M20 PERSONAL COMPUTER

The ASSEMBLER

User Guide

olivetti

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PREFACE

This manual is produced for programmers using the M20 to create Assembly Language programs. The Assembly Language of the Z8001 cpu of the M20 is described in the "M20 Z8000 Assembler Reference Manual". The Reference manual gives the complete instruction set and deals with other aspects of the cpu like operational characteristics, architectural features, etc. This manual supplies additional information to enable the programmer to create Assembly Language programs to run on the M20.

This manual is divided into two parts. Part I illustrates the characteristics of an M20 source file and describes how an executable binary file can be obtained from a source file.
Part II details all the M20 System Calls, and the routines of the M20 Graphics package.

REFERENCES:

Z8000 Assembler Reference Manual
Code 3982410 M (1)

PCOS (Professional Computer Operating System) User Guide
Code 3985280 D (0)

Basic Language Reference Manual
Code 3982430 P (3)

I/O with External Peripherals User Guide
Code 3982300 N (2)

Hardware Architecture and Function
Code 4100630 W (0)

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PART I

1. INTRODUCTION

ABOUT THIS CHAPTER

This part of the manual describes how to create Assembly Language programs on the M20. In this chapter a brief step by step description of the process is given. In each step of this description reference is made to the relevant chapter or manual where it is described in detail.

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CREATING AN EXECUTABLE FILE

An Assembly Language program must be written in an Editor environment; on the M20 this can be done in the Video File Editor environment which is described in the "M20 PCOS (Professional Computer Operating System) User Guide". This edited version of the program is known as the source file. The source file is described in chapter 2, where the Directives and the Assembler Conventions for the M20 are defined. Chapter 2 ends with a description of the PCOS Standard, which defines the format of a source file meant to execute like any PCOS routine.

The next step is to assemble the program using the ASSEMBLER (ASM) command. This command takes a source file as input and outputs a z-type object file. The ASM command is described in chapter 3.

The final step in creating an executable file is performed by the LINK command which is described in chapter 4. LINK takes one or more object files as input and outputs a single executable binary load file. Note that z-type object files created using other computer languages can be linked to z-type object files output by the ASM command.

The process of creating an executable file is shown schematically in fig. 1-1 below.

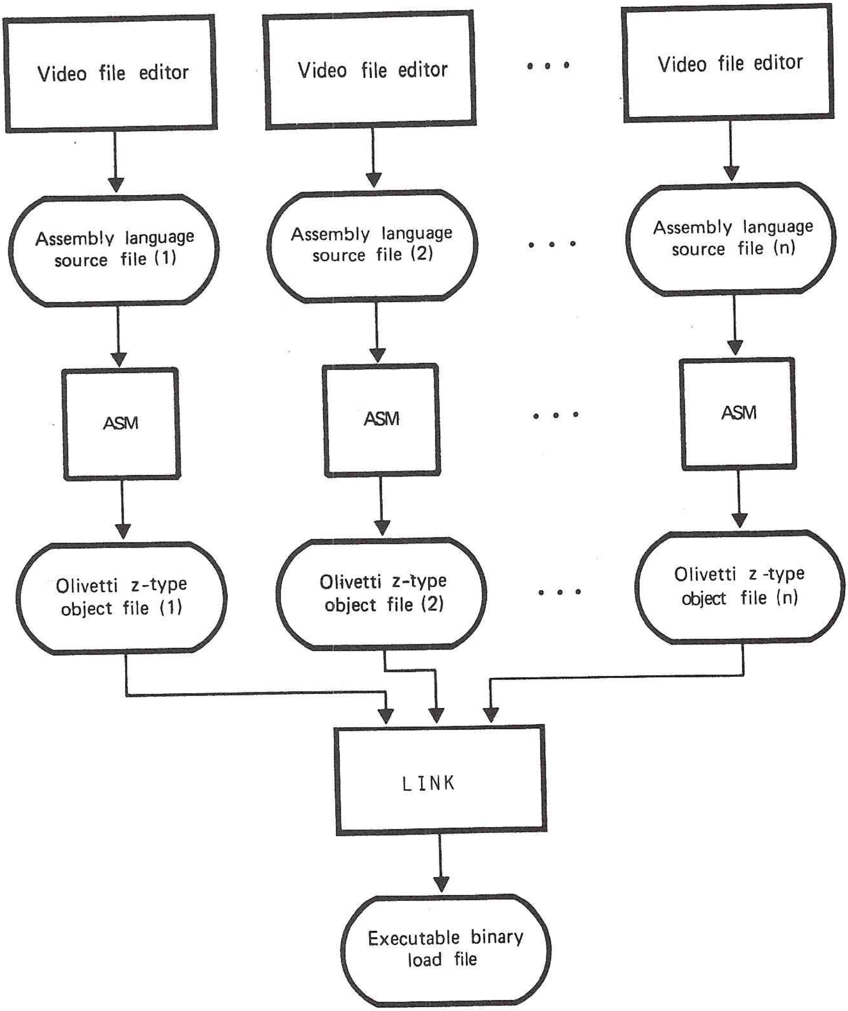

Fig. 1-1 Creating an executable binary file

Dumping Facilities

Throughout the process of creating an executable file the programmer may need to display source files, listing files, object files, etc.. This can be done using the PCOS command FLIST which allows a number of optional features for dumping various types of files. The FLIST command is detailed in the "M20 PCOS User Guide".

THE M20 ASSEMBLER PACKAGE

The M20 Assembler package contains the Assembler (ASM) command, the LINK command, and the Video File Editor mentioned above. Also included in the package are the PDEBUG (Program DEBUG) utility detailed in chapter 5, and the MLIB command for creating library files of object modules described in chapter 6. All of these routines must be invoked from the PCOS environment.

SYSTEM CONFIGURATION

The M20 Assembler package will run on any M20 system configuration.

2. THE ASSEMBLER SOURCE FILE

ABOUT THIS CHAPTER

This chapter contains the main steps to be taken and the Assembler conventions the programmer must adhere to, in order to build source files for the user's own utilities.

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INTRODUCTION

As previously mentioned, to construct the source file, the programmer will make use of the Video File Editor (as described in the "PCOS (Professional Computer Operating System) User Guide"), by means of which he can insert the instructions and the Assembler directives. The instruction set used is precisely that of the Z-8001 CPU, described in detail in the "M20 Z8000 Assembler Reference Manual", which is useful to the programmer for what regards mnemonics, addressing and machine code. As far as the Assembler conventions and directives are concerned, however, (which are M20 specific), these will be examined in more detail in the next two sections entitled "Assembler Conventions" and "Assembler Directives".

The section on "Assembler Conventions" describes in depth the way to represent operands, numerical constants, strings, comments, arithmetic operations, which may appear on a source program line.

The next section provides a description of the "Assembler Directives" i.e. those instructions which are not translated by the Assembler in executeable machine code, but which are used by the Assembler itself to leave uninitialised space in the object program, define strings within the program, make references to variables outside the program and to perform operations which facilitate the programmer's work.

The last section "The PCOS Standard" deals with the structure an Assembler source file must have, so that the user can build himself a utility which is coherent with the PCOS utilities standards, for invoking and for passing parameters.

ASSEMBLER CONVENTIONS

ASSEMBLY LANGUAGE STATEMENT FORMAT

The most fundamental component of an assembly program is the assembly language statement, a single line of text consisting of an instruction and its operands, with an optional comment. The instruction describes an action to be taken; the operands supply the data to be acted upon.

An assembly language statement can include four fields in the following order, from left to right on the line:

- Symbolic Label;

- Instruction Mnemonic;

- Operands;

- Comment.

All fields can be optional depending on the instruction chosen. Each field of the statement must be separated from the others by white space (one or more spaces or tabs). If a field other than the symbolic label is to be omitted but subsequent fields on the line are not, it may be coded as a solitary comma (,). Fields other than the comment field may not contain white space except for the case of character constants or strings in operands (which are enclosed in apostrophes or quotation marks respectively).

Symbolic Label Field

Any statement may contain a symbolic label. Some instructions require it. If provided, the label must begin with the first character of the text line. The absence of the field is indicated by the first character of the line being a white space character. The only way in which a symbol may be defined anywhere in the assembly is for it to appear in the label field of a statement. A particular symbol may appear only once in a label field within one module. Note: a comment line, which is not an assembly instruction, is indicated by the first character of the line being an asterisk (*).

Instruction Field

The instruction is the assembly-language mnemonic describing a specific action to be taken. This may represent either a Z8000 machine instruction or an assembler directive instruction. The instruction must be separated from its operands by white space (one or more spaces or tabs).

```
LD  R2,ALPHA    Load register 2 from memory location ALPHA

JP  BETA            JUMP to location BETA
```

Many of the operations of the Z8000 can be applied to word, byte, or long operands. A simple naming convention has been adopted to distinguish the size of the operands for these particular instructions: the suffix "B" designates a byte instruction, the suffix "L" designates a long word instruction, and no suffix designates a word instruction:

```
ADD     R0,R1          Add word operands

ADDB    RH0,RL0        Add byte operands

ADDL    RR0,RR2        Add long operands
```

Operand Field

Depending on the instruction specified, this field can have zero or more operands. If two or more operands are needed, each must be separated by a comma with no intervening white space. If there are no operands and a comment field is to be placed on the same statement, the operand field must be a single comma standing alone.

```
RET    ,                 No operand

TEST   R2                One operand

LD     R2,R1             Two operands

LDM    R2,ALPHA,#7       Three operands

CPD    R2,@R4,R6,EQ      Four operands
```

Operands supply the information the instruction needs to carry out its action. An operand of a Z8000 machine instruction can be:

- Data to be processed (immediate data);
- The address of a location from which data is to be taken (source address);
- The address of a location where data is to be put (destination address);
- The address of a program location to which program control is to be passed;
- A condition code, used to direct the flow of program control.

Although there are a number of valid combinations of operands, there is one basic convention to remember: the destination operand always precedes the source operand. Refer to the specific instructions in the Reference Manual for valid operand combinatons.

Immediate data can be in the form of a constant , an address , or an expression (constants and/or addresses combined by operators).

```
LD    R2,#7          Load 7 into register 2

LD    R2,#ALPHA      Load address of ALPHA into register 2

LD    R4,#BETA/2     Load value of expression [BETA/2] into
,     ,              register 4
```

As far as the conventions are concerned, for expressing numeric constants and alphanumeric strings, these will be dealt with later in the appropriate section.

Source, destination, and program addresses can also take several forms. Addressing modes are described in detail later. Some examples are:

```
LD    R1,@R2             Load value whose address is in register 2
 ,     ,                 into register 1

LD    R1,ALPHA           Load value located at address labeled
 ,     ,                 ALPHA into register 1

LD    R1,ALPHA+1         Load value at location following that
 ,     ,                 addressed by ALPHA into register 1

JP    EQ,BETA            Jump to program address labeled BETA if
,      ,                 EQ flag is set

JP    NE,BETA+16         Otherwise, jump to location sixteen bytes
,      ,                 following BETA
```

Condition codes are listed in the Reference Manual.

Operands of an assembler directive instruction can be:

- A numerical value or expression;
- Expressions or strings representing initialization data;
- A string such as a file name, a module name, or a section name (such strings cannot be referenced elsewhere in the program);
- A keyword.

Examples of assembler directives:

```
MODULE      device.1,segmented

AT          BETA+16

DSB         27

DDL         %7F01FFF,'AB'
```

The assembler directives are dealt with later in the appropriate section.

Comments

Comments are used to document program code as a guide to program logic and also to simplify present or future program debugging A text line which begins with an asterisk as the first non-white-space character is copied as it appears to the listing file but is ignored by the assembler for all other purposes.

Examples of comment lines:

```
*   This routine is used to compare two strings.  The operands are
*   pointers to the first characters of each string.  The
*   strings are of variable length with a zero byte marking
*   the end of the string.

*   The returned value of this routine is:

*            -1:  first string less than second
*             0:  strings equal
*             1:  first string greater than second
```

Comments may also be placed on the end of each assembler statement All text which appears after the operand field on the line is a comment and is reproduced in the listing file but ignored otherwise. If the operand field or the instruction field are to be omitted the comment field may only be included if the omitted field(s) are coded as a solitary comma (,).

Examples of on-statement comments:

```
        CLR     R2                  Initialize register 2

        IRET    ,                   return from the interrupt NOW!

START.UP ,      ,                   THIS IS THE ENTRY POINT OF THE PROGRAM

        JP      Z,BETA+12 this is a close comment
```

SYMBOLS, CONSTANTS, and STRINGS

Symbols

A symbol may consist of the letters A-Z (upper or lower case), the digits 0-9, the underscore character (_), or a period (.). A symbol may not begin with a digit (0-9). The maximum length of a symbol is 16 characters.

Upper and lower case letters are considered different characters. Thus "Start" and "start" are different symbols.

The following are valid symbols:

```
ValueAssignments
Initial_values
start_up
Pass_2
sort
```

Constants

A constant is a value which stands for itself. It may be either a number or a character sequence.

Numbers can be written in decimal, hexadecimal, binary, or octal notation. The latter three are preceded by a percent sign (%) and, in the case of binary and octal, by a base specifier enclosed in parentheses. If a number has no prefix, decimal is assumed.

```
 42             decimal
%42             hexadecimal
%(8)42          octal
%(2)10110010    binary
```

A characters sequence is a sequence of one to four characters enclosed in apostrophes. Any ASCII character can be included in the character sequence, for example;

```
'A'
'Open'
```

A character can also be represented in a character sequence in the form "%hh," where "hh" is the hexadecimal equivalent of the ASCII code for the character, for example;

```
'E=%1B'
```

For convenience, certain ASCII characters have been assigned shorter, more mnemonic codes as follows:

```
%L  or  %l      Linefeed
%T  or  %t      Tab
%R  or  %r      Carriage Return
%P  or  %p      Page (Form Feed)
%%              Percent Sign
%Q, %q, %'      Apostrophe (Single Quote)
```

Example:

```
     '1%r2%r'     represents the ASCII sequence: 1 /CR/ 2 /CR/
and  '%Qt=%Q'     represents the ASCII sequence: 't='
```

Strings

Strings are sequences of any length of ASCII characters, enclosed in quotation marks. They can be defined only by using the DDB directive (see Data Generation Directives).

Strings also use the above ASCII mnemonic forms. Since strings are enclosed in quotation marks, the mnemonic %" is used for embedded quotation marks.

ARITHMETIC OPERANDS

Run-Time and Assembly-Time Arithmetic

Arithmetic is performed in two ways in an assembly language program Run-time arithmetic is done while the program is actually executing.

```
ADDB RH0,RL2     Add the contents of register
,   ,            RL2 to the contents of register RH0
```

Assembly-time arithmetic is done by the assembler when the program is assembled and involves the evaluation of arithmetic expressions in operands, such as the following:

```
LDL RR14,#[2*one+%10]

JP  Z,BETA+34

AND R5,ALPHA-3
```

Assembly-time arithmetic is more limited than run-time arithmetic.

All assembly-time arithmetic is computed using 32-bit representations of the numbers. Any number in excess of 32 bits (4,294,967,296) loses the extra bits on the left, so all values are calculated "modulo 4,294,967,296". Depending on the number of bits required by the particular instruction, only the rightmost 4, 8, 16, or 32 bits of the resulting 32-bit value are used. If the result of assembly-time arithmetic is to be stored in four bits, the value is taken "modulo 16" to give a result in the range 0 to 15. If the result is to be stored in a single byte location, the value is taken "modulo 256" to give a result in the range 0 to 255 (or -128 to 127 if signed representation is intended). If the result is to be stored in a word, the value is taken "modulo 65536" to give a result in the range 0 to 65535 (or -32768 to 32767 if signed representation is intended).

```
 LDB    RH7,#one*2          Result of "one*2" must be in
*                           range 0 to 255

 JP     BETA+2              Modulo 65536.  Result is the
*                           address 2 bytes beyond BETA

 SUBL   RR2,#one*%80000     Result of "one*%80000" is taken
*                           modulo 4,294,967,296
```

SYMBOLIC VALUES

A symbol can be assigned a value other than that of the current assembly location counter by means of the assembler directive instructions which are described later in this chapter. In this way a symbol can be made to represent an absolute constant value or a relocatable memory location in the same section, in a different section of the same module or in a completely different module. That symbol may then be used in operand expressions anywhere that a value of its type is permissible.

EXPRESSIONS AND OPERATORS

Expressions are formed using arithmetic, logical, shift, and relational operators in combination with constants and variables. These operators allow both unary (one-operand) and binary (two-operand) expressions, as shown below.

Arithmetic Operators

The arithmetic operators are the following:

Operator	Operation
+	Unary plus, binary addition
-	Unary minus, binary subtraction
*	Multiplication
/	Divison
\	Modulus

The division operator (/) truncates any remainder. The modulus operator (\ ) performs the modulo function (i.e. returns the remainder after division)

9/2 = 4

9\2 = 1

-9/2 = -4

If zero is specified as the right operand for either of these operators, the result is undefined.

Examples:

SUBB RL0,#1	1 is subtracted from RL0
SUB R10,#one+[10-3]	Value of one + 7 is subtracted from register 10

Logical Operators

The logical operators are the following:

Operator	Operation
~	(Unary) Logical COMPLEMENT
&	Logical AND
!	Logical OR
^	Logical EXCLUSIVE OR

Logical COMPLEMENT (~) simply complements the bit pattern of its single operand (i.e. all one bits are changed to zero and vice-versa).

```
LD   R11,#~CONSTANT1    Reverse the bits of CONSTANT1 and load into
                        reg 11
```

The effect of Logical AND, Logical OR, and Logical EXCLUSIVE OR can be seen from the following examples. Although 32-bit arithmetic would actually be done by the assembler, 4-bit arithmetic is shown for clarity. Assume two constants, CONSTANT1 and CONSTANT2, which have the bit patterns 1100 and 1010, respectively. The expressions:

```
CONSTANT1&CONSTANT2
CONSTANT1!CONSTANT2
CONSTANT1^CONSTANT2
```

will result in the following evaluations of the operands:

```
AND   1100        OR   1100        EXCLUSIVE OR   1100
      1010             1010                       1010
      ----             ----                       ----
      1000             1110                       0110
```

The assembly-time logical operations performed by Logical COMPLEMENT, Logical AND, Logical OR and Logical EXCLUSIVE OR can also be done at run time by the Z8000 instructions COM, AND, OR, and XOR respectively. The assembly-time operations require less code and register manipulation. The run-time operations allow greater flexibility, however. For example, they can operate on registers (variables) whose contents are not known at assembly time, as well as on known constant values.

Shift Operators

The shift operators are as follows:

{SHR}	Logical shift right
{SHL}	Logical shift left

When used in expressions, the shift operators have the form

```
     d operator n
```

where "d" is the data to be shifted and "n" specifies the number of bits to be shifted. Vacated bits are replaced with zeros. For example, if CONSTANT1 has a value of 00001100, the statement

```
     LD     R10,#[CONSTANT1{SHL}2]
```

would load the value 00110000 into register R10. If the second operand supplied is negative (that is, if the sign bit is set), it has the effect of reversing the direction of the shift.

```
     LD     R10,#[CONSTANT1{SHR}-2]        CONSTANT1 is shifted
*                                          two bit positions LEFT
```

Relational Operators

There are two basic types of relational operators: those which consider their operands to be signed 32-bit integers, and those which consider their operands to be unsigned 32-bit integers.

Signed:

<	Less than
< =	Less than or equal
=	Equal
< >	Not equal
> =	Greater than or equal
>	Greater than

Unsigned:

{ULT}	Less than
{ULE}	Less than or equal
{UEQ}	Equal
{UNE}	Not equal
{UGE}	Greater than or equal
{UGT}	Greater than

The relational operators return a logical TRUE value (all ones) if the comparison of the two operands is true, and return a logical FALSE value (all zeros) otherwise.

```
LD  R0,#[1=2]        Reg 0 is loaded with zeros

LD  R0,#[2+2]<5      Reg 0 is loaded with ones
```

Precedence of Operators

Expressions are generally evaluated left to right with operators having the highest precedence evaluated first. If two operators have equal precedence, the leftmost is evaluated first.

The following lists the assembly-time operators in order of precedence:

- Unary operators: +, -, ~
- Multiplication/ Division/Modulus/Shift/AND: *, /, \, {SHR}, {SHL},&
- Addition/Subtraction/OR/XOR: +, -, !, ^
- Relational operators: <, <=, =,<>, >=, >, {ULT}, {ULE}, {UEQ}, {UNE}, {UGE}, {UGT}

Square brackets ([]) can be used to change the normal order of precedence. Items enclosed in brackets are evaluated first. If brackets are nested, the innermost are evaluated first.

```
100/4 - 48/2 = 1

100/[4 - 48/2]= -5
```

Note: Square brackets are used instead of the traditional parentheses. This is done to avoid all confusion and conflict whether it be syntactical, semantical or conceptual, with the indexed address operand forms described further on in this chapter.

Segmented Address Operators

Two special operators are provided to ease the manipulation of segmented addresses. While addresses can be treated as a single value with a symbolic name assigned by the programmer, occasionally it is useful to determine the segment number or offset associated with a memory location.

The SEGMENT unary operator, {SEGMENT}, is applied to an address expression that contains a symbolic name associated with an address, and returns a 16-bit value. This value is the 7-bit segment number associated with the expression and a one bit in the most significant bit of the high-order byte, and all zero bits in the low-order byte.

The "OFFSET" unary operator, {OFFSET}, is applied to an address expression and returns a 16-bit value which is the offset value associated with the expression.

Example

```
*    Load the segmented address of buffer_pointer into register pair RR12.

         LD   R12,#{SEGMENT}buffer_pointer
         LD   R13,#{OFFSET}buffer_pointer

*    This is functionally equivalent to the following statement:

         LDL  RR12,#buffer_pointer
```

Because of the special properties of these address operators, no other operators can be applied to a subexpression containing a SEGMENT or OFFSET operator, although other operators can be used within the subexpression to which the operator is applied:

```
 {SEGMENT}[buffer_pointer+4]       Valid
[{SEGMENT}buffer_pointer]+4        Invalid
-[{OFFSET}buffer_pointer]          Invalid
```

Z8000 ADDRESSING MODES

With the exception of immediate data and condition codes, all Z8000 machine instruction operands are expressed as addresses: register, memory, and I/O addresses. The various address modes recognized by the Z8000 assembler are as follows:

- Immediate Data
- Register
- Indirect Register
- Direct Address
- Indexed Address
- Relative Address
- Based Address
- Based Indexed Address

Special characters are used in operands to identify some of these address modes. The characters are:

- "R" preceding a word register number;
- "RH" or "RL" preceding a byte register number;
- "RR" preceding a register pair number;
- "RQ" preceding a register quadruple number;
- "@" preceding an indirect-register reference;
- "#" preceding immediate data;
- "()" used to enclose the displacement part of an indexed, based, or based indexed address;
- "$" signifying the current program counter location, usually used in relative addressing.

Immediate Data

The operand value used by the instruction in Immediate Data addressing mode is the value supplied in the operand field itself.

Immediate data is preceded by the special character "#" and can be either a constant (including character constants and symbols representing constants) or an expression as previously described. Immediate data expressions are evaluated using 32-bit arithmetic. Depending on the instruction being used, the value represented by the rightmost 4, 8, 16, or 32 bits is actually used. An error message is generated for values that overflow the valid range for the instruction.

```
    ADDB  RL7,#98            Add 98 to the contents of register RL7

    LDL   RR14,#6789*FOUR
    ,     ,                  Load the value of the multiplication
    ,     ,                  into register pair 14
```

If a variable name or address expression is prefixed by "#", the value used is the address represented by the variable or the result of the expression evaluation, not the contents of the corresponding data location.

The assembler automatically creates the proper format for a long offset address which includes the segment number and the offset in a 32-bit value. It is recommended that symbolic names be used wherever possible, since the corresponding segment number and offset for the symbolic name will be automatically managed by the assembler and can be assigned values later when the module is linked or when the program is loaded for execution.

