB	A = Dir Code
23	Rename File	DE = .FCB	A = Dir Code
24	Return Login Vector	none	HL= Login Vect*
25	Return Current Disk	none	A = Cur Disk#
26	Set DMA Address	DE = .DMA	none
27	Get Addr(Alloc)	none	HL= .Alloc
28	Write Protect Disk	none	see def
29	Get R/O Vector	none	HL= R/O Vect*
3Ø	Set File Attributes	DE = .FCB	see def
31	Get Addr(disk parms)	none	HL= .DPB
32	Set/Get User Code	see def	see def
33	Read Random	DE = .FCB	A = Err Code
34	Write Random	DE = .FCB	A = Err Code
35	Compute File Size	DE = .FCB	rØ, rl, r2
36	Set Random Record	DE = .FCB	rØ, rl, r2

* Note that A = L, and B = H upon return