For those cases where a specific segment is desired, the following notation can be used (the segment designator is enclosed in double angle brackets):

<<segment>>offset

where "segment" is a constant expression that evaluates to a 7- bit value, and "offset" is a constant expression that evaluates to a 16-bit value. This notation is expanded into a long offset address by the assembler.

```
    LDL   RR2,#MESSAGE           Load the address of MESSAGE into
    ,     ,                      register pair RR2

    LDL   RR2,#<<2>>%10          Load the segmented address
    ,     ,                      with segment 2, offset %10
    ,     ,                      into register pair RR2
```

Register Address

In register addressing mode, the operand value is the content of the specified general-purpose register. There are four different sizes of registers on the Z8000:

- Word register (16 bits),

- Byte register (8 bits),

- Register pair (32 bits), and

- Register quadruple (64 bits).

A word register is indicated by the "R" followed by a number from 0 to 15 (decimal) corresponding to the 16 registers of the machine. Either the high or low byte of the first eight registers can be accessed by using the byte register constructs "RH" or "RL" followed by a number from 0 to 7. Any pair of word registers can be accessed as a register pair by using "RR" followed by an even number between 0 and 14. Register quadruples are equivalent to four consecutive word registers and are accessed by the notation "RQ" followed by one of the numbers 0, 4, 8, or 12.

If an odd register number is given with a register pair designator, or a number other than 0, 4, 8, or 12 is given for a register quadruple, an assembly error will result.

In general, the size of a register used in an operation depends on the particular instruction. Byte instructions, which end with the suffix "B" are used with byte registers. Word registers are used with word instructions, which have no special suffix. Register pairs are used with long word instructions, which end with the suffix "L". Register quadruples are used only with three instructions (DIVL, EXTSL and MULTL) which use a 64-bit value. An assembly error will occur if the size of a register does not correspond correctly with the particular instruction.

```
LD     R5,#%5A5A        Load register 5 with the
,      ,                hexadecimal value 5A5A

LDB    RH3,#%A5         Load the high order byte of
,      ,                word register 3 with the
,      ,                hexadecimal value A5

ADDL   RR2,RR4          Add the register pairs 2-3 and
,      ,                4-5 and store the result in 2-3

MULTL  RQ8,RR12         Multiply the value in register
,      ,                pair 10-11 by the value in
,      ,                register pair 12-13 and store the
,      ,                result in register quadruple
,      ,                8-9-10-11
```

Indirect Register Address

In Indirect Register addressing mode, the operand value is the content of the location whose address is contained in the specified register. A register pair is used to hold the address. Any general-purpose register (register pair) can be used except R0 or RR0.

Indirect Register addressing mode is also used with the I/O instructions and always indicates a 16-bit I/O address. Any general-purpose word register can be used except R0.

An Indirect Register address is specified by a "commercial at" symbol (@) followed by either a word register or a register pair designator. For Indirect Register addressing mode, a word register is specified by an "R" followed by a number from 1 to 15, and a register pair is specified by an "RR" followed by an even number from 2 to 14.

```
        LD    @RR2,#15      Load immediate value 15 into
        ,       ,           location addressed by register
        ,       ,           pair 2-3
```

Direct Address

The operand value used by the instruction in Direct addressing mode is the content of the location specified by the address in the instruction. A direct address can be specified as a symbolic name of a memory or I/O location, or an expression that evaluates to an address. For all I/O instructions, the address is a 16-bit value. The memory address is either a 16-bit value (short offset) or a 32-bit value (long offset). All assembly-time address expressions are evaluated using 32-bit arithmetic.

```
    LD    R10,TABLE             Load the contents of the
    ,     ,                     location addressed by TABLE
    ,     ,                     into register 10

    LD    ARRAY+2,R2            Load the contents of register
    ,     ,                     2 into the location addressed
    ,     ,                     by adding 2 to ARRAY

    LDB   RH5,55                Load the contents of the I/O
    ,     ,                     location addressed by 55 into
    ,     ,                     RH5
```

The assembler automatically creates the proper format which includes the segment number and the offset. It is recommended that symbolic names be used wherever possible, since the corresponding segment number and offset for the symbolic name will be automatically managed by the assembler and can be assigned values later when the module is linked or loaded for execution.

For those cases where a specific segment is desired, the following notation can be used (the segment designator is enclosed in double angle brackets):

<<segment>>offset

where "segment" is a constant expression that evaluates to a 7-bit value, and "offset" is a constant expression that evaluates to a 16-bit value. This notation is expanded into a long offset address by the assembler.

To force a short offset address, the segmented address can be enclosed in vertical bars (||). In this case, the offset must be in the range 0 to 255, and the final address includes the segment number and short offset in a 16-bit value.

```
LD   R10,|TABLE|                 Load the contents of the
 "    "                          location addressed by TABLE
 "    "                          (short offset format) into
 "    "                          register 10

LD   &lt;&lt;SEGMENT&gt;&gt;OFFSET,R10       Load the contents of reg-
 "    "                          ister 10 into the location
 "    "                          addressed by the segment
 "    "                          named SEGMENT offset by
 "    "                          OFFSET (long offset format)

JP   |&lt;&lt;SEGMENT&gt;&gt;OFFSET          Jump to location addressed
 "    "                          by segment, offset
 "    "                          (short offset format)
```

Indexed Address

An Indexed address consists of a memory address displaced by the contents of a designated word register (the index). This displacement is added to the memory address and the resulting address points to the location whose contents are used by the instruction. The memory address is specified as an expression that evaluates to either a 16-bit value (short offset) or a 32-bit value (long offset). All assembly-time address expressions are evaluated using 32-bit arithmetic. This address is followed by the index, a word register designator enclosed in parentheses. For Indexed addressing, a word register is specified by an "R" followed by a number from 1 to 15. Any general-purpose word register can be used except R0.

```
LD   R10,TABLE(R3)               Load the contents of the
 "    "                          location addressed by TABLE
 "    "                          plus the contents of reg-
 "    "                          ister 3 into register 10
```

The assembler automatically creates the proper format for the memory address, which includes the segment number and the offset. As with Direct addressing, symbolic names should be used wherever possible so that values can be assigned later when the module is linked or loaded for execution.

For those cases where a specific segment is desired, the following notation can be used (the segment designator is enclosed in double angle brackets):

```
&lt;&lt;segment&gt;&gt;offset(r)
```

where "segment" is a constant expression that evaluates to a 7-bit value, "offset" is a constant expression which evaluates to a 16-bit value, and "r" is a word register designator. This notation is expanded into a long offset address by the assembler.

To force a short offset address, the segmented address may be enclosed in vertical bars (||). In this case, the offset must be in the range 0 to 255, and the final address includes the segment number and short offset in a 16-bit value.

```
LD  R10,|TABLE|(R3)            Load the contents of the
 '    '                        location addressed by
 '    '                        TABLE (short offset format)
 '    '                        plus the contents of reg-
 '    '                        ister 3 into register 10

LD  <<5>>8(R13),R10            Load the contents of regis-
 '    '                        ter 10 into the location ad-
 '    '                        dressed by segment 5
 '    '                        offset by 8 (long off-
 '    '                        set format) plus the con-
 '    '                        tents of register 13
```

Relative Address

Relative address mode is implied by its instruction. It is used by the Call Relative (CALR), Decrement and Jump If Not Zero (DJNZ), Jump Relative (JR), Load Address Relative (LDAR), and Load Relative (LDR) instructions and is the only mode available to these instructions. The operand, in this case, represents a displacement that is added to the contents of the program counter to form the destination address that is relative to the current instruction. The original content of the program counter is taken to be the address of the instruction byte following the instruction. The size and range of the displacement depends on the particular instruction, and is described with each instruction in the Z8000 Assembler Reference Manual.

The displacement value can be expressed in two ways. In the first case, the programmer provides a specific displacement in the form "$+n" where n is a constant expression in the range appropriate for the particular instruction and $ represents the contents of the program counter at the start of the instruction. The assembler automatically subtracts the value of the address of the following instruction to derive the actual displacement.

```
JR OV,$+ONE     Add value of constant ONE to program
 '  '           counter and jump to new location if
 '  '           overflow has occurred
```

In the second case, the assembler calculates the displacement automatically. The programmer simply specifies an expression that evaluates to a number or a program label as in Direct addressing. The address specified by the operand must be in the valid range for the instruction, and the assembler automatically subtracts the value of the address of the following instruction, to derive the actual displacement.

```
DJNZ R5,BETA      Decrement register 5 and jump to
,    ,            BETA if the result is not zero

LDR  R10,ALPHA    Load the contents of the location
,    ,            addressed by ALPHA into register 10
```

Based Address

A Based address consists of a register that contains the base and a 16-bit displacement. The displacement is added to the base and the resulting address indicates the location whose contents are used by the instruction.

The segmented based address is held in a register pair that is specified by an "RR" followed by an even number from 2 to 14. Any general-purpose register pair can be used except RR0. The dispacement is specified as an expression that evaluates to a 16-bit value, preceded by a "#" symbol and enclosed in parentheses.

```
LDL    RR2,R1(#255)        Load into register pair 2-3 the
,      ,                   long word value found in the
,      ,                   location resulting from adding
,      ,                   255 to the address in register 1

LD     RR4(#%4000),R2      Load register 2 into the loca-
,      ,                   tion addressed by adding %4000
,      ,                   to the segmented address found
,      ,                   in register pair 4-5
```

Based Indexed Address

Based Indexed addressing is similar to Based addressing except that the displacement (index) as well as the base is held in a register. The contents of the registers are added together to determine the address used in the instruction.

The segmented based address is held in a register pair that is specified by an "RR" followed by an even number from 2 to 14. Any general-purpose register pair can be used except RR0. The index is held in a word register that is specified by an "R" followed by a number from 1 to 15. Any general-purpose word register can be used except R0.

```
LDB    RR14(R4),RH2     Load register RH2 into the
,      ,                location addressed by the
,      ,                address in RR14 indexed by
,      ,                the value in R4
```

ASSEMBLER DIRECTIVES

Assembler Directives are program statements which have the same format as machine instructions but whose action does not correspond to any machine instruction. These are used to control the operation of the assembler with regard to functions other than producing the machine code for an instruction.

Directives fall into two major categories: data generation directives which allocate and possibly initialize program data areas, and control directives which control and affect the operation of the assembler.

DATA GENERATION DIRECTIVES

These cause data space to be reserved at the current assembly location. Directives differ in element size and ability to initialize the data space.

DS

This directive is used to define uninitialized data. It takes a single required operand which is an expression which evaluates to an absolute value (i.e. not relocatable). No forward referencing of symbols is allowed in the expression. The given number of two-byte words is reserved at the current location, after rounding up to the next even boundary. Note that an operand of "0" may be used to force rounding of the location counter up to an even boundary without reserving any space for data. Also, if a label is defined in the label field of the same statement its value is set to that of the location counter after the rounding operation, but before the data definition.

```
         DS    0        round up to next word boundary

   BUFFER DS   100      reserve a one hundred-word buffer
```

DSB

This directive is used to define uninitialized data. It takes a single required operand which is an expression which evaluates to an absolute value (i.e. not relocatable). The given number of bytes is reserved at the current location. No forward referencing of symbols is allowed in the expression.

	DSB	100	reserve 100 bytes
keyboard_buffer	DSB	number_base_16	define keyboard_buffer

DSL

This directive is used to define uninitialized data. It takes a single required operand which is an expression which evaluates to an absolute value (i.e. not relocatable). No forward referencing of symbols is allowed in the expression. The given number of four-byte longwords is reserved at the current location, after rounding up to the next even boundary. Note that an operand of "0" may be used to force rounding of the location counter up to an even boundary without reserving any space for data. Also, if a label is defined in the label field of the same statement its value is set to that of the location counter after the rounding operation, but before the data definition.

*		DSL	100	leave exactly 400 bytes uninitialized
*	buffer_pointer	DSL	1	define memory pointer variable

DD

The DD directive is used to define initialized data areas consisting of two-byte word values. The directive may take any number of operands and repetition factors may be applied to groups of them (described below). Each operand is an expression which evaluates to either an absolute value or to a relocatable value. In either case only the low-order 16 bits of the value is used. One word of data is generated for each operand supplied at the current location after rounding up to the next even boundary. Also, if a label is defined in the label field of the same statement its value is set to that of the location counter after the rounding operation, but before the data definition.

```
        DD      10244       define one word with contents 10,244 (%2804)

 * Define a power-of-two table of words:

 TABLE   DD  0,1,2,4,8,16,32,64,128
         DD  %100,%200,%400,%800,%1000,%2000,%4000,%8000

 Key     DD  'A'           define word containing %0041
```

DDB

The DDB directive is used to define initialized data areas consisting of byte values. The directive may take any number of operands and repetition factors may be applied to groups of them (described below). Each operand is an expression which evaluates to an absolute value, or a string.

If the operand is a value, only the low-order 8 bits are used and one byte of data is generated at the current location.

```
        DDB     'A'!%40,['Z'+1]!%40      two data bytes
```

String operands are sequences of any length (including zero) of ASCII characters. They are delimited by quotation marks, so an embedded quotation mark is written %" and an embedded percent sign is written %%. The discussion of hexadecimal and mnemonic equivalents for ASCII characters (see Constants) applies as well to strings. One byte of data is generated for each byte of a string, at the current location.

```
string  DDB     "this is a string"

EndOff  DDB     7,%0D,%0A          bell, carriage return, line feed

MESSAGE DDB     "ERROR - INVALID INPUT%r",7,0
```

DDL

DDL is used to define initialized data areas consisting of four-byte long values. The directive may take any number of operands and repetition factors may be applied to groups of them (described below). Each operand is an expression which evaluates to either an absolute value or to a relocatable value. Two words of data are generated for each operand supplied at the current location after rounding up to the next even boundary. Also, if a label is defined in the label field of the same statement its value is set to that of the location counter after the rounding operation, but before the data definition.

```
*  Define table of three long words, the address of the
*  start of the region, the address of the end of the
*  region and the size in byte of the region.

        DDL     START,END,END-START

        DDL     %7f017fff,'AB'     define two long words the first
        ,       ,                  containing hex 7f017fff, and the
        ,       ,                  second hex 00004142
```

The DD, DDB and DDL directives each take an arbitrary number of operands and allow repetition factors to be applied to them. A repetition factor takes the form of an absolute expression. The repetition factor must be followed by the operand enclosed in parentheses. This has the effect of the enclosed operands appearing in sequence, the number of times given by the expression.

Repetitions may be nested. No forward referencing of symbols is allowed.

```
ARRAY   DD   1000(0)      define array of 1000 words,
*                         all initialized to zero.

* define and initialize 8 bytes
CrcTab  DDB  2("asdf")    which would be 8 bytes.
```

The DD directives with repetition factors have the potential to produce voluminous listings. If the generated code is too large to fit the space to the left of the source line, the code will follow the listing line in groups of 8, 16, or 32 data elements (for DDL, DD, and DDB respectively).

CONTROL DIRECTIVES

MODULE

A MODULE statement defines the beginning of each module in the source file. It must occur as the first instruction of each module in the input source file. A module ends either at the next MODULE statement or at the end of the input source file. Modules within the same file are completely unrelated; no symbols may be shared or passed between them.

The first operand of the MODULE statement, the module name, is required. This operand follows the composition rules of a normal symbol, but cannot be referenced elsewhere in the program. The second operand is also required. It must be the keyword "SEGMENTED" to tell the module to contain code for a segmented Z8000.

```
MODULE test_seg,segmented
```

SECTION

A module is composed of sections which are named explicitly by the user. A section is the smallest unit of relocatability within the programming system. Portions of the same section cannot be split further and placed separately at link time.

A SECTION directive must appear in each module before the first machine instructions or data generating directive. The SECTION directive has one required operand which is the section name. This operand follows the composition rules of a normal symbol, but cannot be referenced elsewhere in the program.

If a section name duplicates another section name already declared in the same module, it is taken as a continuation of the same section. The assembly location counter is set to 0 at the beginning of a new section or to the value it had at the previous end of a continued section. The special character asterisk (*) may be specified in place of the section name to indicate the most recent section is to be continued.

All symbols defined within a module must be unique. Thus, symbols may be cross-referenced between sections of the same module.

```
section      some_examples

SECTION      examples

SECTION      *
```

AT

This directive is used to change the assembly location counter. It takes a single operand which is a numeric expression. The expression defines the offset in the current section at which the next instruction or data is to be generated. It may be used to move forward, leaving an uninitialized gap, or to move backward, overwriting code or data previously generated at that location.

The expression must use symbols which have already been defined or constants; no forward referencing of symbols is permitted.

In order to specify a symbolic location with a numeric expression, label the beginning of the section. If the label at the beginning of the section is, for instance, START.up, you could make the following assignments:

```
AT      [$-START.up]+10         same as "DSB  10"

AT      START.up+%100           resume assembling at offset %100
```

TEMPLATE

This directive allows the definition of assembly-time symbols by means of suspending the actual generation of code/data. The effect of the TEMPLATE instruction is to cause all subsequent source statements to be processed normally but no code or data to be generated in the output object file. Thus all symbols are defined, but they are not assigned to any location. Normal processing of assembler instructions is reinstated by the next SECTION, MODULE, COMMON, or TEMPLATE statement.

The TEMPLATE directive takes one required operand. It is an expression which is absolute, internally relocatable or externally relocatable. The symbols subsequently defined are given values relative to that expression.

```
    *  The following statements define the layout
    *  of the REQUEST CONTROL BLOCK. No memory is
    *  reserved at this time but the four symbols
    *  become defined as absolute constants which
    *  are their respective offsets in the block.

                       TEMPLATE    0

    RCB.RQCODE         DSB         1
    RCB.STATUS         DSB         1
    RCB.DATAPTR        DSL         1
    RCB.COUNT          DS          1
```

COMMON

The COMMON directive is used to declare a common data area. Generation of code or data in the object module is suspended until the next MODULE, SECTION, TEMPLATE or COMMON directive. The instructions which follow have the effect of defining the symbols therein declared and of defining the length of the common area. The COMMON directive has no operand but a common name must be provided in the label field of the instruction. This follows the composition rules for external symbols and is itself an external symbol; the COMMON statement serves to declare it as such.

No memory space is reserved for the common area by the assembler. The name and size of the common is placed into the output object module for use by the linker. The common name is a bonafide external symbol and may be used in other places in the assembly where an external symbol is allowed.

```
   *   Define named common area to contain all globally used variables.

   GLOBAL_VARIABLES     COMMON
   Buff.Ptr             DSL      1
   Glob.Flag            DSB      1
   CmdLength            DS       1        *** WARNING, rounding will
                        ,        ,            occur for alignment ***
```

ASSIGN

ASSIGN is used to define an assembly-time symbol. The symbol to be defined appears in the label field of the instruction. The value to be assigned to it is given as the operand. The operand is an expression which may be absolute, internally relocatable or externally relocatable.

The new symbol takes on the value and type of the expression. Symbols in the expression may not be forward referenced. The defined symbol must be unique within the module; it is not permissible to redefine a symbol with an ASSIGN statement.

```
CCCC            ASSIGN   %F           defines a constant symbol

KEY             ASSIGN   'A'          defines a character value

ABSOLUTE_ADDR   ASSIGN   <<3>>%100    defines an absolute address

LOOP2           ASSIGN   $            equivalent to "LOOP2 DSB 0"
                  ,      ,            or to LOOP2 standing alone
                  ,      ,            on a line

LOOP_X          ASSIGN   LOOP2+2      program location after first
                  ,      ,            word of LOOP2 routine.
```

GLOBAL

The GLOBAL directive is used to define a global symbol. This symbol is accessible within the current module, and is also made accessible at link time to all other modules. There are no operands to the directive. The symbol to be defined is given in the label field of the instruction, and must be unique within the module. It receives the value of the current assembler location. This directive may only occur within a section; it may not appear within the range of a TEMPLATE or a COMMON directive.

```
compare global          label first instruction of routine
*                       so it may be used by all modules

*  Define a global word variable, initialized to
*   all ones.

        DS        0   align, to make sure
ONES    GLOBAL
        DD        %(2)1111111111111111
```

EXTERNAL

The EXTERNAL directive is used to declare a symbol which is to be defined at link time in another module. There are no operands. The symbol to be declared is given in the label field of the instruction. Since the symbol is not associated with any particular section, its declaration may appear anywhere in the module.

```
*   Declare routines in utility module needed by this module.

BCD_ADD      EXTERNAL
BCD_SUB      EXTERNAL
BCD_DIV      EXTERNAL
```

IF and ENDIF

These directives are used to implement a conditional assembly facility. The IF instruction takes a single operand which is an expression which may be of any type, but may not contain forward symbol references. If the value of the expression is exactly zero, all statements following the IF and before the corresponding ENDIF are treated as comments. An ENDIF takes no operands. IF-ENDIF pairs may be nested.

Assume an assembly program is to be assembled in one of two different ways, depending on which machine, X or Y, it is going to run on. Using the ASSIGN directive we set the symbols X and Y to show which the current assembly is for. One is set to 1, the symbol for the machine being selected, the other to 0, for that not selected. A portion of the assembly might appear as follows:

```
*   If assembling for the X machine,  invert the value.

        if    X              could also say IF X<>0
        COM   R0
        endif
```

LISTON and LISTOFF

These directives allow the selective inclusion of portions of the assembly in the listing file. They take no operands. If no listing file was named in the assembler command line, then these have no effect since no listing is being produced anyway. Rather than being just an on/off switch listing control is accomplished with a signed counter. The counter starts at zero, each occurance of a LISTON increments it by one and each LISTOFF decrements it by one. Text is placed into the listing file whenever the counter is greater than or equal to zero. This technique provides hierarchical levels of control. The counter is not reinitialized for each new module encountered in the input source file.

PAGE

This directive forces a page break in the listing file following the newline character of the previous line. A page heading along with the current title string is produced following a form-feed character. If no line has been printed since the last automatic or requested page break then the entire instruction is ignored. With no operand, PAGE forces a form feed. With an operand, the operand will set the number of lines per page. This does not include the 5 lines of header information. To get 50 lines per page, the PAGE operand would be 55.

TITLE

This directive allows the programmer to provide a title to be placed in the upper left corner of each listing page. It takes a single operand which is a string enclosed in quotation marks ("). An automatic page break including a new heading is produced using the new title string.

```
TITLE   "LINKER RELEASE 7.44 -- PASS ONE"
```

INCLUDE

This directive causes the insertion of the source from another file into the current assembly at the point at which the directive occurs. There is a single operand consisting of the filename enclosed in quotation marks. The listing file always has the entire line containing the INCLUDE instruction before the insertion is done. If a page break occurs for any reason while in the included file the page heading shows the name of the file currently being processed. INCLUDEs may be nested, but they may not contain MODULE directives.

```
include "stdio.h"          get standard i/o package definitions

INCLUDE "Def_Insert"       place insertion source for Def here
```

THE PCOS STANDARD.

This section describes how to write Assembler source programs in order to obtain maximum compatibility with the operating system (PCOS) routines.
This will allow user programs to use the same procedures as for any PCOS utility for invoking and for passing parameters to the Assembler program.

The following figure shows the way in which an Assembler utility is connected to various parts of the system.

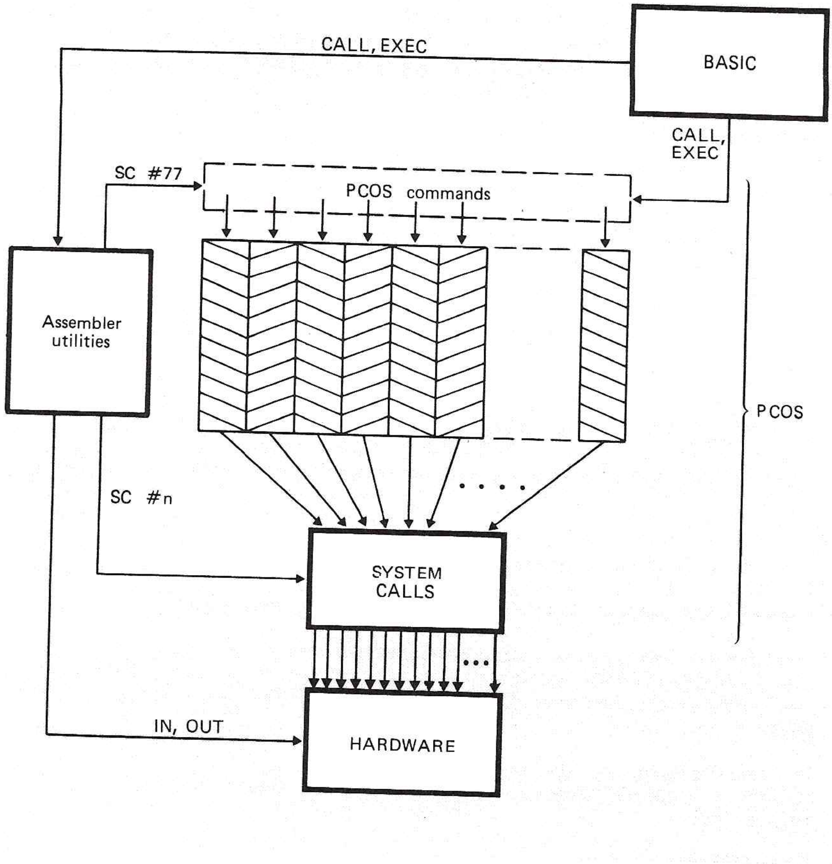


Fig. 2-1 Connection between Assembler utilities and other parts of the system

If Assembler routines are written following a certain standard, it is possible to invoke them like a simple PCOS command, or from a BASIC program.
By means of conventions on the passing of paramèters, the same Assembler utilities can call PCOS commands or access a group of small routines (system calls), that are also used by the operating system (PCOS). These provide a certain number of elementary operations on the system hardware, thus facilitating programming.
Direct access to the system hardware will consequently be possible, by

means of the Assembler instructions IN, OUT (see Appendix F for a list of I/O port assignments and consult M20 hardware literature).
It is also possible to access PCOS commands from an Assembler utility, using the Assembler instruction SC 77 which is described in the second part of this manual.
Let us now summarise the various ways to call (from PCOS and BASIC respectively) an Assembler utility (e.g. MYFILE) which is written according to the PCOS standard, to which the parameters para1, para2 and para3 are passed.

PCOS

```
MYFILE    PARA1,PARA2,PARA3
```

BASIC

```
CALL "MYFILE"(PARA1,PARA2,PARA3)
```

Where PARA1,PARA2,PARA3 can be either constant or variable parameters.

or

```
EXEC "MYFILE PARA1,PARA2,PARA3"
```

Where PARA1,PARA2,PARA3 can only be constant parameters.

Furthermore, certain conventions within our Assembler source file, will also make it possible to obtain the identification of our program, while the program is being loaded (by using the PCOS commands PLOAD or PDE-BUG).

The instructions and the Assembler directives to be used in order to obtain a routine compatible with the PCOS standard, are dealt with in this order:

1. Configuration code

2. Header

3. How to pass the parameters

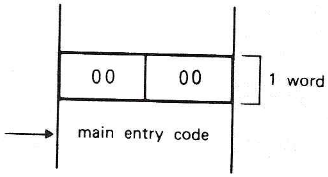
4. Exit Routine

5. Example

1. Configuration Code

The first "word" of an executable program, will provide information (while the program itself is being loaded) on how it will be configured in memory. This word, being the first word of the program, must assume the value zero and indicates that the word immediately following, is the entry point.

Schematically:



To obtain a source program complying with configuration code 0, the first statement must be DD 0.
Other types of configuration codes are allowed by the system software, but cannot be utilised by the user.

2. Header

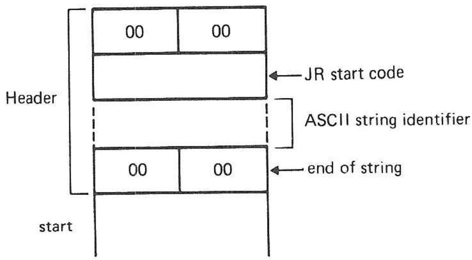
When an executable file is being loaded using PLOAD or PDEBUG, the M20 displays some information on the screen, amongst which the program name. This program name can be inserted at source program level in the "header" of the program itself.

The header is that part of the program containing both the configuration code previously mentioned and a string identifier which will be the program name. For example, the "header" of a source file can contain any of the following Assembler instructions:

```
              module      echo, segmented
              section     example
Header      [ dd          0              type 0
            | JR          start
            | ddb         "File Echo "   string ident. prog.
            [ dd          0
  start       .
              .
              .
            program
              .
              .
```

In practice, the string identifier is placed in memory between the second word and the first occurrence of a "null (00)". This string must be skipped by means of the instruction "JR start" in the source program. It is important that the jump instruction of the string identifier is JR and not JP, as JR only occupies 1 word, thus allowing the start of the string from the third word of the executable program.

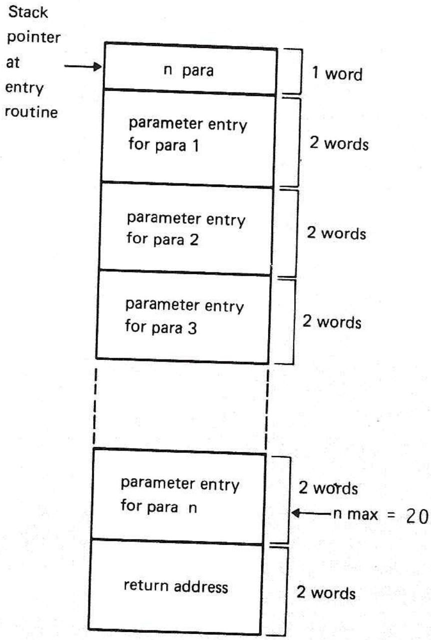
The situation of the program in memory will be the following:



3. How to pass the parameters

When an assembler utility is invoked by PCOS or by BASIC, all the parameters passed to it are placed (pushed) in the stack by the system so that they can be extracted (popped) from the stack in the order and in the way in which they were placed.

The maximum number of parameters that can be passed is 20. The pointers to the parameters (parameter entry) will be allocated in the stack when the routine is invoked, in the following way:



The user program must however extract information about the various parameters by means of as many "pop" instructions from the stack, as the corresponding number of parameters.
As seen in the figure, the number of parameters is given by the first word addressed by the stack pointer when the routine is invoked by PCOS or BASIC.

It is possible to have 3 types of parameters:

- Null	with	hexadecimal	code	00
- Integer	"	"	"	02
- String	"	"	"	03

The code for each type of these parameters is memorized in the 2nd byte of the 1st word for each "parameter entry"

no. seg	type parameter
offset	

For the type "null" the "parameter entry" does not contain an actual pointer, but for compatibility, it will be of the type:

FF	00
FF	FF

This type of "parameter entry" is created when, for example, the routine is invoked in the following way:

```
my para1,,para3
```

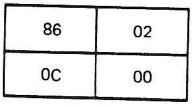
It can be seen therfore, that the second parameter has been jumped (para 2). This means in practise, that a pointer to a dummy parameter (parameter entry) is created (with FF00 FFFF) in order to maintain compatibility with the standard.

For the integer type (02) there will be a real pointer to the parameter, constructed in the following way:

n seg	02
offset	

The segment number and the offset constitute the effective address to a word integer (this is a Z-8001 compatible segmented address)

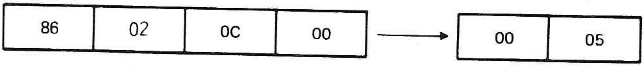
For example, the "parameter entry" for integer 5 could be:



In this case, the address for the word containing integer 5 will be:

<<6>> 0C00

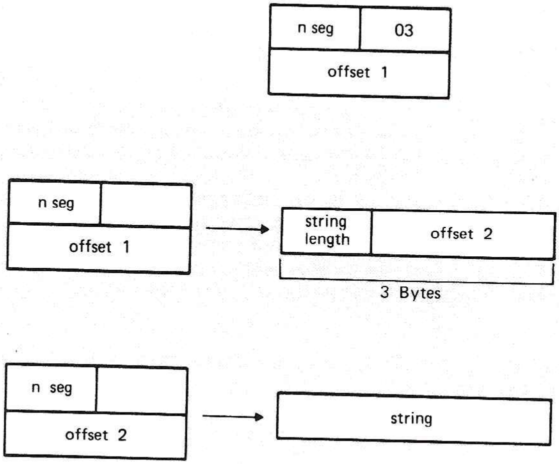
This can be represented schematically as:



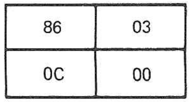
(Note that once the type has been identified the second byte is ignored)

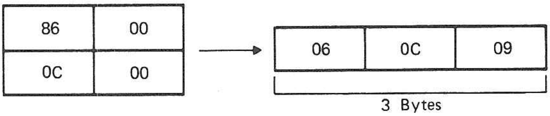
However, if the parameter is a "string" (type 03), the procedure for pointing to the string is more complex than the previous two.
In this case, the pointer (entry parameter) points to a set of 3 bytes, the first of which contains the string length, whereas the other two contain the address (significant only for the offset part as the seg. no. is the same as the entry parameter) pointing to the string itself.

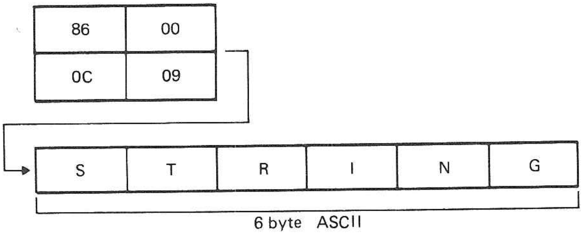
e.g.



For example, the "Parameter Entry" for the string "STRING" must have the following structure:







4. Exit Routine

The Assembler programmer is advised to write his programs so that he can easily handle the exit from the program by means of the instruction RET, in order to return to the environment from which it was called.

It is convenient to save in 2 words (RETADR) the stack address which points to the program return address. In this way, the stack pointer can be set to this address before exiting the program (using the "RET" instruction). In order to access the program return address, you will have to use the "number of parameters" saved in the first stack location.

To accomplish this, the following Assembler instructions can be used at the start of the utility:

```
          .
          .
          .
          POP R0,@RR14    no. par in R0
          CLR R2
          LD  R3,R0
          SLL R3,#2         no. par x4
          ADD RR2,RR14    pointer to reurn address in RR2
          LDL RETADR,RR2  store RR2
          .
          .
          .
       program
          .
          .
          LDL RR14,RETADR
          RET
   RETADR DSL 1
          .
          .
          .
          .
```

5. Example

Here a complete example is given of a simple Assembler source program in which the standard (which we have seen up till now) is taken into account. In input, this program takes a string as a parameter and echoes the string itself in output. Once the program has been assembled and linked in an executable file "echo.cmd", it can be called from PCOS in the following way:

```
ec string /CR/
```

```
*************************************************************************************
*                                                                                   *
*   Echo string input to this ruotine                                               *
*   An example of the use of the M20 Assembler Package                              *
*                                                                                   *
*                                                                                   *
*************************************************************************************
*
          MODULE     echo,SEGMENTED
          SECTION    example
          TITLE      "ROUTINE SEGMENTED ECHO"
*
*   program header
*
          DD         0               configuration code--MANDATORY HERE
          JR         echo            PCOS expects this instruction format
str       DDB        "File Echo "    program identifier
          DDB        "%r"            carriage return
          DDB        0               end of program header
*
*   code
*
echo      ASSIGN     $
          LDA        RR12,str        point to message
          SC         #89             display string identifier
          POP        R0,@RR14        get parameter count
          CLR        R2
          LD         R3,R0           use R3 as working register
          SLL        R3,#2           multiply # parameters by 4
          ADDL       RR2,RR14        add to stack to point to return addr
          LDL        retadr,RR2      save it for later return
*
*   Now test for # parameters passed and reject if wrong
*
          TEST       R0              how many parameters?
          JP         NZ,echo1        not zero parameters so go on
          LD         erconu,#76      Message = "error in parameter"
          JP         error           exit with error message
*
*   So we have one or more parameters passed
*   Transfer parameters to registers, checking data types...
*
echo1     ASSIGN     $
          POPL       RR2,@RR14       get pointer to parameter in rr2
          CPB        RL2,#3          is parameter a string?  (type 3)
          JP         EQ,echo2        yes, go service, else....
          LD         erconu,#13      Message = "type mismatch"
          JP         error
*
*   Main program code here
*
echo2     ASSIGN     $               print input string to screen
          CLRB       RL2             clear data type byte
          CLR        R7
          CLRB       RH6
          LDB        RL6,@RR2        string length in RL6
          INC        R3              RR2 points to the next byte
          LDB        RH1,@RR2
          INC        R3              RR2 points to the next byte
          LDB        RL1,@RR2
```

```
              LD        R10,R2
              LD        R11,R1           RR10 points to the string parameter
              LD        R8,#17           prepare registers for SC #13
              LD        R9,R6
              SC        #13              display string
              CLR       R5               assume no error returned by SC #13
              SC        #90              add a CR/LF
              CLR       R5               assume no error returned by SC #90
              JR        n_return         jump around error service
*
*   Exit with appropriate error message
*
error         ASSIGN    $
              LD        R5,erconu        must have been set up first !!!
              SC        #88              display error message
*
*   Normal return
*
n_return      ASSIGN    $
              LDL       RR14,retadr      point stack pointer to return address
              RET       ,                and return to caller
*
*   Storage area
*
              SECTION   area
*
retadr        DSL       1                storage for return address
erconu        DS        1                storage for error type code
*
*   End (echo)
*
```

3. THE ASSEMBLER (ASM) COMMAND

ABOUT THIS CHAPTER

This chapter details the ASSEMBLER (ASM) command. This command processes an Assembly language source file and produces an object file.

CONTENTS

ASM 3-1

The ASM command processes an Assembly Language source file of ASCII text and produces a file containing the corresponding Z8000 machine code. This file is known as an object file. Optionally the ASM command produces a listing file. When such a file is listed the video displays the source file program lines on the right and the generated code or symbol values along with other information about each program line on the left. If the XREF option is specified for a listing file then it will also include a cross-reference table at the end. Examples of object and listing files are shown at the end of this chapter.

The ASM command is called from PCOS like any other PCOS command. When called it is loaded into memory and executed. After execution the system returns to the PCOS environment. The command syntax is shown in figure 3-1 below.

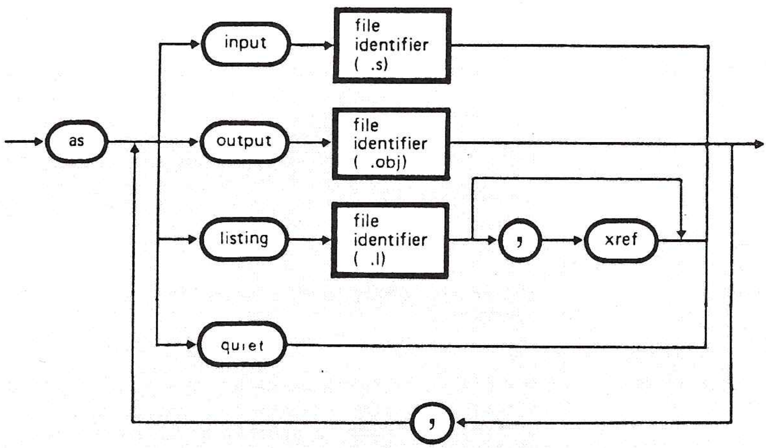


Fig. 3-1 The ASM command

Where

SYNTAX ELEMENT	MEANING
INPUT	The keyword which must precede the source file identifier
file identifier (.s)	The source file identifier complete with any necessary volume identifier and/or password. Usually a source file name is assigned a '.s' extension.
OUTPUT	The keyword which must precede the object file identifier
file identifier (.obj)	The object file identifier complete with any necessary volume identifier and/or password. Here again it is good programming practice to assign the extension '.obj' to an object file name. If the file specified does not exist then it will be created; if on the other hand the file exists then it will be overwritten with the new object file.
LISTING	The keyword which must precede the listing file identifier.
file identifier (.l)	The listing file identifier complete with any necessary volume identifier and/or password. A listing file name is usually assigned the extension '.l'. If the file specified does not exist then it will be created; if on the other hand the file exists then it will be overwritten with the new listing file.

XREF	The Cross-Reference keyword. If specified then a cross-reference table is included at the end of the listing file. This table contains an entry for each symbol defined in the assembly with the following information: - The statement number at which the symbol is defined. - Its value and type. - An ordered list of statement numbers which reference the symbol.
QUIET	The Quiet keyword. Specifying this keyword in an ASM command line will suppress all the messages normally output on the video except for error messages which abort the command.

An ASM command parameter is identified by the command line interpreter by its keyword; for this reason parameters can be entered in any order.

The command "AS" by itself causes the command parameters to be displayed on the screen.

If the OUTPUT and LISTING options are omitted then the respective object and listing files will not be created.

Characteristics

The ASM command is executed in a number of stages depending on the number of modules in the input source file. In the first stage the header is assembled; each module is then assembled in subsequent stages. Each assembly stage is done in two passes.

During execution, unless the QUIET keyword was specified, the video displays information indicating the end of each pass, and short messages for warnings, and errors discovered. These messages specify the line number and the code for each error and/or warning. When execution is complete the video displays a summary line with the total number of errors and warnings. A listing file printout will turn out to be very useful for subsequent analysis of errors. ASM error and warning codes are listed in appendix B.

Examples

IF you enter	THEN ...
as input 1:test.s,output 1:test.obj /CR/	the source file "test.s" which is on the disk inserted in drive 1 is assembled. The resulting object file is written into a file called "test.obj" on the disk inserted in drive 1. If this file already exists then it will be overwritten with the new object file, if on the other hand it does not exist then it will be created.
as input 1:myfile.s,output 1:myfile.obj,listing 1:myfile.l,xref /CR/	the source file "myfile.s" which is on the disk inserted in drive 1 is assembled, as in the previous example, however this time a listing file is also created. The listing file "myfile.l" is created on the disk inserted in drive 1. The file "myfile.l" will have a cross-reference table included.

The sample printout on the following pages is that of the listing file corresponding to the source file shown in chapter 2. This listing file includes a cross-reference table. This file was obtained using the following command:

```
as input 1:echo.s,output 1:echo.obj,listing 1:echo.l,xref /CR/
```

```
                                        M20 Assembler v 2. 1. 7. 0               06/08/1983 08:38:27  Page   1

                              Source  Ref  File  1:echo.s
Location Code/Value            Line  Line  Line  Source Text
-------------------------------------------------------------------------------------------------------------
                                  1           1  ****************************************************************************
                                  2           2  *                                                                          *
                                  3           3  *   Echo string input to this ruotine                                      *
                                  4           4  *   An example of the use of the M20 Assembler Package                     *
                                  5           5  *                                                                          *
                                  6           6  *                                                                          *
                                  7           7  ****************************************************************************
                                  8           8  *

8 Lines, 0 Warnings, 0 Errors in Header

                                  9           9              MODULE     echo,SEGMENTED
                                 10          10              SECTION    example
                                 11          11              TITLE      "ROUTINE SEGMENTED ECHO"
                                 12          12  *
                                 13          13  *   program header
                                 14          14  *
00,0000 0000                     15          15              DD         0              configuration code--MANDATORY HERE
00,0002 E806                     16    23    16              JR         echo           PCOS expects this instruction format
00,0004 46 69 6C 65 20 45 63     17          17  str         DDB        "File Echo "   program identifier
00,000B 68 6F 20
00,000E 0D                       18          18              DDB        "%r"           carriage return
00,000F 00                       19          19              DDB        0              end of program header
                                 20          20  *
                                 21          21  *   code
                                 22          22  *
      00,0010                    23          23  echo        ASSIGN     $
00,0010 760C 00,0004             24    17    24              LDA        RR12,str       point to message
00,0016 7F59                     25          25              SC         #89            display string identifier
00,0018 97E0                     26          26              POP        R0,@RR14       get parameter count
00,001A 8D28                     27          27              CLR        R2
00,001C A103                     28          28              LD         R3,R0          use R3 as working register
00,001E B331 0002                29          29              SLL        R3,#2          multiply # parameters by 4
00,0022 96E2                     30          30              ADDL       RR2,RR14       add to stack to point to return addr
00,0024 5D02 01,0000             31    87    31              LDL        retadr,RR2     save it for later return
                                 32          32  *
                                 33          33  *   Now test for # parameters passed and reject if wrong
                                 34          34  *
00,002A 8D04                     35          35              TEST       R0             how many parameters?
00,002C 5E0E 00,0040             36    43    36              JP         NZ,echo1       not zero parameters so go on
00,0032 4D05 01,0004 004C        37    88    37              LD         erconu,#76     Message = "error in parameter"
00,003A 5E08 00,007E             38    73    38              JP         error          exit with error message
                                 39          39  *
                                 40          40  *   So we have one or more parameters passed
                                 41          41  *   Transfer parameters to registers, checking data types...
                                 42          42  *
      00,0040                    43          43  echo1       ASSIGN     $
00,0040 95E2                     44          44              POPL       RR2,@RR14      get pointer to parameter in rr2
00,0042 0A0A 0303                45          45              CPB        RL2,#3         is parameter a string?  (type 3)
00,0046 5E06 00,005A             46    52    46              JP         EQ,echo2       yes, go service, else....
00,004C 4D05 01,0004 000D        47    88    47              LD         erconu,#13     Message = "type mismatch"
00,0054 5E08 00,007E             48    73    48              JP         error
                                 49          49  *
                                 50          50  *   Main program code here
```

```
ROUTINE SEGMENTED ECHO                           M20 Assembler v 2. 1. 7. 0                      06/08/1983 08:38:50  Page   2

                                    Source  Ref  File  1:echo.s
Location Code/Value                  Line  Line  Line  Source Text
------------------------------------------------------------------------------------------------------------------------------
                                      51          51  *
        00,005A                       52          52  echo2     ASSIGN     $             print input string to screen
00,005A 8CA8                          53          53            CLRB       RL2           clear data type byte
00,005C 8D78                          54          54            CLR        R7
00,005E 8C68                          55          55            CLRB       RH6
00,0060 202E                          56          56            LDB        RL6,@RR2      string length in RL6
00,0062 A930                          57          57            INC        R3            RR2 points to the next byte
00,0064 2021                          58          58            LDB        RH1,@RR2
00,0066 A930                          59          59            INC        R3            RR2 points to the next byte
00,0068 2029                          60          60            LDB        RL1,@RR2
00,006A A12A                          61          61            LD         R10,R2
00,006C A11B                          62          62            LD         R11,R1        RR10 points to the string parameter
00,006E 2108 0011                     63          63            LD         R8,#17        prepare registers for SC #13
00,0072 A169                          64          64            LD         R9,R6
00,0074 7F0D                          65          65            SC         #13           display string
00,0076 8D58                          66          66            CLR        R5            assume no error returned by SC #13
00,0078 7F5A                          67          67            SC         #90           add a CR/LF
00,007A 8D58                          68          68            CLR        R5            assume no error returned by SC #90
00,007C E804                          69    79    69            JR         n_return      jump around error service
                                      70          70  *
                                      71          71  *   Exit with appropriate error message
                                      72          72  *
        00,007E                       73          73  error     ASSIGN     $
00,007E 6105 01,0004                  74    88    74            LD         R5,erconu     must have been set up first !!!
00,0084 7F58                          75          75            SC         #88           display error message
                                      76          76  *
                                      77          77  *   Normal return
                                      78          78  *
        00,0086                       79          79  n_return  ASSIGN     $
00,0086 540E 01,0000                  80    87    80            LDL        RR14,retadr   point stack pointer to return address
00,008C 9E08                          81          81            RET        ,             and return to caller
                                      82          82  *
                                      83          83  *   Storage area
                                      84          84  *
                                      85          85            SECTION    area
                                      86          86  *
01,0000                               87          87  retadr    DSL        1             storage for return address
01,0004                               88          88  erconu    DS         1             storage for error type code
                                      89          89  *
                                      90          90  *   End (echo)
                                      91          91  *

83 Lines, 0 Warnings, 0 Errors in Module echo
```

```
Index for Module echo                              M20 Assembler v 2. 1. 7. 0                        06/08/1983 08:39:00  Page   3

                                                                  Source Lines
Type and (Base or Section)      Name            Value      Defining  Uses
---------------------------------------------------------------------------------------------------------------------------------
Section                         area            01,0006       85#
Module                          echo          0000_0094        9#
Relocatable (example)           echo            00,0010       23#     16
Relocatable (example)           echo1           00,0040       43#     36
Relocatable (example)           echo2           00,005A       52#     46
Relocatable (area)              erconu          01,0004       88#     37      47      74
Relocatable (example)           error           00,007E       73#     38      48
Section                         example         00,008E       10#
Relocatable (example)           n_return        00,0086       79#     69
Relocatable (area)              retadr          01,0000       87#     31      80
Relocatable (example)           str             00,0004       17#     24
```

```
ROUTINE SEGMENTED ECHO                             M20 Assembler v 2. 1. 7. 0                        06/08/1983 08:39:07  Page   4

                             Source  Ref  File  1:echo.s
Location Code/Value           Line  Line  Line  Source Text
---------------------------------------------------------------------------------------------------------------------------------
91 Lines, 0 Warnings, 0 Errors in 1:echo.s
```

4. THE LINK COMMAND

ABOUT THIS CHAPTER

This chapter describes the LINK command and all its keyword parameters. The chapter ends with an example and sample printouts of a command file and a map file.

CONTENTS

LINK	4-1
PARAMETERS	4-1
COMMENTS	4-3
MINIMUM COMMAND ELEMENTS	4-3
THE KEYWORDS	4-4
MULTI-FILE KEYWORDS	4-5
FILE KEYWORDS	4-5
SIMPLE KEYWORDS	4-8
BLOCK KEYWORD	4-9
KEYWORD ORDER	4-9
ERRORS	4-10

LINK

LINK is a linkage editor and locater which converts z-type object modules into a PCOS 3.0 relocatable load file. The LINK command must be called from the PCOS environment like any other PCOS command. LINK inputs one or more Olivetti Z-type object files, and outputs a single executable load file.

The LINK command allows a number of optional features described below.

PARAMETERS

There are six types of parameters which can be passed to LINK. These parameters are of the Keyword type, and can have parameters of their own. The keywords are listed below, grouped according to their type.

- Multifile keywords:	INPUT	LIBRARY
- File keywords:	COMMAND MAP	OUTPUT
- Value keywords:	BLOCKTYPE STACKSIZE ATTRIBUTE1	BLOCKSIZE ATTRIBUTE0 ATTRIBUTE2
- String keywords:	ENTRY	MESSAGE
- Simple keywords:	QUIET STATISTICS	VERBOSE OPTIMIZE
- Block keyword:	BLOCK	

The command syntax is shown in figure 4-1 below.

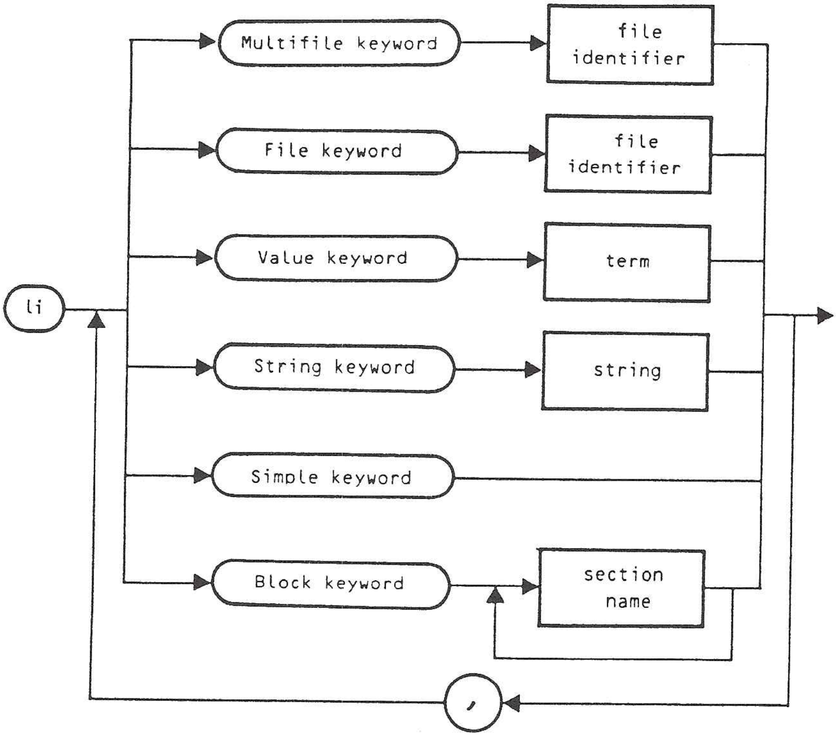


Fig. 4-1 The LINK command

Where

SYNTAX ELEMENT	MEANING
file identifier	The name of a file complete with any necessary volume identifier, and/or file password. Depending on the keyword in question the file will be accessed for reading or writing. In the latter case if the file specified already exists it will be overwritten with the new output.

	In the case of Multifile keywords you can use the two PCOS wild card characters (*) and (?) to specify more than one file; an asterisk (*) matches any string and a question mark (?) matches any single character.
term	A hexadecimal number preceded by a "%" sign, or a decimal number. In both cases the number can optionally be followed by a "K" symbol (upper or lower case) which multiplies the number by %1000 in the case of a hexadecimal number or by 1000 in the case of a decimal number.
string	Any string of ASCII characters.
section name	The name of a program section that exists in the input program modules. More than one program sections can be specified by one section name with the use of the following Wild Card characters: - An asterisk (*) which matches any string of characters, - A question mark (?) which matches any one character, - [ab...] which matches any one character inside the square brackets, - [a-b] which matches any one character in the interval a-b.

COMMENTS

Comments, enclosed in exclamation marks, can be inserted in a LINK command between parameters. This facility is useful to comment command files which you may use for LINKing specific types of programs. An example of a commented command file is given at the end of this chapter.

MINIMUM COMMAND ELEMENTS

The required elements of a LINK command which outputs a PCOS 3.0 executable file are the following:

- The multifile keyword INPUT followed by the file identifier(s) of the input file(s).

- The file keyword OUTPUT followed by the file identifier of the output file.

Commonly used options are:

- The multifile keyword LIBRARIES followed by the file identifier(s) of a library file(s).

- The file keyword MAP followed by the file identifier of a map file.

- The ENTRY keyword followed by the the program entry point.

- The file keyword COMMAND followed by the file identifier of a file containing part of a LINK command line.

- The BLOCK keyword followed by instructions ordering program sections.

These and other keywords are described in more detail in the next section.

Note: Care must be taken that no more than 20 parameters are specified in one LINK command; this is the maximum number of parameters that the PCOS command line interpreter can handle. In cases where more than 20 parameters need to be specified the COMMAND keyword can solve the problem (the COMMAND keyword is described below in the section on File Keywords).

THE KEYWORDS

In the following section all the LINK keywords are described. Each description has the keyword as a heading. In the command line keywords must be entered as they appear in this heading in either capital or small letters.

MULTI-FILE KEYWORDS

INPUT

The INPUT keyword may occur any number of times. It specifies files containing Z-type object modules which contain code sections to be located.

LIBRARY

This keyword instructs the program to select from the named library files the modules which have been referenced in the input file(s).

A library file can be created using the MLIB command described in chapter 6.

FILE KEYWORDS

COMMAND

The COMMAND keyword can be used in the command line to insert parameters from another named file (command file). Up to two levels of insertion are allowed (i.e. you can insert a COMMAND keyword in a command file called from standard input, but you cannot specify another COMMAND keyword in the file specified by a COMMAND keyword in a command file).

Such files containing part of a command line can be created using the Video File Editor. Comments, enclosed in exclamation marks, can be inserted in a command file between parameters.

An example of a Command file is shown at the end of this chapter.

OUTPUT

The OUTPUT keyword occurs once and only once. It specifies a file to receive the executable binary load file. The file is created if it does not exist or is completely replaced with the new output if it does exist.

The load file can be assigned any legal name, however there are two filename extensions which have a special meaning to PCOS; these are ".cmd" and ".sav". These filename extensions allow files to be called and executed from the PCOS environment like any other PCOS command (i.e.

by entering the first two characters of the file name). If a file has niether of these extensions it can be invoked by entering the complete file identifier. When a file which has no ".sav" extension is called it will be loaded from disk to the M20's memory, and executed. After execution the memory space that was occupied by the program is again made available to the system. This means that if the program is to be executed a second time it will have to be reloaded from disk to memory. In the case of a ".sav" extension the file will be permanently loaded and executed. In this case the file can be executed again even if the disk the file was loaded from is removed from its disk drive.

MAP

The MAP keyword may occur once. It specifies the file to receive the formatted map. It is created if it does not exist or is completely replaced with the new map if it does exist. If no MAP keyword is given, no map file is produced.

A map file will contain a copy of the LINK command line being executed, diagnostic messages, a location ordered map of sections and an alphabetical list of section names and global symbols with their corresponding locations.

VALUE KEYWORDS

BLOCKTYPE

The parameter passed to the BLOCKTYPE keyword sets a byte in each program text header of the output load file for all subsequently defined blocks.

In this version of LINK this byte is forced to zero, therefore this keyword has no effect at all even though it is recognised as a valid parameter.

BLOCKSIZE

The BLOCKSIZE keyword may occur any number of times. Its parameter specifies the maximum size for each block defined subsequently on the command line. The maximum block size that can be specified is 65528 (i.e. 64K less 8 bytes) which is the size of a processor segment. In the absence of a BLOCKSIZE keyword on the command line, the maximum block size is assumed by default.

STACKSIZE

The STACKSIZE keyword may occur only once. If specified its parameter determines the number of bytes of run-time stack that are to be dedicated to the linked program alone. If not specified the linked program will use the PCOS stack area (200 bytes in total).

ATTRIBUTE0, ATTRIBUTE1 and ATTRIBUTE2

The parameter passed to each of ATTRIBUTE0, ATTRIBUTE1 and ATTRIBUTE2 is placed in the first, second and third attribute bytes respectively in the header part of the output load file.

FOR ROUTINES TO RUN ON RELEASE 3.0 OF PCOS IT IS NECESSARY TO SET THESE ATTRIBUTES AS FOLLOWS:

- ATTRIBUTE0 TO ONE
- ATTRIBUTE1 TO ZERO
- ATTRIBUTE2 TO ZERO

AS THESE ARE ALSO THE DEFAULT VALUES OF THE ATTRIBUTE KEYWORDS IT IS NOT NECESSARY TO SPECIFY THESE KEYWORDS AT ALL.

STRING KEYWORDS

ENTRY

The ENTRY keyword may occur once. It provides a global symbol name which is to be made the entry point of the executable program. The entry point is determined as follows:

- If an ENTRY keyword is given, then the entry point specified is used, regardless of any definition within the input module itself.
- If no ENTRY keyword is given, then the entry point is set as defined in the input module.

MESSAGE

A MESSAGE keyword supplies the ASCII text (which must be one string) to go in the message record of the load file. There may be any number of MESSAGE keywords in one LINK command. The message record is the last record of the load file and does not form part of the executable program itself. It can be used for comments, remarks, date and time of operation, etc.

SIMPLE KEYWORDS

QUIET

The QUIET keyword causes output normally sent to the standard output to be suppressed, except for fatal error messages. If no QUIET keyword is given, the following information will be displayed:

- The LINK header line and version number.
- All error messages.
- A list of unresolved references.

VERBOSE

This keyword causes extra information to be sent to standard output. The command line being executed is displayed, entry to each new module is noted, and a warning is issued each time the possibility of an error is encountered.

STATISTICS

The STATISTICS keyword, if specified, causes the program to output statistics on how much of LINK's memory was used.

OPTIMIZE

Specifying the OPTIMIZE keyword in the command line causes the output file to be optimized by not including uninitialized memory at the beginning or the end of the program text section of the output load file. This produces a smaller load file and saves time in loading the program into memory.

BLOCK KEYWORD

BLOCK

The parameters of a BLOCK keyword are names of program sections that are to be loaded in one contiguous region of memory (i.e. a block). The BLOCK keyword may occur any number of times on a LINK command line. The program sections can also be specified by patterns with the use of the following Wild Card characters;

- An asterisk (*) which matches any string.
- A question mark (?) which matches any single character.
- [ab...] which matches any single character in the square brackets.
- [a-b] which matches any single character in the interval a-b

A pattern stands for all the section names which match that pattern, and which have not been used previously in the current or any other block. The sections are taken in the same order that they occur in the input object modules.

If a section does not fit in the first block that it matches, a warning message is issued by LINK , and the section is left as a candidate for other blocks that it also matches. Any sections which remain unplaced are reported via a warning message and ignored thereafter.

In the absence of a BLOCK keyword, "BLOCK *" is assumed by default as the last keyword on the command line. This means that LINK will attempt to place all sections in one block the size of which is defined in the command line (see BLOCKSIZE). If a program does not fit in one block then two or more BLOCK keywords need to be specified for a successful LINK operation. You can use BLOCK keywords to group sections in a LINKed program. For example, in a program where all stack section names end in "_s" and all data section names end in "_d", the three keywords,

```
block *_s,block *_d,block *
```

will cause LINK to group all stack sections in one block followed by all the data sections in another block followed by all the other sections in another block.

KEYWORD ORDER

The order in which keywords appear has no gross effect on the outcome of the operation. The effects of ordering are due to the fact that files are opened and flags are set when their respective keywords are encountered. For example, keywords which appear before the MAP or the VERBOSE keyword do not get echoed into the MAP file, or on standard output. The relative order of the BLOCKSIZE and BLOCKTYPE keywords is important because their parameters are used as default values for subsequently defined blocks.

ERRORS

If any fatal error occurs during the parsing of keywords or the execution of the locate operation, the program is stopped immediately with an error message on standard output and, if it was specified, the map file.

Examples

The following LINK command will create an executable file "echo.cmd" from the object file created in the example shown in chapter 3, "echo.obj". The command will also create a map file "echo.map".

```
li map 1:echo.map, input 1:echo.obj,output 1:echo.cmd, /CR/
```

The same result can also be obtained by specifying the command file shown below in the following command:

```
li command 1:comlist /CR/
```

On the following page is a listing of the file "comlist":

```
!          Command file for LINKing the ECHO example          !

                      MAP 1:echo.map

! Create a map file  "echo.map"  on  the  disk  inserted  in !
! drive 1. Note that as this is the  first  keyword  in  the !
! file all that follows will appear in the map file.          !

                      INPUT 1:echo.obj

! If more than one  file  need  to  be  specified  these can !
! follow even on successive lines as long as  there  are  no !
! intervening keywords.                                       !

                      OUTPUT 1:echo.cmd

!            Only one output file can be specified            !
```

On the following page is a listing of the map file created by this command.

```
Olivetti LINK -- Release s2.5

Commands (starting with Map command):
Map 1:echo.map

! Create a map file  "echo.map"  on  the  disk  inserted  in !
! drive 1. Note that as this is the  first  keyword  in  the !
! file all that follows will appear in the map file.         !


                        INPUT 1:echo.obj

! If more than one  file  need  to  be  specified  these can !
! follow even on successive lines as long as  there  are  no !
! intervening keywords.                                      !


                       OUTPUT 1:echo.cmd

!           Only one output file can be specified            !


=============================================================

Procedures and warnings:
    First pass - 1:echo.obj
    Second pass - 1:echo.obj

=============================================================

Input Map

file    module  section          size (hex)

1:echo.obj
        echo
                example             8e
                area                 6

=============================================================

Block Map  (all values in hex)

block  offset   size    end    section

  0        0     8e      8d    example
          8e      6      93    area

=============================================================

Global Symbols and Section Names (all values in hex)

symbol            block offset    section

area                0      8e      -
example             0       0      -

=============================================================

LINK complete
```

5. THE PDEBUG UTILITY

ABOUT THIS CHAPTER

This chapter describes how to load the PDEBUG utility, and details all the PDEBUG commands.

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INTRODUCTION

The PDEBUG (Program DEBUG) utility is used for debugging and testing programs. When the PDEBUG utility is invoked the M20 enters the PDEBUG environment, the prompt is changed to an asterisk and the cursor stops blinking; the M20 is ready to execute any PDEBUG command. This utility is stored on disk in a ".sav" type of file so that once it is loaded in the M20's memory it remains there until the system is re-booted.

LOADING AND INVOKING PDEBUG

There are two ways in which the "pdebug.sav" file can be loaded in the M20's memory for the rest of a working session; 1. by executing a PDEBUG command from PCOS (see below), or 2. by PLOADing the utility (see the PLOAD command in the "M20 PCOS User Guide").

When PDEBUG is in memory the user can enter the PDEBUG environment in any of the following ways:

- by executing a PDEBUG command from PCOS (see below)

- by pressing /CTRL//B/ when the M20 is in Execution mode (see below)

Moreover as PDEBUG modifies some tables in PCOS when it is loaded into memory, the following conditions also cause PDEBUG to be entered: Segment Violation Traps, Extended Processing Traps, Priveledged Instruction trap, Illegal Vectored Interrupts, and Non-Maskable Interrupts.

Another way of entering and exiting the PDEBUG environment is possible with the use of breakpoints. This is described in detail in the PDEBUG BREAKPOINT command description.

PDEBUG

Loads and invokes the PDEBUG utility, optionally loading a specified program from disk to memory.

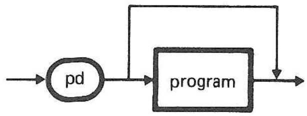

Fig. 5-1 The PDEBUG command

Where

SYNTAX ELEMENT	MEANING
program	EITHER the first two letters of a program name which has a ".sav", or a ".cmd" extension, OR the file identifier of a program file complete with any necessary volume identifier, extension, and/or file password.

Example

If both the PDEBUG utility and the program file "myprog.cmd" exist on any disk inserted in any of the two drives, and,

IF you enter	THEN ...
pd my /CR/	the program "myprog.cmd" is PLOADed and the M20 enters the PDEBUG environment. When the M20 PLOADs "myprog.cmd" the video displays information about the location of "myprog.cmd" in memory. This information will enable the user to access "myprog.cmd" directly in memory.

/CTRL//B/

When the M20 is in program execution mode, the /CTRL//B/ key combination will invoke the PDEBUG utility if it is already resident in memory. When /CTRL//B/ is pressed the video displays a message specifying the location in memory where program execution was halted, and the PDEBUG prompt is returned. The interrupted program remains in memory, and control can be returned to it by using the PDEBUG GO or JUMP commands.

TERMINATING A PDEBUG SESSION

At the end of a PDEBUG session the user can exit the PDEBUG environment and return to PCOS using the QUIT command.

q /CR/

If the state of the CPU is modified during a PDEBUG session (e.g. by breakpoint usage) then the QUIT command will force a re-boot of PCOS. If the state is not modified then a simple return to PCOS is done.

ENTERING PDEBUG COMMANDS

PDEBUG commands can be entered when the PDEBUG prompt (*) appears on the screen. Commands can be entered in either upper or lower case and are terminated by a carriage return. All numbers input to and output by PDEBUG are in hexadecimal ASCII format, and may be entered in either upper or lower case.

An address is specified either with a segment number and an offset, or with just an offset. The segment number is enclosed on the left with a less than symbol (<) and on the right with a greater than symbol (>) (i.e. <6> for segment 6). If only an offset is specified then either the last segment number used since PDEBUG was loaded, or, if none were specified yet, segment 0 is assumed by default.

An alternate method of specifying addresses is to use one of the 26 address registers ("a" to "z") preceded by the "@" sign. For example "@r25e" specifies the address given by the contents of register "r" plus "25E". An address register can be set using the OFFSET (register) command.

All the PDEBUG commands are described in this chapter. The commands are listed in alphabetical order. At the end of this chapter there are two PDEBUG tutorial sessions which demonstrate the use of the more commonly used PDEBUG commands.

A list of all the commands is displayed on the screen if the user enters a question mark (?) followed by a carriage return whenever the PDEBUG prompt (*) is returned.

CALCULATOR FACILITY

When in the PDEBUG environment the M20 can be used as a calculator for quick calculations in hexadecimal. The following binary operations can be performed:

+ A,B	adds B to A
- A,B	subtracts B from A
* A,B	multiplies A by B
/ A,B	divides A by B

where A and B are positive hexadecimal numbers in the range 0 to FFFF.

In each of these cases the returned result is also in this range, thus if the absolute value of the result (say C) is outside this range then the value returned will be hexadecimal "C mod 10000". For example,

	- 2,6	will return the value FFFC
and	+ ffff,1	will return the value 0000

THE COMMANDS

BREAKPOINT

Sets a breakpoint or displays the currently active breakpoints.

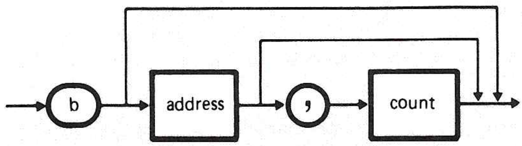

Fig. 5-2 The BREAKPOINT command

Where

SYNTAX ELEMENT	MEANING
address	The breakpoint address
count	The number of times the breakpoint is meant to execute when encountered. If this parameter is set to 0 then the specified breakpoint executes every time it is encountered, and is not deleted until specifically cleared using the CLEAR breakpoint command. If not specified the breakpoint is deleted when it is hit for the first time. Note that this parameter must be expressed in hexadecimal.

Note: The BREAKPOINT instruction is not placed in memory until a GO or JUMP command is executed. Thus provisions have to be made to return to PCOS using any one of these commands if the set breakpoints are to be executed.

When the M20 is in execution mode and a breakpoint is encountered, execution is halted, the video displays a break message with the address where the break was encountered, and the PDEBUG prompt is returned.

CLEAR BREAKPOINT

Clears either an active breakpoint specified by its memory address or all currently active breakpoints.

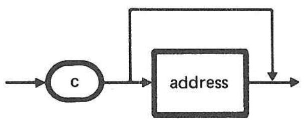

Fig. 5-3 The CLEAR BREAKPOINT command

Where

SYNTAX ELEMENT	MEANING
address	The memory address of an active breakpoint. If this parameter is not specified then all the currently active breakpoints will be cleared.

CHANGE I/O

Switches the main input and output from the console to the RS-232-C serial port and vice versa.

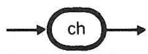

Fig. 5-4 The CHANGE I/O command

Issuing the CHANGE I/O command while using an external terminal causes the main I/O channel to be switched back to the console. Note that the the PCOS RS232 command has to be executed before entering the PDEBUG environment in order to use this PDEBUG command.

COMPARE MEMORY

Compares two blocks of memory and returns any differences encountered.

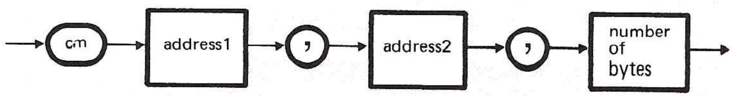

Fig. 5-5 The COMPARE MEMORY command

Where

SYNTAX ELEMENT	MEANING
address 1	The starting point of the first block
address 2	The starting point of the second block
number of bytes	The number of bytes to be compared

While the differences are being output the screen image can be suspended by pressing /CTRL//S/. The command can be aborted by pressing any key. If no differences are found this command simply returns the PDEBUG prompt.

Note: This command uses byte compare operations.

DISPLACEMENT REGISTER

Sets up a displacement value that will be added to all addresses input and subtracted from all addresses output by the PDEBUG program.

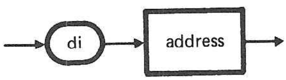

Fig. 5-6 The DISPLACEMENT REGISTER command

Where

SYNTAX ELEMENT	MEANING
address	The displacement value which will be added to the addresses specified in subsequent PDEBUG commands.

The command

di /CR/

will cause the current default segment and offset to be displayed.

This facility is very useful if a user is working on a listing that has a displaced origin in memory. Using this command the displacement register can be set to the value of the address where the listing begins so that all addresses input and output will match the listing.

DISPLAY MEMORY

Displays blocks of memory or single memory locations. In the latter case the command interacts with the user for modification of single memory locations.

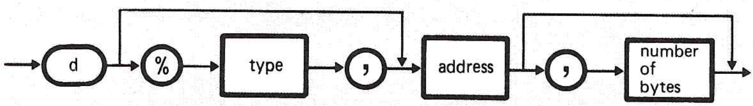

Fig. 5-7 The DISPLAY MEMORY command

Where

SYNTAX ELEMENT	MEANING
type	Word or Byte operations, specified as "W" or "B" (capital or small letters) respectively. Depending on whether the Word or the Byte option is in operation the information will be displayed accordingly. The default value is either the option specified in the last DISPLAY MEMORY or FILL MEMORY command executed in the same PDEBUG session or, in the absence of any, the Word option.
address	The memory address where the display is to start
number of bytes	The number of bytes to be displayed starting from the address specified in the "address" parameter. Note: this number must be expressed in hexadecimal, and must be greater than 1.

Characteristics

When the "number of bytes" parameter is specified, the M20 displays the specified memory block in lines of sixteen bytes each. Each line is organized in the following way:

- The memory address of the first of the sixteen bytes is on the extreme left followed by the contents of the sixteen bytes expressed in hexadecimal code and grouped in words (or in bytes if the "B" (byte) option is specified). If the "number of bytes" paremeter is greater than or equal to sixteen, then the ASCII translation of the sixteen bytes is displayed on the right on the same line. Codes that have no ASCII translation are represented by dots.

When blocks of memory are being displayed, any scroll movement can be halted by entering any character on the keyboard, output can be resumed by entering any character on the keyboard a second time. If you enter the key combination /CTRL/ /C/ then the output will be terminated and the PDEBUG promt is returned.

Modification of Words

If the "number of bytes" parameter is not specified, then the word starting at the memory address specified is displayed followed by the cursor. At this point you can do any of the following operations:

IF you enter	THEN ...
/CR/	the next memory word is displayed.
Ω /CR/	the preceding memory word is displayed.
(a valid hex number) /CR/	the content of the displayed word is changed to the hex number entered, and the next memory location is displayed.
@ /CR/	the current and next words are interpreted as an address and the word specified by that address is displayed.
"(string) /CR/	the string entered is written directly into memory (in hex code) starting from the current address.
q /CR/	the PDEBUG prompt is returned.

FILL MEMORY

Fills a specified block of memory with a given word or byte pattern.

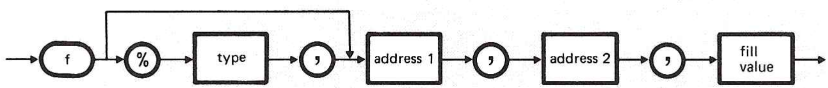

Fig. 5-8 The FILL MEMORY command

Where

SYNTAX ELEMENT	MEANING
type	Word or byte operations, specified as "W" or "B" (capital or small letters) respectively. Depending on whether the Word or the Byte option is in operation the fill value will be interpreted as a word or a byte respectively. The default value is either that specified in the last DISPLAY MEMORY or FILL MEMORY command executed in the same PDEBUG session, or, in the absence of any, the Word option.
address 1	The memory address where the writing operation is to start.
address 2	The memory address where the writing operation is to end. Note that the final location is not written to.
fill value	Fill Value. This is the word (or byte if "B" is specified in the "type" parameter) pattern, expressed in hexadecimal code to be written in the specified memory block.

GO

Resumes the execution of a program at the location specified by the program counter.

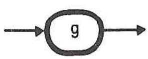

Fig. 5-9 The GO command

Characteristics

Execution of this command causes all the breakpoints (previously specified in the same PDEBUG session) to be placed in memory prior to the start of execution.

JUMP

Executes a memory resident program starting from a specified address.

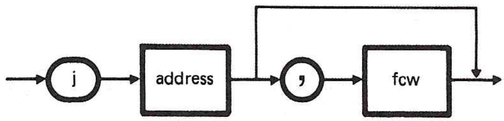

Fig. 5-10 The JUMP command

Where

SYNTAX ELEMENT	MEANING
address	The memory address where execution is to start
fcw	Flag and Control Word.

Characteristics

This command causes all of the breakpoints (previously specified in the same PDEBUG session) to be placed in memory prior to the start of execution.

MOVE MEMORY

Copies a source memory block into a target memory block.

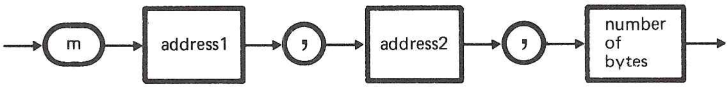

Fig. 5-11 The MOVE MEMORY command

Where

SYNTAX ELEMENT	MEANING
address 1	The memory address where the source memory block begins.
address 2	The memory address where the target memory block begins.
number of bytes	The number of successive bytes starting from the beginning of the source block to be copied.

NEXT

Executes one or more program instructions starting at the location specified by the Program Counter (PC).

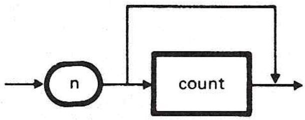

Fig. 5-12 The NEXT command

Where

SYNTAX ELEMENT	MEANING
count	The number of instructions to be executed. The default value is one instruction.

Characteristics

When a specified number of instructions are executed using a NEXT command, the registers are saved, and a message indicating the address of the last instruction executed and the current value of the PC (i.e. the address of the next instruction) is displayed.

A NEXT command is aborted if a breakpoint is encountered in the specified sequence of instructions.

The following situations cause the NEXT command to crash:

- using NEXT through instructions that modify the PSAP (Program Status Area Pointer) in the CPU.
- using NEXT through instructions that disable the non-vectored interrupt.

- using NEXT through instructions that change the programming of the 8253 timer chip.

OFFSET REGISTER

Sets an offset register to a given address.

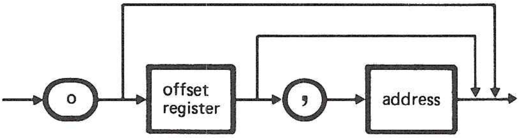

Fig. 5-13 The OFFSET REGISTER command

Where

SYNTAX ELEMENT	MEANING
offset register	Any one of the 26 offset registers ("a" to "z")
address	The memory address to be associated with the offset register.

When the "address" parameter is left out the specified register is printed with its current address. The command without parameters prints all the offset registers with their current addresses.

Offset registers can be used when specifying an address in any PDEBUG command. If register "x" is set to "<2>1000" then "@x5" will represent the address "<2>1005" in any PDEBUG command. This facility is very useful when dealing with module listings; offset registers can be set to the beginning address of each section.

PORT (I/O) READ

Reads a specified I/O port.

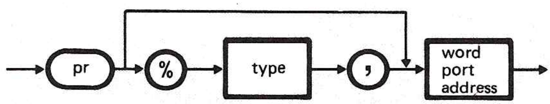

Fig. 5-14 The PORT (I/O) READ command

Where

SYNTAX ELEMENT	MEANING
type	Word or Byte operations specified as "W" or "B" (capital or small letters) respectively. The default value is either the option specified in the last PORT (I/O) READ or PORT (I/O) WRITE command executed in the same PDEBUG session, or, in the absence of any, the Byte option.
port address	A valid I/O port address. A list of all the M20 I/O port addresses is given in appendix F.

PORT (I/O) WRITE

Writes to a specified port address

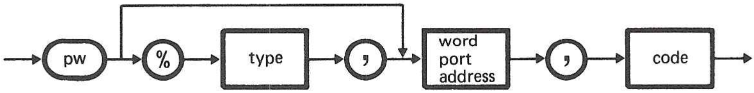

Fig. 5-15 The PORT (I/O) WRITE command

Where

SYNTAX ELEMENT	MEANING
type	Word or Byte operations specified as "W" or "B" (capital or small letters) respectively. The default value is either the option specified in the last PORT (I/O) READ or PORT (I/O) WRITE command executed in the same PDEBUG session, or, in the absence of any, the Byte option.
port address	A valid I/O port address. A list of all the M20 I/O port addresses is given in appendix F.
code	The hexadecimal code of the byte (or word, if the "word" option is specified) to be written to the port.

PRINT OUTPUT

Toggles a flag which causes all output from the PDEBUG program to be sent to a parallel printer as well as to be displayed on the console.

Fig. 5-16 The PRINT OUTPUT command

This means that the first "p" command during a PDEBUG session will cause output to be sent to the printer, and the second will turn off the output to the printer.

QUIT

Causes a return to the PCOS environment.

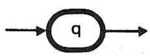

Fig. 5-17 The QUIT command'

Note: Depending on the state of the CPU the QUIT command will cause either a simple return to the PCOS environment or a re-boot of PCOS.

REGISTER

Displays or modifies the registers saved in memory.

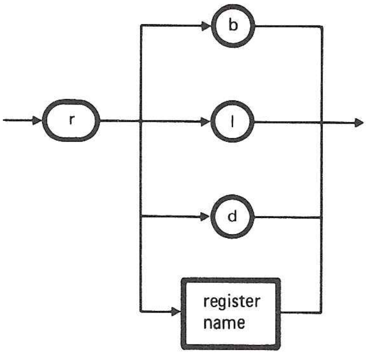

Fig. 5-18 The REGISTER command

Where

SYNTAX ELEMENT	MEANING
b	The registers are displayed as byte registers.
l	The registers are displayed as word registers.
d	All the registers changed by the last GO or JUMP command will be displayed.
register name	A valid register name. With this option the specified register will be displayed, and subsequently the user can modify the contents of it by entering a valid hexadecimal number.

If the command is entered without any parameters, then all the registers are displayed as word registers.

The Registers

When the PDEBUG environment is invoked the registers are initialized to the following values:

REGISTER	INITIALIZED TO
r0 to r13	zero
System Stack Pointer and Normal Stack Pointer	a stack space of 16 words in length
Flag and Control Worc (FCW)	system mode, segmented mode with interrupts enabled.
Program Status Area Pointer (PSAP)	the PCOS program status area
Program Counter (PC)	the "return to PCOS" address.

TRACE

Traces through "count" number of instructions, starting from the instruction specified by the program counter, optionally including any calls, call relatives, or system calls (otherwise treated as a single instruction), and optionally displaying any changed registers after each instruction.

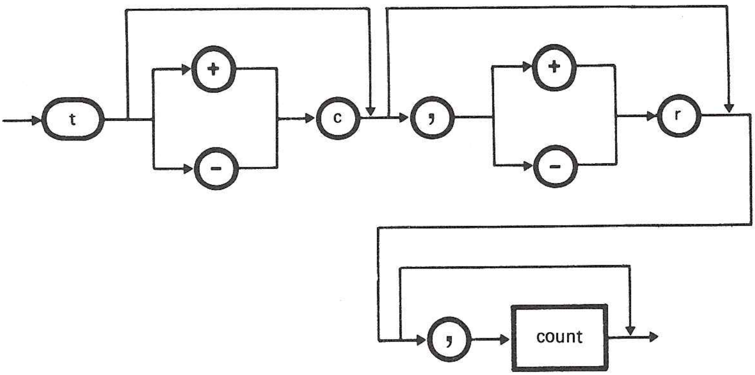

Fig. 5-19 The TRACE command

Where

SYNTAX ELEMENT	MEANING
c	Calls will be included while tracing
r	Any changed registers will be displayed after each instruction.
count	The number of instructions to be executed in each command.

The "+" and "-" sign turn the "c" and "r" options on and off respectively.

When not specified, parameters assume the values specified in the last TRACE command, or, in the absence of any, the following command is executed:

```
t -c,+r,1
```

EXAMPLES

The following two PDEBUG tutorial sessions demonstrate the use of the more commonly used PDEBUG commands.

TUTORIAL PDEBUG SESSION I

DISPLAY	COMMENTS
0>pd ec Disk file name = echo.cmd Program name = File Echo Operation Mode = Segmented / System Main entry = <0A>%DD08; Init entry = --None-- Memory allocated: Block No. %00; Starting address = <0A>%DD06; Size = %009E PDebug Rev. 2.0	This command PLOADs the program file "myprog.cmd" and invokes the PDEBUG environment from PCOS. The PLOAD signon message is displayed and the PDEBUG prompt is returned.
* di <a>dd06	Here the DISPLACEMENT REGISTER command is used to set up a displacement value so that address "<a>dd06" (which in this case is the starting address of "echo.cmd") now becomes "0"

```
* r pc

 pc     =<0>4EDA : <a>0002
* r
  r0     r1     r2     r3     r4     r5     r6     r7
 0000   0000   0000   0000   0000   0000   0000   0000

  r8     r9    r10    r11    r12    r13    r14    r15
 0000   0000   0000   0000   0000   0000   2468   5555

 r14'   r15'   fcw      psap       pc
 8200   FFCC   D820   <2>23FA   <2>0002
```

The REGISTER command is here used to set the program counter (PC) to the main entry address of the program in memory.

```
* t +c,+r,3
pc=<A>0016 12=8A00 13=DD0A
File Echo
pc=<A>0018
```

Having set the program counter to the main entry of "echo.cmd" this command traces through the first three instructions.

```
* t
pc=<A>001A 0=0A00
pc=<A>001C
pc=<A>001E 3=0A00
```

This second trace command assumes the parameter values of the preceding one.

```
* q
```

This QUIT command causes a re-boot of PCOS.

TUTORIAL PDEBUG SESSION II

DISPLAY	COMMENTS
0>pd ec Disk file name = echo.cmd Program name = File Echo Operation Mode = Segmented / System Main entry = <0A>%DD08; Init entry = --None-- Memory allocated: Block No. %00; Starting address = <0A>%DD06; Size = %009E PDebug Rev. 2.0	This command PLOADs the program file "echo.cmd" invokes the PDEBUG environment from PCOS. The PLOAD signon message is displayed and the PBEBUG prompt is returned
* b <a>dd08	A BREAKPOINT command is used to set up a breakpoint in segment ten offset DD08. The breakpoint will be deleted the first time it is encountered.
* g 1> ec param *** BREAK AT <A>DD08	Here the GO command causes a return to PCOS. This happens because of the default setting of the PC on entering the PDEBUG environment. The previously set breakpoint is placed in memory so that it is executed when "echo.cmd" is invoked.

```
* r

 r0    r1    r2    r3    r4    r5    r6    r7
0A00  D800  0A00  DD08  8200  FFC8  FFFF  FFFF

 r8    r9   r10   r11   r12   r13   r14   r15
FFFF  FFFF  0A00  FF34  8200  16DF  2468  5555

r14'  r15'  fcw    psap      pc
8200  FFC2  D800  <2>0100  <A>DD08
```

When the breakpoint is hit, the PBEBUG prompt is returned and any PDEBUG command can be executed; in this case the REGISTER command is used to display the current values of all the registers.

Note that the PC is now set to the next instruction of the interrupted program.

```
* o a,<a>dd06
```

Here the OFFSET REGISTER command is used to set the offset register "a" to the main entry address of "echo.cmd".

```
* d @a2,30

A-DD08 E806 4669 6C65 2045 6368 6F20 0D00 760C ..File Echo ..v.
A-DD18 8A00 DD0A 7F59 97E0 8D28 A103 B331 0002 .....Y...[...1..
A-DD28 96E2 5D02 8A00 DD9C 8D04 5E0E 8A00 DD46 ..]......^....F
```

Having set the offset register "a", it is here used in a DISPLAY MEMORY command.

```
* d <2>ffc2
<2>FFC2 0001  :
<2>FFC4 8203  :
<2>FFC6 1687  :^
<2>FFC4 8203  :@
<2>1687 DC05  :q
```

Here the DISPLAY MEMORY command is used in an interactive way. The PDEBUG prompt is returned when "q" is entered.

```
* b @a1c
```

Another breakpoint is set, here again to execute only once.

```
* g
File Echo
***BREAK AT <A>DD22
```

Here the GO command resumes the execution of the interrupted program. However execution is again interrupted by the next breakpoint.

```
* g
param

1>
```

This final GO command resumes the execution of the program, and subsequently the PCOS prompt is returned.

6. LIBRARIES

ABOUT THIS CHAPTER

This chapter describes the use of libraries and the MLIB command for creating library files.

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INTRODUCTION 6-1

MLIB 6-1

THE M20 GRAPHICS LIBRARY 6-3

INTRODUCTION

It is common programming practice to use a library of subroutines to be made available to a series of programs. Mathematical programs, for instance might use a library of subroutines for calculating trigonometric functions, and text oriented programs might use a library of string comparison functions.

When LINK discovers an external variable which is not present in any input file, then, if the LIBRARY keyword was specified, it will search through the list of library file(s) (specified after the LIBRARY keyword) for a "global" definition. Once the subroutine name is found, the module containing the subroutine is incorporated into the output load file. Only the modules referenced by input files are included in the output load file along with the rest of the input modules. A library module "Y" referenced by another library module "X" in the same library file will only be included if "X" is located before "Y" in the library.

Library files can be created using the MLIB command described below.

MLIB

Creates a library file of object modules from a group of object files.

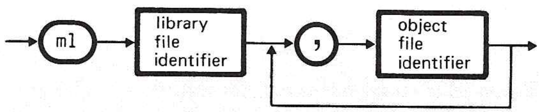

Fig. 6-1 The MLIB command

Where

SYNTAX ELEMENT	MEANING
library file identifier	The name of the file that is to contain all the object modules in the specified object files. This must be complete with any necessary volume identifier and/or file password. The file will be created if it does not exist or, if it already exists, it will be overwritten with the new output. A library file is usually assigned the extension ".lib".
object file identifier	The name of an object file complete with any necessary volume identifier and/or file password. You can use the two PCOS wild card characters (*) and (?) to specify more than one file; an asterisk (*) matches any string and a question mark (?) matches any single character.

Characteristics

During execution the MLIB command needs to create a temporary work file on the disk inserted in the last selected disk drive. This means that MLIB will not execute if called from your write protected Assembler diskette. Rather than remove write protection from the Assembler diskette it is recomended to PLOAD the MLIB command or to copy the file "mlib.cmd" from your copy protected diskette onto the disk where you want to create your library files, or some other disk.

Example

IF you enter	THEN
ml 1:asm.lib,1:prog1.obj, 1:prog2.obj /CR/	the file "asm.lib" is created on the diskette inserted in drive 1. This file will contain all the object modules contained in the object files "prog1.obj" and "prog2.obj" both of which are resident on the same diskette inserted in drive 1.

THE M20 GRAPHICS LIBRARY

The M20 Graphics Library is available in the file "graph.lib". This library is an integrated package of over forty subroutines offering a set of functionalities for two dimensional graphics applications. The Graphics Library presents a consistent and easily comprehensible structure that reflects proposed international standards for graphics. The routines in this library use the PCOS graphics system calls which are also described in this manual (see chapters 7 and 8).

To use a Graphics Library routine in an Assembly language program you must first declare it as an EXTERNAL routine. In the program the routine can then be invoked by the CALL instruction. When LINKing the program you must specify the library file "graph.lib" using the LIBRARY keyword.

The graphics library is introduced in chapter 9 and all the routines are detailed in chapter 10.

PART II

7. INTRODUCTION TO SYSTEM CALLS

ABOUT THIS CHAPTER

This chapter is a general description of the M20 System Calls. The calls are divided in functional groups and the characteristics of each group are discussed. This is followed by the call descriptions.

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INTRODUCTION

These two chapters describe all of the System Calls (SCs) developed for the M20. System Calls are PCOS procedures, used to interface with I/O or to manage memory. System Calls can be accessed by assembly language programs.

All calls made from BASIC, some other utility program, or from user code, will access the I/O and resource management facilities of PCOS via the Z8000 System Call (SC) instruction. The SC instruction includes a 1-byte request code which indicates the function to be performed.

Example:

```
        sc#3            system call, request code = 3
```

Parameters are generally passed in registers numbered from R5 to R13. If strings or other large data structures are to be passed, pointers to the structures are passed as parameters in the registers.

In general, parameters are passed as 16-bit unsigned values. ASCII characters are passed occupying the lower bytes of a register

All system calls use R5 to return any error condition. Zero indicates no-error, non-zero indicates the error and condition code.

SYSTEM CALL DESCRIPTIONS

Each call has been assigned an unique number and a label. The label may be used to reference the call globally, if a table assigning each call number to the respective label is created.

Each call description begins at a new page, and on the page are the name or label, the SC number, and a list of the specific register assignments for each parameter passed. This is followed by a description of the function of the call, and any error codes that might be returned.

The descriptions are arranged in ascending order by SC number.

REGISTER ASSIGNMENTS

Register assignments are given in synopsis form, and input and output are identified. For example (see SC 32):

INPUT/OUTPUT PARAMETERS

Input:	R7 ←	length
	RR8 ←	start
	RR10 ←	destination
Output:	R5 →	error status

Before calling SC 32, the block length, source address and destination address must be loaded in registers R7, RR8 and RR10 respectively. The only output for this call is the error status, which is returned in R5.

ERROR MESSAGES

Following the system call, if there are no errors, a zero (0) is returned in R5. If any error occurs, the appropriate error code will be returned. A list of error codes and messages is given in the appendix.

FUNCTIONAL GROUPS

In this chapter the System Calls are treated in general in functional groups as follows:

- Bytestream Calls
- Block transfer Calls
- Storage Allocation Calls
- Graphics Calls
- Time and Date Calls
- User Code Calls
- IEEE 488 Calls
- Miscellaneous Calls

See the Appendix for lists all system calls in functional groups, for tables of DIDs (Device IDs), as well as lists of error codes.

BYTESTREAM CALLS

Bytestream system calls are used for:

a) Transferring bytes of data to or from an I/O device

b) Sending control information to a device or to a device driver

c) Receiving status information from a device

The following are a list of bytestream I/O calls used to interface with the disk, printer, RS-232 communications port, and console (keyboard and video).

LookByte (9)	SetControlByte (20)
GetByte (10)	GetStatusByte (21)
PutByte (11)	OpenFile (22)
ReadBytes (12)	DSeek (23)
WriteBytes (13)	DGetLen (24)
ReadLine (14)	DGetPosition (25)
Eof (16)	DRemove (26)
ResetByte (18)	DRename (27)
Close (19)	DDirectory (28)

DID (Device IDentifier) Numbers

A DID is an integer used to identify I/O devices (or files) like the keyboard, an open disk file etc.. The operating system maintains a table associating DIDs with a File Pointer. The latter consists of pointers to data structures and routines describing the I/O streams.

Device Pointers

Opening a disk file creates a stream data structure, and places a pointer to it in the device pointer table. Closing the disk file sets this pointer to nil, and releases any table space associated with the file. Some 'devices' or files are always open. For example, the keyboard and the screen (the default window) are always open. They can, however, be closed and re-opened by using the PCOS Device Rerouting feature.

BASIC file numbers translate simply into PCOS DIDs, but BASIC window numbers for the screen are distinct from DIDs. A table of DID assignments is included in the Appendix.

Disk Bytestream I/O Calls

Disk input and output are all done by bytestream system calls. A stream structure for an open file maintains a 32-bit pointer to the current position in the file, at which the next byte will be read or written. Files will be extended automatically as they are written, in increments specified by the system globals.

The functions Close, OpenFile, DSeek,DGetLen, DGetPosition, DRemove, DRename and DDirectory are all used for disk files. Of these, only DSeek, DGetPos, DDirectory, DRemove and DRename are disk specific. The other calls can be also used for other devices (printer, console or communication ports). The RS-232 device driver is described in the "M20 I/O with External Peripherals User Guide", and device rerouting in general are described in the "M20 PCOS User Guide"

BLOCK TRANSFER CALLS

The block transfer system calls allow the programmer to set memory to a fixed value, to transfer data from one segment to another, and clear memory. In particular, the block transfer calls are used by the PCOS system to transfer the BASIC interpreter's fixed tables from ROM to RAM.

BASIC will be able to use the block transfer system calls to transfer other tables from ROM to RAM, for initialization of BASIC.

List of Calls

The following are the Block Transfer calls:

BSet (29)	BClear (31)
BWSet (30)	BMove (32)

STORAGE ALLOCATION CALLS

It is possible for a user program to call PCOS and then allocate or release heap space.

Functions which open a disk file, split a window, or close a file or a window, will use these system calls internally to either allocate heap space or release space.

The following are the Storage Allocation calls:

NewSameSegment (33)	New (120)
Dispose (34)	BrandNewAbsolute (121)
MaxSize (99)	NewLargestBlock (122)
NewAbsolute (104)	StickyNew (123)

GRAPHIC CALLS

The screen area for the M20 display has 256 scanlines by 512 pixels for either black-and-white or (optional) colour display. There is a relationship between the pixels on the screen and the bits of an area in RAM called Bit-Map. This area is grouped in words, and each word in the Bit-Map can be identified by the first word of the graphics accumulator (C-value) described below. The following types of system calls are provided to set global variables or change attributes.

Clear Window

System call Cls (35) clears the screen (or current window) and positions the cursor(s).

Cursor(s)

The PCOS system provides two cursors, text or graphics, for the screen. These may be placed anywhere and XORed with the normal contents of the screen. The cursor may be blinking or nonblinking. There is only one cursor displayed for the whole screen. System calls 36 through 44 provide the capability to select the text or graphics cursor, select blinkrate, and update its position:

ChgCur0 (36)	ChgCur1 (37)	ChgCur2 (38)
ChgCur3 (39)	ChgCur4 (40)	ChgCur5 (41)
ReadCur0 (42)	ReadCur1 (43)	SelectCur1 (44)

Colour

The M20 is available with either a black and white, or a colour video. Colour videos can be of two types; one type can display 4 colours simultaneously out of a choice of 8 (the four colours can be selected using System Call 46 "PaletteSet") and the other type can display 8 colours simultaneously.

A colour code is a value from 0 to 7 and is therefore expressed on three bits, say bit 0, bit 1 and bit 2. For a black and white system if a colour code in the range 2-7 is specified then PCOS maps the code to the value obtained when bits 0, 1 and 2 are ORed together. For a four colour system, colour codes in the range 4-7 are mapped into the value obtained when bit 2 is ORed with bit 0.

Windows

The screen may be divided into windows by splitting along horizontal or vertical lines. There may be a maximum of sixteen windows on the screen, which are assigned window numbers 1 to 16 in order of creation. System calls 45, 47 through 51, and 113 are provided to initialize the screen, create and/or close windows:

GrfInit (45)	ChgWindow (50)
DefineWindow (47)	CloseWindow (51)
SelectWindow (48)	CloseAllWindows (113)
ReadWindow (49)	

Graphics Accumulator

The graphics routines make use of a global variable referred to as the 'graphics accumulator' to define the current absolute screen location. This graphics accumulator is said to be of type 'C'. A C-variable is a 32-bit variable containing a memory address and a bit mask for the specified group of pixels at that address. The "memory address" (2 bytes) selects a word in the Bit-Map area, and is in the range %0 to %3FFE (8192 words). The "bit mask" is a word each bit of which relates a pixel on the screen to a bit in that area of the Bit-Map specified in the "memory address" (bit=1 for ON and bit=0 for OFF). For example, if the graphics accumulator is assigned the value %20208000 then the first word identifies the sixteen pixels at the centre of the screen and the second word selects the first of these sixteen pixels. Conversion routines are provided for converting local x-y coordinates for windows to or from the C-type variable in the graphics accumulator. Most plotting routines manipulate the graphics accumulator in an abstract and machine-independent way. In general, the plotting of a point is at the position defined by the contents of the graphics accumulator.

Likewise, the 'current attribute' is a global variable representing the current foreground colour. Any plotting or painting routine will set this to the colour specified in the higher-level BASIC (or other) routine by using SetAtr (set attribute), SC 61, or is assumed to be the current window's current foreground colour by default.

A set of system calls (52 through 67,115 and 116) are provided for scaling or converting coordinates, for manipulating the accumulator, and for drawing lines:

ScaleXY (52)	DownC (58)	NSetCX (64)
MapXYC (53)	LeftC (59)	NSetCY (65)
MapCXY (54)	RightC (60)	NRead (66)
FetchC (55)	SetAtr (61)	NWrite (67)
StoreC (56)	SetC (62)	ClearText (115)
UpC (57)	ReadC (63)	ScrollText (116)

Paint Graphics Calls

M20 BASIC supports a PAINT operation which fills an area of a window bounded by a specified boundary colour (and the window boundaries) with another specified brush colour. The following system calls are used to implement the PAINT operation:

PntInit (68)	ScanL (71)
TDownC (69)	ScanR (72)
TUpC (70)	

These calls set the global colour attributes, move the position of the graphics accumulator up or down, (checking first if the move is within the boundaries of the current window, if not an error is returned); and scan left or right to paint the window.

TIME AND DATE CALLS

The M20 system has a real-time clock which maintains both date and time. This clock must be reset each time the system is turned on.

Time or date setting are done by passing the address of an ASCII string to the operating system. Likewise, the time or date may be read by transferring an ASCII string from the operating system. The format of these strings are defined by the calls listed below. These will correspond to the string values passed in BASIC by manipulating the TIME$ and DATE$ pseudo-strings.

The following system calls perform clock reading and setting:

SetTime (73)	GetTime (75)
SetDate (74)	GetDate (76)

USER CODE CALLS

One system call has been provided to allow the user to execute any program or routine on diskette that could be executed from the PCOS command line. The call is:

CallUser (77)

The call can be used in Assembler utilities to process PCOS user commands.

IEEE 488 CALLS

The IEEE 488 package consists of a group of programs which execute the following BASIC IEEE statements:

ISET, IRESET, ON SRQ GOSUB, POLL, PRINT@,
WBYTE, RBYTE, INPUT@, and LINE INPUT@.

these statements allow the user to perform the following operations on an IEEE-488 bus:

a) Controlling the IFC (interface clear) and REN (remote enable) lines;

b) Receiving a service request from another device on the bus, identifying the requesting device through serial polling, and processing the service request;

c) Writing control bytes (e.g.: "Device Clear", "Device Trigger", etc.) to other devices;

d) Addressing, writing data to, and reading data from, other devices; and

e) Allowing the devices within an IEEE-488 network to transfer data on the bus (i.e.: assigning "Talker" status to one device, and "Listener" status to one or more devices).

The following system calls are assigned to the IEEE package. On exiting from any of these procedures, register R5 will contain hex 0A if the system does not have an IEEE option board.

IBSrQ0 (78)	IBPrnt (83)
IBSrQ1 (79)	IBWByt (84)
IBPoll (80)	IBInpt (85)
IBISet (81)	IBLinpt (86)
IBRSet (82)	IBRByt (87)

For further details on the IEEE-488 interface see the "M20 I/O with

External Peripherals User Guide".

MISCELLANEOUS CALLS

The following miscellaneous calls complete the list of System calls:

- Error (88)
- Dstring (89)
- CrLf (90)
- DHexByte (91)
- DHex (92)
- DHexLong (93)
- DNumW (94)
- DLong (95)
- DisectName (96)
- CheckVolume (97)
- Search (98)
- SetVol (102)
- NewAbsolute (104)
- StringLen (105)
- DiskFree (106)
- BootSystem (107)
- SetSysSeg (108)
- SearchDevTab (109)
- CtlCharDisp (111)
- KbSetLock (114)
- GetVol (119)

8. THE M20 SYSTEM CALLS

ABOUT THIS CHAPTER

In this chapter the system calls are described in detail. The descriptions follow each other in numeric order. A list of system calls in functional groups is given in Appendix C.

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9 LookByte

Returns the next byte from the designated device buffer without removing the byte from the buffer.

Input/Output Parameters

Input:	R8 ← DID
Output:	RL7 → returned byte RH7 → buffer status (00 or FF) R5 → error status

Characteristics

This function returns the first byte of a device input buffer (undefined if none), without removing it from the buffer. The DID is an integer, identifying the device. Valid DIDs are listed below. Also returned is the status of the device buffer, FF if the buffer is not empty, 00 otherwise.

Note: Ring buffers are maintained for the interrupt driven input devices. Characters are placed into the buffers immediately as they are received and are available to programs via the two system calls LookByte and GetByte.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

17	console
19,25,26	Com (RS-232-C), Com1, Com2

10 GetByte

Returns the first byte from a designated device, removing the byte from the device buffer.

Input/Output Parameters

Input:	R8 ← DID	
Output:	R7 → returned byte	
	R5 → error status	

Characteristics

This call returns the first byte in the input buffer (from file or designated device) and places that byte in register R7. The DID is an integer which identifies the source of the input. Valid DID numbers are listed below.

In the case where the DID is either 17 or 19, if the input device buffer is empty , the system will wait until a byte is input and available in the buffer before returning to the caller with the byte in R7.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
17	console
20 - 24	disk files (PCOS)
19,25,26	Com (RS-232-C), Com1, Com2

11 PutByte

Transmits a byte to a specified device.

Input/Output Parameters

Input:	R8 ←	DID
	RL7 ←	input byte
Output:	R5 →	error status

Characteristics

This transmits the byte supplied in RL7 to the device or file specified by the DID. Valid DIDs are identified below. For files, no information is returned about the validity or EOF state of the DID.

If the device is the RS-232-C port, and the port is not ready to send, the driver will wait for a timeout period and then return an error if nothing is sent.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
17	console
18	printer
20 - 24	disk files (PCOS)
19,25,26	Com (RS-232-C), Com1, Com2

12 ReadBytes

Reads and counts bytes, from a device, into a buffer in memory.

Input/Output Parameters

Input:

R8 ← DID
R9 ← count to be read
RR10 ← pointer to memory buffer

Output:

R7 → count returned
R5 → error status

Characteristics

FILES

This function reads a specified number of bytes from a file into memory, and returns a count of the number of bytes actually read.

The count returned is used to determine EOF status for the file. The EOF status is determined when the "count returned" in R7 is less than the "count to be read" input in R9, (because there are no more bytes to be read).

The input to RR10 is a segmented pointer to the first byte of memory where these bytes will be stored. The output "count returned" is the actual number of bytes read.

RS-232-C

This call transfers a specified number of bytes from the input buffer to the user specified buffer.

If the number of characters in the input buffer is less than the number requested, the driver will wait for the needed characters to arrive.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
17	console
20 - 24	disk files (PCOS)
19,25,26	Com (RS-232-C), Com1, Com2

13 WriteBytes

Writes a specified number of bytes from memory to a file or device.

Input/Output Parameters

Input:	R8 ←	DID
	R9 ←	count
	RR10 ←	start
Output:	R7 →	count returned
	R5 →	error status

Characteristics

FILES

This function writes a specified number of bytes from memory into a file. It returns a count of the number of bytes actually transferred. Valid DIDs are listed below.

The input "count" is the number of bytes to be transferred. The input "start" is a segmented pointer to the first byte in memory from which these bytes will be written.

The output "count returned" is the actual number of bytes transferred.

RS-232-C

This call transfers data bytes from the specified memory buffer to the RS-232-C port.

The meanings of the inputs and outputs is the same. If the port is not ready to send, the driver will wait a timeout period, and then return an error if nothing is sent.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
17	console
20 - 24	disk files (PCOS)
19,25,26	Com (RS-232-C), Com1, Com2

14 ReadLine

Reads and counts bytes input from the keyboard, until the first /CR/, into a memory buffer (at a specified address).

Input/Output Parameters

Input:	R8 ←	DID
	R9 ←	count
	RR10 ←	destination
Output:	R6 →	count returned
	R5 →	error status

Characteristics

This function reads a specified number of bytes from the standard input device into memory. Input will be terminated when the next input byte is equal to /CR/ or if the maximum "count" is exceeded. The /CR/ is not put into the string.

The input DID (17) identifies the standard input. It is the only valid DID for this call. The input "count" specifies the maximum number of bytes to be read, and the input "destination" is a pointer to address of the first byte of memory where these bytes will be stored.

The output "count returned" is the actual size, in bytes, of the input string. If a /CTRL//C/ is pressed, R6 will return a 'FFFF'. Characters are echoed to the standard output device (DID 17) and editing features,(/CTRL//H/ i.e.:backspace and /CTRL//I/, i.e.: TAB) and hide mode /CTRL//G/ are implemented.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

17	Console (keyboard) only

16 Eof

Checks if an input character is available from a device.

Input/Output Parameters

Input:	R8 ← DID
Output:	R9 → returned status R5 → error status

Characteristics

The function "EOF" (end of file) will return a zero (0) if an input character is available from the selected device.

It returns a one (1) in each of the following cases:

1. The selected file is not open.
2. The file is open for output only.
3. The console has been selected but no key has been struck.
4. The end of the disk file has been reached.

The input "DID" identifies the device; valid DIDs are listed below.

RS-232-C

For use with the RS-232-C, this call returns a zero (0) if the input buffer is not empty, and a one (1) if the buffer is empty.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
17	console
19,25,26	Com (RS-232-C), Com1, Com2

Resets an input file or device.

Input/Output Parameters

Input: R8 ← DID

Output: R5 → error status

Characteristics

This function is used to reset an input device. In the case of the console, it will clear the keyboard ring buffer, and initialize the screen driver. It can also be used with communications (RS-232-C), in which case it re-initializes the hardware and clears the input buffer. The input "DID" identifies the device.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

17	console
19,25,26	Com (RS-232-C), Com1, Com2

19 Close

Closes a specified disk file or device.

Input/Output Parameters

Input: R8 ← DID number

Output: R5 → error status

Characteristics

This call closes the specified file or device and then releases both buffer and table space. The input "DID" is an integer representing the file or device.

Note: This call is not used to close screen windows (see CloseWindow, SC 51).

RS-232-C

When used with the RS-232-C, the call disables the hardware interrupts, and the input buffer is removed from the heap.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
20 - 24	disk files (PCOS)
19, 25, 26	Com (RS-232-C), Com1, Com2

20 SetControlByte

Writes a word into the Device Parameter Table.

Input/Output Parameters

Input:	R8	←	DID
	R9	←	word number
	R10	←	word
Output:	R5	→	error status

Characteristics

This call allows a single word to be written into the Device Parameter Table (see appendix H). The input to R9 is the word number to be written to; the input to R10 is the word to be written to the Device Parameter Table.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

19, 25, 26   Com (RS-232-C), Com1, Com2,

21 GetStatusByte

Reads a single word from the Device Parameters Table.

Input/Output Parameters

Input:	R8 ←	DID
	R9 ←	word number
Output:	R10 →	word read
	R5 →	error status

Characteristics

This call allows a single word to be read from the Device Parameter Table (see appendix H). The input to R9 is the word number to be read. The outputs are the words read from the Device Parameter Table (in R10), and the error status (in R5).

Errors

If there are any errors, a non-zero number will be returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

19, 25, 26	Com(RS-232-C), Com1, Com2

22 OpenFile

Opens a specified file or device for read, write, etc.

Input/Output Parameters

	Files	RS-232-C
Input:	R6 ← extent length	
	R7 ← mode	
	R8 ← DID	R8 ← DID
	R9 ← file identifier length	
	RR10 ← address	
Output:	R5 ← error status	R5 → error status

Characteristics

DEVICES

The function of this call is to open the specified device; its characteristics, however, depend upon the device. For example, for the RS-232-C there are no parameters except the input DID.

FILES

In this case the function of this call is to open the designated file, specify the mode (append, read, write, or read/write), and to allocate sectors (write or append modes only).

The input "file identifier length" is the number of characters in the file identifier. The input "address" is the address of the file identifier.

The input "mode" designates whether the file will be opened for read, write or append, as follows:

0: Read, always from current position.

1: Write, always placing a new end of file.

2: Read/Write, allocating sectors beyond old EOF.

3: Append, seeks to end upon open, and then writes.

A file that does not exist cannot be opened in the read mode. A nonexistent file, if opened by write or read/write, will be created. If it does exist, write mode will write over the old file.

If an existing file has been opened in the read/write mode, the user can then position the file pointer to its end,to extend it, using Dseek (SC 23). However, Append mode does this automatically, and then operates the same as the write mode.

The input "extent length" designates the number of sectors to be allocated if the file is to be created. The request should always be one sector larger then the data requirements. If a zero is entered, the number of sectors will be the default value (usually 8). The input DID number identifies the file (see list below).

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
20 - 24	disk files (PCOS)
19,25,26	Com (RS-232-C), Com1, Com2

23 DSeek

Positions a file pointer as specified.

Input/Output Parameters

Input:	R8 ← DID	
	RR10 ← position	
Output:	R5 → error status	

Characteristics

This will position the file pointer for the specified stream (opened file) to the position specified. The input "DID" identifies the device. The input "position" is a 32-bit pointer. Zero is the first byte.

Seeking past the EOF while the file is opened for read/write will automatically allocate new sectors.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
20 - 24	disk files (PCOS)

24DGetLen

Returns either the length of a file or the number of bytes in the input buffer.

Input/Output Parameters

	Files	Devices
Input:	R8 ← DID	R8 ← DID
Output:	RR10 → length R5 → error status	R10 → zero status R11 → number R5 → error status

Characteristics

DEVICES

This call returns the number of bytes currently in the input buffer. There are no inputs except the DID number.

FILES

This call returns the length of the file as a long word. The output "length" is the length of the file.

Errors

If there are no errors, a zero (0) will be returned in R5. If the disk file is not open, a -1 is returned in RR10 and error code (hex) 4E is returned in R5. If a bad parameter is input, error (hex) 4C is returned in R5.

Valid DID Numbers

1 - 15	disk files (BASIC)
20 - 24	disk files (PCOS)
19,25,26	Com, Com1, Com2

25 DGetPosition

Gets the position of the next byte to be read or written.

Input/Output Parameters

Input: R8 ← DID

Output: RR10 → position
R5 → error status

Characteristics

This call returns the position, in bytes, of the next byte to be read or written. The input "DID" identifies the file. A list of valid DIDs is given below.

The output "position" contains the position in the file, in bytes, where the next byte will be read or written.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Valid DID Numbers

1 - 15	disk files (BASIC)
20 - 24	disk files (PCOS)

26 DRemove

Removes a specified file name from a disk directory.

Input/Output Parameters

Input:	R9 ← length RR10 ← address
Output:	R5 → error status

Characteristics

This call is used only for disk files. It removes the specified disk file (and related data) from the directory of the volume.

The input "address" points to the file identifier. The input "length" is the length of the file identifier.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

27 DRename

Renames a specified file.

Input/Output Parameters

Input:	RR6 ←	old address
	R8 ←	old length
	RR10 ←	new address
	R9 ←	new length
Output:	R5 →	error status

Characteristics

This call is used only for disks. It will rename the file specified by the old file identifier with the new file name.

The input addresses point to the old file identifier and to the new file name respectively. The inputs called "length" are the lengths of the old file identifier and new file names, and are given in words.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

28 DDirectory

Displays a list of files from a specified disk.

Input/Output Parameters

Input: R9 ← file identifier length
RR10 ← file identifier address

Output: R5 → error status

Characteristics

This call is used only for files. It lists the contents of the directory of the specified volume, on the current window of the M20 screen. The input "length" is the number of bytes in the file identifier. The input "address" is the address of the file identifier. The file identifier may contain a volume identifier and/or wild card characters ("*" and "?"). If R9 is zero, DDirectory assumes the name "*", and will list the entire directory.

The display lists the names of the specified files on the specified (or default) volume in compact form.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Sets a block of bytes to a specified value.

Input/Output Parameters

Input: RL7 ← n (byte value)
RR8 ← start
R10 ← length

Output: R5 → error status

Characteristics

This call sets a block of memory to the indicated byte value. The input "start" is a segmented pointer to the first byte of memory to be set. The input "length" is the number of bytes to be set.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

30 BWSet

Sets a block of words to a specified value.

Input/Output Parameters

```
Input:          R7   <---- n (word value)
                RR8  <---- start
                R10  <---- length

Output:         R5   ----> error status
```

Characteristics

This routine sets the block of memory specified to the input value, n. The input "n" is the word value to be loaded into each memory location. The input "start" is a segmented pointer to the first word of memory to be set. The input "length" is the number of words to be set.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

31 BClear

Sets a specified block of memory to zero.

Input/Output Parameters

Input: RR8 ← start
R10 ← length

Output: R5 → error status

Characteristics

A block of bytes, of the length specified, and starting at a specified source, is set to zero. The input "start" is a segmented pointer to the first byte of memory to be set. The input called "length" is the number of bytes to be set to zero.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

32 BMove

Moves a block of bytes from one location to another.

Input/Output Parameters

```
Search          R7   <----length
                RR8  <----start
                RR10 <----destination

Output:         R5   ---->error status
```

Characteristics

A block of bytes, of specified length, and starting at a specified source, is moved to a block starting at a specified destination. The input "start" is a segmented pointer to the first byte of memory to be moved. The input "length" is the number of bytes to be moved. The input "destination" is a segmented pointer to the first byte of the destination memory block.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

33 NewSameSegment

Allocates a block of bytes from heap in the current segment.

Input/Output Parameters

Input: RR8 ← address of block pointer
R10 ← length

Output: R5 → error status
@RR8 → block pointer

Characteristics

This call allocates blocks in the "SameSegment". This is segment 2 unless the program has done a "BrandNewAbsolute" system call, in which case the segment number is that specified in the most recent "BrandNewAbsolute".

This call is a subset of System Call 120 "New". It has been maintained for compatibility with preceding releases.

A simple way to change the segment number for a program is to do a SC 121 "BrandNewAbsolute" with a block length of 0.

The input "address of block pointer" is the address of a long word which specifies the start address where NewSameSegment will store the block. The input 'length' is the number of bytes to be allocated. If the block cannot be allocated, @RR8 will contain a nil (hex FFFFFFFF) pointer, without returning an error in R5.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

34 Dispose

Releases heap space.

Input/Output Parameters

Input:	RR8 ←	address of block pointer
	R10 ←	length
Output:	@RR8 →	hex FFFFFFFF
	R5 →	error status

Characteristics

This routine releases memory space. The input address is a long word, pointing to the start address of this space. It is important that this be a valid heap space. Once the call has been executed, the address specified in RR8 will contain hex FFFFFFFF (nil).

EXAMPLE:

In this example assume that addptr is a long variable which has been initialized as in the example for New (SC 120):

```
LDA   RR8,addptr
LD    R10,#length
sc    #34
```

Errors

If 'addptr' does not point to the start of a valid heap space, the system issues an error. If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Clears the current window.

Input/Output Parameters

This call has no parameters.

Characteristics

This routine clears the current window to the current background colour (usually black). There are no parameters. The call sets the position of the text cursor to the top left of the window, and sets both the graphics cursor and the accumulator to the center of the window.

Errors

No error checks are made and no errors are reported.

36 ChgCur0

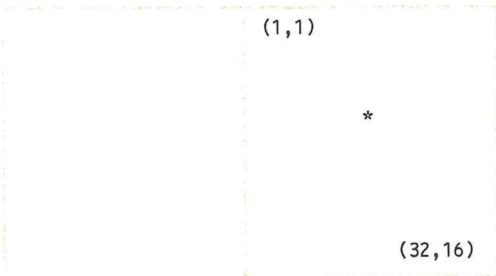
Positions the text cursor.

Input/Output Parameters

Input:	R8 ← column	
	R9 ← row	
Output:	R5 → error status	

Characteristics

This routine sets the position of the text cursor, on the current window, to the column and row specified. The upper left corner position of the current window is (1,1). The position of the lower right corner depends upon the display character size (64 by 16 or 80 by 25), and the size of the window (see example below).



* current window, 64 by 16 mode

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

37 ChgCur1

Positions the graphics cursor.

Input/Output Parameters

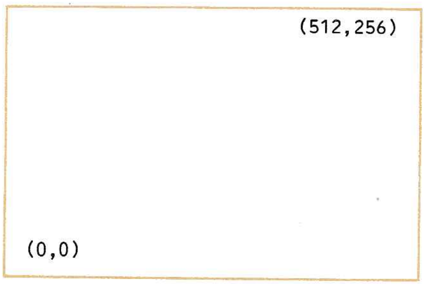
Input: R8 ← x
R9 ← y

Output: there is no output

Characteristics

This routine sets the position of the graphics cursor, of the current window, to the x-position and y-position specified.

The lower left corner position of the current window is always (0,0). The position of the upper right corner will depend upon the size of the window and the display character size (64 by 16 or 80 by 25). The example below shows the coordinates for a full screen in 64 by 16 characters format.



Errors

Range checking is done, and if out of bounds the cursor is not moved; however no error code is returned.

38 ChgCur2

Sets the blink rate of the text cursor.

Input/Output Parameters

Input:	R8 ← rate
Output:	there is no output

Characteristics

This routine changes the blink rate of the cursor of the current window to a new value. The value will be the blink rate per second.

Valid values are 0 to 20, with a resolution of 50 ms. A zero value is non-blinking.

Errors

No error codes are returned.

Sets the blink rate of the graphics cursor.

Input/Output Parameters

Input: R8 ← rate

Output: there is no output

Characteristics

This routine changes the blink rate of the cursor of the current window to a new value. The value will be the blink rate per second.

Valid values range from 0 to 20, with a resolution of 50 ms. A zero value is non-blinking.

Errors

No error codes are returned.

40 ChgCur4

Sets the shape of the text cursor.

Input/Output Parameters

Input: RR8 ◄—— address

Output: there is no output

Characteristics

This call is used to change the shape of the text cursor of the current window. The input "address" points to the address of the new byte array which describes the new shape of the cursor. This array is 12 bytes long, the first byte being the first scan line of the cursor.

It is suggested that the most significant bit of each byte is not used as part of the cursor as it would then touch the previous character.

If the text cursor is being displayed at the time this call is made, it will be turned off, updated, and then turned back on.

EXAMPLES:

For a solid cursor:

```
array = %7F %7F %7F %7F
        %7F %7F %7F %7F
        %7F %7F %7F %7F
```

For a checkerboard:

```
array = %00 %55 %2A %55
        %2A %55 %2A %55
        %2A %55 %2A %55
```

Errors

No errors are returned.

41 ChgCur5

Sets the shape of the graphics cursor.

Input/Output Parameters

Input: RR8 ← address

Output: there is no output

Characteristics

This call is used to change the shape of the graphics cursor of the current window. The input "address" points to the address of the new byte array which describes the new shape of the cursor. This array is 12 bytes long, the first byte being the first scan line of the cursor.

It is suggested that the most significant bit of each byte is not used as part of the cursor as it would then touch the previous character.

If the graphics cursor is being displayed at the time this call is made, it will be turned off, updated, and then turned back on.

Errors

No errors are returned.

42 ReadCur0

Returns the position (column and row), and the blinkrate of the current window's text cursor.

Input/Output Parameters

Input: RR10 ← address

Output:
R7 → blinkrate
R8 → column
R9 → row
R5 → error status

Characteristics

This call is the same as ReadCur1 (SC 43), except that it returns the blinkrate and position (column and row) of the current window's text cursor. The input 'address' points to the byte array for the current shape.

Errors

No errors are returned.

43 ReadCur1

Returns the position (column and row), and the blinkrate of the current window's graphics cursor.

Input/Output Parameters

Input: RR10 ← address

Output:
R7 → blinkrate
R8 → x position
R9 → y position
R5 → error status

Characteristics

This call is the same as ReadCur0 (SC 42), except that it returns the x,y position and blinkrate of the current windows graphics cursor. The input 'address' points to the byte array for the current shape.

Errors

No errors are returned.

44 SelectCur

Selects the graphics or the text cursor, or turns off the current cursor.

Input/Output Parameters

Input: R8 ← select

Output: there is no output

Characteristics

This routine chooses the state of the cursor for the current window, according to the value of the input "select" as follows:

- 0: Turns off the cursor for the current window. (selecting another window will also turn off the cursor).
- 1: Selects and displays the graphics cursor in the current window.
- 2: Selects and displays the text cursor in the current window.

Note that only one cursor can be displayed at a given time, regardless of the number of windows.

Errors

No errors are returned.

45 GrfInit

Initializes the screen and sets defaults.

Input/Output Parameters

Input: there are no inputs

Output: R8 → colour flag
RR10 → pointer

Characteristics

This function must be called to initialize the screen. It sets the screen to contain one window (number 1), sets default global attributes for the screen, and default attributes for the window.

Default conditions are: one window for a full screen, green or white colour (depending upon hardware) on a black background and cursor off.

The outputs are a pointer and a colour flag. The latter is "0" for a black and white system, and "1" for a colour system. These values are determined by hardware jumpers.

The pointer is the address of a mailbox area (8 bytes), also used by the IEEE driver, and declared globally by PCOS. These 8 bytes (0-7) are used by the IEEE-488 and keyboard drivers. On calling GrfInit, the interpreter will be passed the address of this area in RR10.

Errors

No errors are returned.

46 PaletteSet

Selects a global four colour set (only for four colour systems).

Input/Output Parameters

Input: R8 ← colour A
R9 ← colour B
R10 ← colour C
R11 ← colour D

Output: R5 → error status

Characteristics

This call selects 4 colours out of a possible 8 for the global colour set. The four inputs are chosen from the following set:

0	black
1	green
2	blue
3	cyan
4	red
5	yellow
6	magenta
7	white

and a check is made that the inputs are in the range from 0 to 7, but no check is made for colour duplications.
The BASIC COLOUR statement is implemented by a call to this routine. Also, this routine is called by GrfInit to initialize to the default colours.

Note: This system call has no effect on black and white and eight colour systems.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Creates a new window.

Input/Output Parameters

Input:

R8 ← quadrant
R9 ← position
R10 ← vertical spacing
R12 ← horizontal spacing

Output:

R11 → window number
R5 → error status

Characteristics

This routine is used to create a new window by splitting the current window into two parts. A unique window number is returned for the new window and the current window remains selected.

The input 'quadrant' indicates that part of the old window from which the new one is to be created. The choices are as follows:

0	TOP PORTION
1	BOTTOM PORTION
2	LEFT PORTION
3	RIGHT PORTION

The value and meaning of the input 'position' depends upon whether the split is done horizontally or vertically. If the split is to be on a horizontal line (quadrant = 0 or 1), 'position' is measured in scanlines, from the top of the current window. The allowable range is then:

(Vspace + 1) to (Height - Vspace);

where 'Vspace' is the text line spacing of the existing window. If the split is to be on a vertical line (quadrant = 2 or 3), 'position' is measured in the number of characters, counting from the left. The allowable range is then from 1 to width minus 1.

The input 'vertical spacing' is the number of scanlines between the tops of the characters in two consecutive text lines. It may be a number from 10 to 16.

The input 'horizontal spacing' is the number of pixels between the right edges of two consecutive characters. It can have a value of 6 or 8. If the values for vertical or horizontal spacing are omitted or entered as zero, their spacing defaults to the values for the parent window.

When a window is created, it will have the same foreground and background colours as its parent window (window 1 is always initialised with foreground and background colours of 1 and 0, respectively i.e. green and black in a colour system, and white and black in a monochrome system). The new window will have its text cursor placed at the top left of the window. The graphics cursor and graphics accumulator positions will be set at the center of the new window, with no cursor displayed.

The parent window's cursor and graphics accumulator positions will automatically be adjusted by the amount taken by the new window. The parent window remains selected.

In the graphics coordinate system supported by the PCOS, the lower left-hand corner of a window is the origin, with coordinates (0,0); the coordinates will be scanlines vertically and pixels (bits) horizontally. The origin of the text coordinate system is the upper left-hand character position of the window, with coordinates (1,1).

Calling DefineWindow with quadrant = 0 and position = 0 will have the effect of setting the spacing of the current window. If window 1 is the only window and its spacing is changed, then the display character size is changed from the current format to the other. If horizontal spacing is 6 then the system goes into 80x25 format. The size of the screen is reduced from 512 by 256 pixels to 480 by 256 (with 2-byte margins on the right and left). If horizontal spacing is given as 8, then the system goes into 64x16 mode, and the screen is expanded back to 512 by 256 pixels.

Errors

An error condition leaves the returned window number equal to -1, and returns a (hex) 24 in R5. If there are no errors, a zero (0) will be returned.

48 SelectWindow

Selects another window.

Input/Output Parameters

Input: R8 ← window number

Output: R5 → error status

Characteristics

This routine is used to change the current window to another already existing window. The input "window number" is the number of the window (1 to 16) to be selected. Any screen output routines which have a window number as a parameter must call SelectWindow.

Errors

If there are any errors, a status code is returned in R5. If there are no errors, a zero (0) will be returned. A hex value of 23 will be returned in R5 if the window specified does not exist.

49 ReadWindow

Returns the attributes of the current window.

Input/Output Parameters

Input: there are no inputs

Output:

R7 → window number
R8 → x
R9 → y
R10 → foreground
R11 → background
R5 → error status

Characteristics

This routine returns the attributes of the current window. The outputs are:

'window' -- current window identifier number

'x' -- window width in bytes

'y' -- window hight in pixels

'foreground' -- foreground colour of current window

'background' -- background colour of current window

Colour Attributes

The colour values returned will belong to one of the sets shown below.

The colour selection of four (A - D) is originally made from the eight listed under PaletteSet (SC 46):

Monochrome	Four-Colour Systems	Eight-Colour Systems
0 black	0 colour A	0 black
1 white	1 colour B	1 green
	2 colour C	2 blue
	3 colour D	3 cyan
		4 red
		5 yellow
		6 magenta
		7 white

Errors

No errors are returned.

50 ChgWindow

Changes window colours.

Input/Output Parameters

Input: R8 ← foreground
R9 ← background

Output: R5 → error status

Characteristics

This routine changes the colour attributes for the current window. The inputs 'foreground' and 'background' are integers specifying the foreground and background colours respectively. They are chosen from those listed under "Colour Attributes" (see below).

Colour Attributes

The colour values selected must belong to one of the sets shown below. The colour selection of four (A - D) is originally made from the eight listed under PaletteSet (SC 46):

Monochrome	Four-Colour Systems	Eight-Colour Systems
0 black	0 colour A	0 black
1 white	1 colour B	1 green
	2 colour C	2 blue
	3 colour D	3 cyan
		4 red
		5 yellow
		6 magenta
		7 white

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

51 CloseWindow

Closes the selected window.

Input/Output Parameters

Input: R8 ⟵ window

Output: there are no outputs

Characteristics

This routine is used to close an existing window.

The input 'window' is the window number. The area of the window is returned to the parent window, and the background colour is cleared to that of the parent window.

It should be noted that window 1 cannot be closed.

Errors

No errors are returned.

52 ScaleXY

Checks coordinates against the current window boundaries.

Input/Output Parameters

Input: R8 $\leftarrow$ x
R9 $\leftarrow$ y

Output: R10 $\rightarrow$ return_value

Characteristics

The inputs 'x' and 'y' are graphics coordinates.

The system call checks their values against the window size of the current window,and returns a true value in R10 if and only if the coordinates are within the boundaries of the window. The 'return' is 1 for true.

Errors

No errors are returned.

53 MapXYC

Converts x-y to absolute coordinates and stores the result in the graphics accumulator.

Input/Output Parameters

Input: R8 ⟵ x
R9 ⟵ y

Output: there are no outputs

Characteristics

The inputs 'x' and 'y' are the specified screen coordinates.

The system call converts these coordinates to the absolute screen position (of C-type) for the current window, and stores the resulting value in the graphics accumulator.

Note: The input values are not checked for being within range. ScaleXY should be called first.

Errors

No errors are returned.

54 MapCXY

Converts the C-value in the graphics accumulator to x-y coordinates.

Input/Output Parameters

Input: there are no inputs

Output:

R8 ——► x
R9 ——► y

Characteristics

This call converts the current value in the graphics accumulator to x-y coordinates for the current window.

If the value in the graphics accumulator is outside the current window, the results are undefined.

Errors

There are no errors returned.

55 FetchC

Returns the contents of the graphics accumulator.

Input/Output Parameters

Input: there are no inputs

Output: RR8 ——► C-value

Characteristics

This call saves the current value of the graphics accumulator for future use.

There are no input parameters. The output "C-value" is the contents of the 32-bit graphics accumulator.

Errors

No errors are returned.

56 StoreC

Sets the graphics accumulator to a specified C-value.

Input/Output Parameters

Input:	RR8 ←—— C-value
Output:	there are no outputs

Characteristics

This call sets the graphics accumulator to a specified C-value.

The structure of the C-value is described in chapter 7. If the C-value input is outside the current window, the results are undefined.

Errors

No errors are returned.

57 UpC

Moves the position of the graphics accumulator up by one pixel.

Input/Output Parameters

This call has no parameters

Characteristics

This call moves the graphics accumulator up by one pixel position.

There is no checking with respect to window boundaries or the screen boundary; it is expected that the calling program will perform a check before executing a sequence of code using these routines.

Errors

No errors are returned.

Remarks

For the routine which does perform checks, see TUpC (SC 70).

58 DownC

Moves the position of the graphics accumulator down by one pixel.

Input/Output Parameters

This call has no parameters

Characteristics

This call move the graphics accumulator down by one pixel position.

There is no checking with respect to window boundaries or the screen boundary; it is expected that the calling program will perform a check before executing a sequence of code using these routines.

Errors

No errors are returned.

Remarks

For the routine which does perform checks, see TDownC (SC 69).

59 LeftC

Moves the position of the graphics accumulator left by one pixel.

Input/Output Parameters

This call has no parameters

Characteristics

This call move the graphics accumulator left by one pixel position.

There is no checking with respect to window boundaries or the screen boundary; it is expected that the calling program will perform a check before executing a sequence of code using these routines.

Errors

No errors are returned.

Remarks

For the routine which does perform checks, see ScaleXY (SC 52).

60 RightC

Moves the position of the graphics accumulator right by one pixel.

Input/Output Parameters

This call has no parameters

Characteristics

This call move the graphics accumulator right by one position.

There is no checking with respect to window boundaries or the screen boundary; it is expected that the calling program will perform a check before executing a sequence of code using these routines.

Errors

No errors are returned.

Remarks

For the routine which does perform checks, see ScaleXY (SC 52).

Sets the current colour attribute.

Input/Output Parameters

Input: R8 ⟵ colour

Output: R5 ⟶ error status

Characteristics

The input "colour" is the desired current attribute, or brush colour. This call sets the current attribute to that colour.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Plots a single point.

Input/Output Parameters

Input: R8 ← operation

Output: there are no outputs

Characteristics

This system call plots a single point. If the input 'operation' is equal to 0, a point having the current colour attribute is plotted at the position specified by the graphics accumulator.

For other values of 'operation', logical operations are performed (see table below). These are between the current attribute and the attribute of the pixel at the specified point; the result is then stored for the specified location.

0	PSET	The current attribute is stored.
1	XOR	The current attribute is XORed with the pixel.
2	AND	The current attribute is ANDed with the pixel.
3	NOT	The complement of the pixel is stored.
4	OR	The current attribute is ORed with the pixel.
5	PRESET	The current background colour is stored.

For example, the XOR function with a current attribute of 1 for monochrome or 3 for colour can be used for plotting a temporary point or line on the screen; repeating the function will then restore the screen to its original state.

Errors

No errors are returned.

63 ReadC

Returns the colour attribute of the current point.

Input/Output Parameters

Input:	there are no inputs
Output:	R8 ⟶ colour

Characteristics

This routine returns the attribute of the current point ("colour") as an integer (0..7) for eight colour systems, (0..3) for four colour systems, or (0..1) for monochrome, and stores it in register R8.

Colour Attributes

The colour values returned will belong to one of the sets shown below. The colour selection of four (A - D) is made from the eight listed under PaletteSet (SC 46):

Monochrome	Four-Colour Systems	Eight-Colour Systems
0 black	0 colour A	0 black
1 white	1 colour B	1 green
	2 colour C	2 blue
	3 colour D	3 cyan
		4 red
		5 yellow
		6 magenta
		7 white

Errors

No errors are returned.

64 NSetCX

Draws a horizontal line.

Input/Output Parameters

Input:	R8 ⟵ count	
	R9 ⟵ operation	
Output:	there are no outputs	

Characteristics

This call draws "count" number of pixels along a horizontal line, starting from the position specified by the current value of the graphics accumulator towards the right. The inputs are "count" (the number of points to be plotted) and "operation" which has the same meaning as used in SetC (62).

This call is the same as calling SetC (62) and RightC (60) 'count' times, but it has been optimized for speed.

Errors

No error checking is done. It is assumed that range checking is done by the caller.

65 NSetCY

Draw a vertical line.

Input/Output Parameters

Input:	R8 ← count R9 ← operation
Output:	there are no outputs

Characteristics

This call draws "count" number of pixels along a vertical line, starting from the position specified by the current value of the graphics accumulator downwards. The inputs are "count" (the number of points to be plotted) and "operation" which has the same meaning as used in SetC (62).

Using this call is the same as calling SetC (62) and DownC (58) 'count' times, but it has been optimized for speed.

Errors

No error checking is done. It is assumed that range checking is done by the caller.

66 NRead

Reads a screen rectangle into an array.

Input/Output Parameters

Input:	R8 ←	width (in pixels)
	R9 ←	height (in pixels)
	RR10 ←	pointer to byte array
Output:	@RR10 →	address of byte array
	R5 →	always cleared (no error conditions)

Characteristics

This call reads a screen rectangle into an array in memory.

The size (in pixels) of a rectangle on the screen is specified by the first two coordinates. The position of the upper left-hand corner of the rectangle is determined by the current Graphics Accumulator (which can be set using system call 53 MapXYC).

The third parameter is a pointer to a byte array which consists of a 6-byte header followed by an array of two-byte entries, each of which is a sixteen-bit integer.

The byte array is structured as follows:

byte	contents
0	width (high byte)
1	" (low byte)
2	hight (high byte)
3	" (low byte)
4	colour flag (high byte - always 0)
5	" " (low byte)
6	picture data
.	.
.	.
.	.
n	picture data

The colour flag is equal to 0 for a monochrome system, 1 for a 4-colour system and 2 for an 8-colour system.

If the width of the rectangle is W pixels, each scanline of the rectangle (for each colour plane) is stored in INT((W+15)/16) two-byte integer entries in the byte array, with the bit array left-justified in the integer array, so that the last two-byte entry for each scanline may have up to fifteen undefined bits.

The screen data is stored starting from top to bottom, with data for various colour memory planes interleaved scanline by scanline.
In other words, the integer array for the top scanline, plane 0 is stored first, followed in succession by the integer arrays for screen memory planes 1 and 2, if they exist on the system; these are followed in turn by the data for successive scanlines.

Errors

The caller is assumed to have done error checking.

67 NWrite

Transfers a graphics rectangle from an array to the screen.

Input/Output Parameters

Input:	R7	←	logical function
	R8	←	maximum width of rectangle in pixels
	R9	←	maximum height of rectangle in scanlines
	RR10	←	pointer to a byte array
Output:	R5	→	always cleared (no error condition)

Characteristics

This system call is used for inserting screen data, previously read from the screen using the NRead system call, somewhere on the screen.

Values of logical function for NWrite system calls:

0	overwrite what is already there
1	XOR (exclusive OR) array contents with destination
2	AND array contents with destination
3	COM: complement destination, no copy
4	OR array contents with destination
5	INVERT: complement text, copy

The logical function is useful in a variety of situations. For example, XOR may be used to display an object which can be erased with another XOR, leaving the screen as it was before the first XOR. AND may be used to selectively erase parts of the screen to colour 0, using a specially constructed array. OR may be used similarily to erase parts of the screen to all white.

The height and width parameters are used to determine what proportion of the rectangle saved in the array is actually written onto the screen; this has dimensions which are the minima of the parameters and the height and width values saved in the array; the rectangle written includes the upper left-hand corner of the saved rectangle in all cases.

As with NRead, the upper left-hand corner of the rectangle is determined by the current Graphics Accumulator.

Compatibility exists between colour and monochrome systems in the following sense:
if screen data is read with NRead on a monochrome system, and written with NWrite on a colour system, the data is written only into screen plane 0; screen plane 1 (or 2 for the 8-colour system) is left unchanged. On the other hand, if screen data is read on a colour system and written from the same array on a monochrome system, only data for colour memory plane 0 is written on the monochrome system.

Errors

The caller is assumed to have done error checking.

68 PntInit

Specifies the global colour attributes for paint routines.

Input/Output Parameters

Input:	R8 ←	paint colour
	R9 ←	border colour
Output:	R5 →	error status

Characteristics

The inputs 'paint' and 'border' must be legal screen colours as shown below. The colour selection of four (A - D) is made from the eight listed under PaletteSet (SC 46):

Monochrome	Four-Colour Systems	Eight-Colour Systems
0 black	0 colour A	0 black
1 white	1 colour B	1 green
	2 colour C	2 blue
	3 colour D	3 cyan
		4 red
		5 yellow
		6 magenta
		7 white

The attributes set are globals, like the main screen attribute, not window attributes.

This routine must be called before doing "ScanL" (SC 71) or "ScanR" (SC 72) or they will be undefined. (Usually, both paint colour and border colour are 1).

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

69 TDownC

Moves the graphics accumulator down by one pixel after checking the window boundary.

Input/Output Parameters

Input: there are no inputs

Output: R8 $\longrightarrow$ check value

Characteristics

This has the same effect as DownC, except that the position of the graphics accumulator is checked against the lower boundary position of the current window before it is changed.

If the new position is out of bounds, a false 'check value' is returned in R8 and the graphics accumulator is unchanged. If the new position is within bounds, the position is moved down one pixel and a true value is returned.

Errors

No errors are returned.

70 TUpC

Moves the graphics accumulator up by one pixel after checking the window boundary.

Input/Output Parameters

Input: there are no inputs

Output: R8 ⟶ check value

Characteristics

This has the same effect as UpC, except that the position of the graphics accumulator is checked against the lower boundary position of the current window before it is changed.

If the new position is out of bounds, a false 'check value' is returned in R8 and the graphics accumulator is unchanged. If the new position is within bounds, the position is moved up one pixel and a true value is returned.

Errors

No errors are returned.

Paints left on a scanline up to a border.

Input/Output Parameters

Input: there are no inputs

Output:

R9 ⟶ count-1
R10 ⟶ margin flag
R11 ⟶ painted flag

Characteristics

The purpose of this routine is to paint part of an enclosed region in the current window, moving left along a scanline.

All points starting at the initial position of the graphics accumulator are painted to the paintcolour. If any points painted were not already painted, the 'painted flag' is set.

The routine stops when the border colour has been reached or when the left margin of the window has been reached. The 'margin flag' is set if the left margin has been reached.

The output called 'count-1' is the number of pixels scanned (painted), regardless of whether their original colour was the paintcolour.

The graphics accumulator position is left at the end of the scan.

Errors

No errors are returned.

72 ScanR

Paints right on a scan line up to a border.

Input/Output Parameters

Input: R8 ← maxcount

Output:
RR6 → C-type
R8 → maxcount
R9 → count-r
R10 → margin flag
R11 → painted flag

Characteristics

The purpose of this routine is to paint part of an enclosed region in the current window, moving right along a scanline. At first the routine skips over a maximum of 'maxcount' points of the border colour.

If more than 'maxcount' border points are skipped, then ScanR stops immediately and returns R8 = 0 and R9 = 0 (and RR6 undefined).

All points following the initial border region are then painted to the paintcolour. If any points painted were not already painted, the 'painted flag' is set.

The routine stops when the border colour has been reached or when the right margin of the window has been reached. The 'margin flag' is set if the right margin has been reached. The output called 'count-r' value is the length in pixels of the painted segment.

The output 'C-type' points to the position of the first pixel painted. The graphics accumulator position is left at the end of the scan.

Errors

No errors are returned.

Sets the system clock.

Input/Output Parameters

Input:	RR8	←	address
	R10	←	length
Output:	R5	→	error status

Characteristics

The input 'address' points to an address in the caller's data area which contains the time of day. The input 'length' gives the length of the ASCII string. The format of the data in the string must be:

hh:mm:ss

where 'hh' is the hour (in 24-hour time), 'mm' is minutes, and 'ss' is seconds. Leading zeros need not be supplied. Any non-numeric character can be selected for delimiter as shown in examples below, using the PCOS SSYS (set system) command.

```
ss 04/15/82,13:12:45

ss "04 15 82",08:10:00
```

Time is initialized to 00:00:00 at system startup. If blanks are selected for delimiters, as in the second example, the expression must be put in quotes.

Errors

The value returned in R5 is zero if the clock was correctly set.

74 SetDate

Sets the system date-clock.

Input/Output Parameters

Input:	RR8 ← address	
	R10 ← length	
Output:	R5 → error status	

Characteristics

The input 'address' points to an address in the caller's data area which contains the date. The input 'length' gives the length of the ASCII string.

The format of the data in the string, except for the delimiter, must be:

dd:mm:yyyy

where 'dd' is the day, 'mm' is the month, and 'yyyy' is the year; leading zeroes need not be supplied.

Any non-numeric character may be used in place of the colon, as shown in the examples for SetTime (73).

The date is initialized to January 1, 1982 at system startup. If only two digits are input for the year, the century is assumed to be 19.

Errors

The value returned in R5 is zero if and only if the date was correctly set.

75 GetTime

Returns the system time.

Input/Output Parameters

Input:	RR8 ←	address
	R10 ←	length
Output:	R5 →	error status

Characteristics

This call returns the ASCII string giving the system time. The two inputs are the address and maximum length of the string, which is stored in the BASIC data area.

The format of the time returned is:

hh:mm:ss

where 'hh' is the hour (in 24-hour time), 'mm' is the minutes, and 'ss' is the seconds.

There will be leading zeroes to make each field 2 characters in length, and the character separating the various fields for the time will be that used in the last call to 'SetTime'. The system initializes the separator character to ':'.

Errors

If there are any errors, a non-zero value is returned in R5; a zero is returned if there were no errors.

76 GetDate

Returns the system date.

Input/Output Parameters

Input: RR8 ← address
R10 ← length

Output: R5 → error status

Characteristics

This call returns the ASCII string giving the system date. The two inputs are the address and maximum length of the string, which is stored in the BASIC data area.

The format of the returned date is:

dd:mm:yyyy

where 'dd' is the day, 'mm' is the month, and 'yyyy' is the year.

There will be leading zeroes to make each field two characters in length and the character separating the various fields for the date will be that used in the last call to 'SetDate'. The system initializes the separator character to ':'.

Errors

If there are any errors, a non-zero value is returned in R5; a zero is returned if there were no errors.

77 CallUser

Calls a user or a PCOS utility or command.

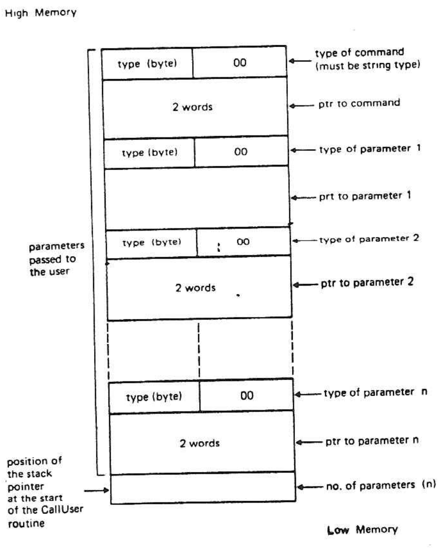
Input/Output Parameters

Input: RR14 ← stack pointer

Output: R5 → error status

Characteristics

This SC allows the Assembler programmer to invoke from his programs PCOS utilities and other utilities resident on disk or in memory. The input to RR14 points to an area in the stack where the parameters to the routine being called have been stored. Before invoking the SC 77 the user must prepare his parameters in the stack in the following way:



As far as the "types" are concerned, the same rules apply as previously stated in chapter 2 in the section which deals which the PCOS standard. In this case however the command parameters will have to be obtained using a series of "push"es rather than a series of "pop"s. The parameter pointers will be of the Z-8001 format.

The following table illustrates schematically the types already dealt with in chapter 2.

Data Types

Category	Data Type	Pointer Value	Description
null	0	%0000FFFF	for null parameters
integer	2	segmented ptr	integers occupy one word
string	3	segmented ptr	pointer to a 3-byte descriptor: 1-byte for the string length & 2-byte unsegmented ptr to the actual string

The following is an example of an Assembler source file, which, (by means of SC 77) makes use of the PCOS utility "filenew", which allocates a certain number of blocks on disk under the name of a given file.

In practice, it is a question of invoking from an assembler utility, that which can be invoked from PCOS in the following way:

```
fn FILE,100
```

The following is a sequence of Assembler instructions to be used for preparing the stack before the SC 77.

```
                                  .
                                  .
                                  .
                             push    @rr14,#%0300     type 3(string)
                             lda     rr2,cmd
                             ld      ptrcmd+2,r3      store offset
                             lda     rr2,ptrcmd+1
                             pushl   @rr14,rr2
                             push    @rr14,#%0300     type 3(string)
                             lda     rr2,filenam
                             ld      ptr1+2,r3        store offset
                             lda     rr2,ptr1+1
                             pushl   @rr14,rr2
                             push    @rr14,#%0200     type 2(integer)
                             lda     rr2,nblock
                             pushl   @rr14,rr2
                             push    @rr14,#2         no. of parameters
                             sc      #77
                                  .
                                  .
                                  .
   cmd                       ddb     "fn"
   ptrcmd                    dd      0002,0000
   filenam                   ddb     "FILE"
   ptr1                      dd      0004,0000
   nblock                    dd      0100             no. of blocks
                                  .
                                  .
                                  .
```

Errors

If there are any errors, the status code is returned in R5. If there are no errors a zero will be returned.

78 IBSrQ0

Disables the service request (SRQ) interrupt.

Input/Output Parameters

Input: there are no input parameters

Output: R5 ——→ error status

Characteristics

The statement "ON SRQ GOSUB 0" will cause the system call IBSrQ0 to be executed; this system call will disable the SRQ interrupt (for further details on the interrupt system, see SC 79).

Errors

If the system does not have an IEEE option board, R5 will contain a Hex 0A. If there are no errors, a zero (0) will be returned.

79 IBSrQ1

Enables the service request (SRQ) interrupt.

Input/Output Parameters

Input: there are no input parameters

Output: R5 ⟶ error status

Characteristics

The statement "ON SRQ GOSUB <line number>" will cause the system call IBSrQ1 to be executed; this system call enables the SRQ interrupt.

The IEEE-488 interrupt service routine will set the global flag "srq_488" (byte) to 1 when an SRQ interrupt occurs. (This flag is stored in the mailbox area).

This flag will be tested by the interpreter before the execution of each source statement following the ON SRQ GOSUB. If set, it will be reset by the interpreter, and the subroutine entered (see call GrfInit (SC 45)).

Errors

If the system does not have an IEEE option board, R5 will contain a Hex 0A. If there are no errors, a zero (0) will be returned.

80 IBPoll

Polls a specified device on an instrument bus.

Input/Output Parameters

Input: R8 ← talker addr

Output: RR10 → ptr to status
R5 → error status

Characteristics

This call polls the device specified, within a serial service request poll. The input 'talker addr' identifies the device.

The call tests the device address, reads the device status byte, and saves it in an address pointed to by'ptr to status'.

Errors

If the system does not have an IEEE option board, R5 will contain a Hex 0A. If the talker address is invalid (ie., greater than 001E), R5 will contain '09'. If there are no errors, a zero (0) will be returned.

81 IBISet

Causes a remote enable (REN) or an interface clear (IFC) to be sent.

Input/Output Parameters

Input: R8 ← operand

Output: R5 → error status

Characteristics

This call causes the remote enable (REN) message or the interface clear (IFC) pulse to be transmitted, depending upon the value of the input 'operand'.

If '0' is loaded into R8, then the REN message is sent true; if '1' is loaded, then the IFC pulse is sent.

Errors

If the system does not have an IEEE option board, R5 will contain a Hex 0A. If there are no errors, a zero (0) will be returned.

82 IBRSet

Causes the remote enable (REN) message to be sent false.

Input/Output Parameters

Input: there are no parameters

Output: R5 ——► error status

Characteristics

This call causes the remote enable (REN) message to be sent false.

Errors

If the system does not have an IEEE option board, R5 will contain a Hex 0A. If there are no errors, a zero (0) will be returned.

83 IBPrnt

Checks the address and then causes output of data bytes.

Input/Output Parameters

Input:	RR6 ←	buffer addr
	R8 ←	listener addr
	R9 ←	buffer len, in bytes
	R10 ←	delimiter
Output:	R5 →	error status

Characteristics

Before calling the driver, the BASIC interpreter will transfer the output bytes to a buffer, from which they will be sequentially transferred by the driver.

This call will test the listener address in R8; if less than 001F, writes listener address, if specified.

The input to R10 is zero if END is to be specified as data-stream delimiter, and 1 if it is not (CR, END as data-stream delimiter sequence). If there are any output bytes for transfer, writes them to bus, with ATN false.

Errors

If the system does not have an IEEE option board, R5 will contain a Hex 0A. If the listener address in R8 is greater than 001F, this call returns an error code of 09. If there are no errors, a zero (0) will be returned.

84 IBWByt

Outputs commands (optional) and writes data bytes (optional).

Input/Output Parameters

Input: RR6 ← numval addr
R8 ← comlist length
R9 ← numval length
RR10 ← comlist addr

Output: R5 → error status

Characteristics

If there is a command list, asserts ATN and outputs commands. If there are any data bytes to be output, writes them to bus with ATN false.

The input 'comlist addr' points to the address of the command list. This list, if present, is stored as a sequence of bytes, 2 to the word. The input 'comlist length' is the command list length in 15 low-order bits; high-order bit: 1 if "@" option (END sent with last byte of data as statement delimiter) specified, 0 if not (END with CR terminates data).

The input 'numval addr' points to the address of the list of numeric values . It, too, is stored as a sequence of bytes, 2 to a word. The input 'numval length' is 0 if not specified.

Errors

If the system does not have an IEEE option board, R5 will contain a Hex 0A. If there are no errors, a zero (0) will be returned.

Places bytes received, into a buffer.

Input/Output Parameters

Input:

- R7 ← buffer length
- R8 ← talker addr
- R9 ← listener addr
- RR10 ← buffer addr

Output:

- R5 → error status
- R7 → number of bytes not read

Characteristics

This procedure calls IBLinpt. Both IBInpt and IBLinpt place bytes received sequentially from a driver into a single buffer. They differ in that, for IBInpt, the BASIC interpreter transfers the buffer contents to the variables in the variable list provided by the user; for IBLinpt the user specifies the buffer for a single line of data.

On entry, the 'buffer length' (R7) is given in bytes; on exit, this represents the number of bytes not read (buffer length minus number of bytes read). The 'buffer addr' points to the buffer which will receive the data bytes. The 'talker addr' (R8) and 'listener addr' (R9) will both be 001F if not specified.

Errors

The error codes which can be returned in R5 are:

ERROR CODE	MEANING
03	Invalid termination of input bytestream. The two valid cases are: - the number of data bytes received equals the value provided in R7 (string variable length, in bytes). The last data byte is accompanied by the END condition (EOI true, ATN false). - the number of data bytes received equals the value provided in R7 (string variable length, in bytes). The last data byte is followed by a CR, LF pair with the END condition accompanying the LF.
09	Talker or Listener address greater than 1F.
0A	IEEE board not present.
0B	15 second polling loop (for 'byte in', 'byte out' , or 'input buffer empty' condition) timed out; handshake could not be completed within 15 seconds.

If there are no errors, a zero (0) will be returned.

86 IBLinpt

Places bytes received into a buffer as a single line of data.

Input/Output Parameters

Input:	R7 ←	buffer length
	R8 ←	talker addr
	R9 ←	listener addr
	RR10 ←	buffer addr
Output:	R5 →	error status
	R7 →	number of bytes not read

Characteristics

Both IBLinpt and IBInpt place bytes received sequentially from a driver into a single buffer. They differ in that, for IBLinpt the user specifies the buffer for a single line of data; for IBInpt, the BASIC interpreter transfers the buffer contents to the variables in the variable list provided by the user.

On entry, the 'buffer length' (R7) is given in bytes; on exit, this represents the number of bytes not read (buffer length minus number of bytes not read). The 'buffer addr' points to the buffer which will receive the data bytes. The 'talker addr' (R8) and 'listener addr' (R9) will both be 001F if not specified.

Errors

The error codes which can be returned in R5 are:

ERROR CODE	MEANING
03	Invalid termination of input bytestream. The two valid cases are: - the number of data bytes received equals the value provided in R7 (string variable length, in bytes). The last data byte is accompanied by the END condition (EOI true, ATN false). - the number of data bytes received equals the value provided in R7 (string variable length, in bytes). The last data byte is followed by a CR, LF pair with the END condition accompanying the LF.
09	Talker or Listener address greater than 1F.
0A	IEEE board not present.
0B	15 second polling loop (for 'byte in', 'byte out' , or 'input buffer empty' condition) timed out; handshake could not be completed within 15 seconds.

If there are no errors, a zero (0) will be returned.

87 IBRByt

Outputs commands (optional) and reads data bytes (optional).

Input/Output Parameters

Input: RR6 ← buffer addr
R8 ← comlist length
R9 ← buffer len, in bytes
RR10 ← comlist addr

Output: R5 → error status

Characteristics

If there is a command list, asserts ATN and outputs commands. It then reads the assigned number of bytes, and places them sequentially in a buffer.

The input 'comlist addr' points to the address of the command list. This list, if present, is stored as a sequence of bytes, 2 to the word.

The input 'comlist length' is the command list length in 15 low-order bits; high-order bit is always zero (0).

The input 'buffer addr' points to the buffer which will receive the data bytes. The input 'buffer len, in bytes' indicates the number of bytes to be read.

Errors

If the system does not have an IEEE option board, R5 will contain a Hex 0A. If any handshake is not completed within 15 seconds, R5 will contain Hex '000B'. If there are no errors, a zero (0) will be returned.

88 Error

Displays standard error message.

Input/Output Parameters

Input: RH5 ← parameter number
RL5 ← error code

Output: there are no outputs

Characteristics

This procedure is only called if there are errors. The routine displays the message 'Error nn' in parameter xx' where nn is one of the standard error codes and xx is the parameter number passed in RH5. If xx is 00 then only the message 'Error nn' is displayed.

Note:

If the EPRINT command is resident, then an error message will be displayed.

89 DString

Displays a string message.

Input/Output Parameters

Input: RR12 ⟵ address

Output: R5 ⟶ error status

Characteristics

This routine displays a string message. The string must be terminated with a null (0) byte.

The message may include any number of carriage returns, but note that a linefeed will be automatically displayed after each carriage return in the string.

The input 'address' is the address of the string.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

90 CrLf

Does a CR and a LF.

Input/Output Parameters

Input: there are no parameters

Output: R5 ⟶ error status

Characteristics

This routine will do a carriage return and a line feed. There are no parameters.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Displays a byte in Hex.

Input/Output Parameters

Input: R12 ← byte

Output: R5 → error status

Characteristics

The byte supplied in the lower half of R12 is displayed as two hex digits.

Errors

If there are any errors, the status code is returned in R5. If There are no errors, a zero (0) will be returned.

92 DHex

Displays a word in hex.

Input/Output Parameters

Input: R12 ← word

Output: R5 → error status

Characteristics

This routine displays the 16-bit number in R12 as four hex digits.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

93 DHexLong

Displays a long word in hexadecimal.

Input/Output Parameters

Input: RR12 ← long word

Output: R5 → error status

Characteristics

The long word supplied in RR12 is displayed as eight hex digits.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

94 DNumW

Displays a number as an unsigned decimal integer.

Input/Output Parameters

Input: R12 ← integer
R13 ← field width

Output: R5 → error status

Characteristics

The number in R12 is displayed as an unsigned decimal integer. R13 specifies the field width for display.

The display is right-justified in the field, with leading zeroes changed to spaces.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

Displays a number as an unsigned decimal integer.

Input/Output Parameters

Input: RR12 ← long integer

Output: R5 → error status

Characteristics

The number supplied in RR12 is displayed as an unsigned decimal integer, left-justified with leading zeroes omitted.

Errors

If there are any errors, the status code is returned in R. If there are no errors, a zero (0) will be returned.

96 DisectName

Parses a file or a volume name.

Input/Output Parameters

Input:	R9 ← string length	
	RR10 ← string address	
	RR12 ← names record address	
Output:	@RR12 → names record	
	R7 → volume number	
	R5 → error status	

Characteristics

This call takes a file identifier of the form

"<volname>'/'<volpswd>':'<filename>'/'<filepswd>"

and parses it into its various components. A drive unit is acceptable as <volname>.

Each component is placed into the appropriate compartment of the names record as follows:

```
volname : 14 byte array
volpswd : 14 byte array
filename : 14 byte array
filepswd : 14 byte array
```

The input string length is the length of the file identifier string (this includes the volume identifier), which in turn is input in the address specified in RR10.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

97 CheckVolume

Forces a check of disk volumes

Input/Output Parameters

Input: there are no parameters

Output: R5 → error status

Characteristics

There are no input registers for this call. All volumes are forced to read their verification codes on their access.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

98 Search

Searches on a specified disk for a specified file name.

Input/Output Parameters

Input:

R6	←	drive
R7	←	search mode
R9	←	length
RR10	←	file pointer
RR12	←	name pointer

Output:

R9	→	length of output filename
RR10	→	file pointer
RR12	→	modified
R5	→	error status

Characteristics

This call searches on a disk for a file name supplied by the user. The file name may contain wild card characters.

The input called 'drive' identifies the drive to be searched (input a '-1' for the current drive). The input 'search mode' is either a '1' for a search from the beginning, or a '0' for a search from the last file found. The input 'length' is the length of the file name, in bytes. To search for any file, input a zero length.

The input 'file pointer' points to the memory location where the name of the file, if found, will be written. The input 'name pointer' is the address where the input string will be stored. If the file is found, the address of the name of the file is returned in RR10. The content of the register RR12 is modified by the Operating System.

Errors

If there are any errors, the status code is returned in R5. If the file is found, a zero (0) will be returned.

99 MaxSize

Returns maximum free heap size

Input/Output Parameters

Input: there are no parameters

Output: R8 → size
R5 → error status

Characteristics

This call returns the size of the largest free heap block in the current segment. Size is returned in bytes.

This call operates in segment 2 unless the program has done a BrandNewAbsolute system call (121), in which case the segment number is that specified in the most recent "BrandNewAbsolute".

A simple way to change the segment number for a program is to do a SC 121 "BrandNewAbsolute" with a block length of 0.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

102 SetVol

Sets a specified volume for the next access.

Input/Output Parameters

Input: R7 ← vol number

Output: R5 → error status

Characteristics

This call sets the volume for the next access. The input 'vol number' is the volume number to be used for the next access.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

104 NewAbsolute

Allocates a block at a specified address.

Input/Output Parameters

Input:	RR8 ←	address of block pointer
	R10 ←	length
	@RR8 ←	block pointer
Output:	R5 →	error status

Characteristics

This call is similar to NewSameSegment (SC 33) except that the block allocated will be at a specified address. The input address (RR8) should be the address of a long (4-byte) memory location; this is where the desired address is stored. The input to R10 is the number of bytes requested, and must be even.

On exit from this call, the memory location that RR8 points to will contain a 32-bit address of the actual block allocated. If the requested value is too close to the end of a previous block, the actual value may be two bytes lower than the requested value, but will still include the requested length. If the space requested is not available, a nil-pointer (hex FFFFFFFF) will be returned in the memory location that RR8 points to, but no error will be returned in R5.

It is important to remember that RR8 does not contain the memory block address specified.

This call allocates blocks in the "SameSegment". This is segment 2 unless the program has done a "BrandNewAbsolute" system call, in which case the segment number is that specified in the most recent "Brand-NewAbsolute". A simple way to change the segment number for a program is to do a SC 121 "BrandNewAbsolute" with a block length of 0.
This call is a subset of system call 121 "BrandNewAbsolute". It has been maintained for compatibility with preceding releases.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

105 StringLen

Returns the length of the input string.

Input/Output Parameters

Input:	RR12 ← pointer
Output:	R7 → length
	R5 → error status

Characteristics

This call returns the length of the input string. The input 'pointer' points to the string; the output in R7 is the length read (until a null encountered, or 14, if no null in that length).

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

106 DiskFree

Returns the number of free sectors on the disk.

Input/Output Parameters

Input: R7 ← volume number

Output: RR10 → num of sectors
R5 → error status

Characteristics

This call returns the number of sectors that are available for use on the disk. The input 'volume number' is the volume to be checked (enter -1 for the current volume).

The number of sectors that are free on the volume will be returned in RR10.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

107 BootSystem

Reboots (initializes) the system.

Input/Output Parameters

Input: this call has no parameters

Output: R5 ⟶ error status

Characteristics

This system call can be used to reboot the system, exactly as does pressing the blue shift plus reset keys. In other words, the system reboots, but bypasses the diagnostic checks.

Errors

There are no error checks with this call. If an error occurs, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

108 SetSysSeg

Returns the caller to segmented system mode.

Input/Output Parameters

Input: this call has no parameters

Output:
R5 ——► error status

Characteristics

This call will return the caller to the segmented system mode, regardless of which mode the system is in.

Errors

There are no error checks with this call. If an error occurs, the status code will be returned in R5. If there are no errors, a zero (0) will be returned.

109 SearchDevTab

Searches the system device table for a device name.

Input/Output Parameters

```
Input:        RR10<----ptr to device name
              R9  <----device name length

Output:
              RL5 ---->entry number
              RH5 ---->device type
              RR8 ---->ptr table entry
              R5  ---->error status
```

Characteristics

This command searches the system device table for the device named. The input 'ptr to device name' is the address where the first ASCII character of the name is stored; the input 'device name length' is the number of bytes in the name. If the call finds the device name, it returns the entry number of the device in RL5 and the device type in RH5 (1 = Read, 2 = Write, 3 = Read/Write); it also returns a pointer to the first entry in the particular device table in RR8.

EXAMPLE:

```
                        .
                        .
table_pointer  DSL     1
device_name    DDB     "cons"
                        .
                        .
               ld      r9,#4                   search_devtab string length
               lda     rr10,device_name        search_devtab string pointer
               sc      #109
               test    r5                      name not found
               jr      nz,command_err
               ldl     table_pointer,rr8
                        .
                        .
```

Errors

If the device is not found, a Hex FFFF (nil) is returned in R5.

111 CtlCharDisp

Enables or disables the display of special control characters.

Input/Output Parameters

Input:	R8	on/off (nonzero/zero)
Output	there is no output	

Characteristics

This system call will enable the display of special control characters if a nonzero value is input to R8. If R8 contains zero, then the display of special control characters is disabled.

For a list of special control characters and their respective character font definitions see the "M20 PCOS User Guide".

Errors

No errors are returned.

113 CloseAllWindows

Closes any existing windows from 2 to 16.

Input/Output Parameters

This call has no parameters

Characteristics

This call will close all existing windows except for window 1.

Errors

No errors are returned.

114 KbSetLock

Sets the state of both the shift lock and the cursor lock flags.

Input/Output Parameters

Input:	R6	←	integer flag
Output:	R7	→	previous flag
	R5	→	error status

Characteristics

The "integer flag" input in R6 is in the range 0-3 and sets the shift lock (for the alpha keys on the alphanumeric keypad) and cursor lock (for the numeric keypad) as follows:

0 = Both flags reset

1 = Shift lock on and cursor lock off

2 = Shift lock off and cursor lock on

3 = Both flags set

Note: The cursor lock condition can also be obtained with the key combination "Control /", while the shift lock with the key combination "Command /".

Errors

If there are any errors the status is returned in R5. If there are no errors, a zero will be returned in R5.

115 ClearText

Clears a rectangle of text in the current window.

Input/Output Parameters

Input: R10 ← column (left edge of cleared rectangle)
R11 ← row (top row of cleared rectangle)
R12 ← column count (width of rectangle)
R13 ← row count (height of rectangle)

Output: R5 → error status

Characteristics

ClearText simply clears the specified rectangle to the current background colour of the window. In a colour system, ClearText always clears all screen planes in the specified rectangle, which have corresponding bits set in the Colour Plane Mask parameter (see ScrollText SC 116).

In this system call, the Colour Plane Mask parameter is set to 7, so that a complete clear of the rectangle is done, no matter what system this is executed on.

The range of a column parameter is from 1 to the width of the current window, and the range of a row parameter is from 1 to the number of text lines in a window, i.e. :

1 <= Column + Column_count -1 <= width of window, and

1 <= Row + Row_count - 1 <= number of text lines in the window

Errors

The ranges of the above parameters are checked. An error is returned in R5 if the specified rectangles are not entirely within the window.

116 ScrollText

Copies a rectangle of text characters in a window to another position of the same window.

Input/Output Parameters

Input:	R6	←	colour plane mask
	R7	←	logical function (0 for normal copy)
	R8	←	source column (left edge of source)
	R9	←	source row (top row of source)
	R10	←	destination column (left edge of destination)
	R11	←	destination row (top row of destination)
	R12	←	column count (width of rectangle)
	R13	←	row count (height of rectangle)
Output:	R5	→	error status

Characteristics

ScrollText is used for copying a rectangular block of text from one portion of a screen window to another. (Note that this cannot be used for copying from one window to another window.) The source and destination areas may overlap; in this case, copying is done in such a way that the overlapped area is copied last: the destination will be a true copy of the the original source, even though the source has been overwritten.

The values for the "logical function" input in R7 are:

0	Copy text
1	XOR (exclusive OR) source with destination
2	AND source with destination
3	COM: Complement destination, no copy
4	OR source with destination
5	INVERT: Complement text, copy

The "colour plane mask" parameter determines which memory planes are affected by the ScrollText call. It only applies when logical functions 1, 3, or 5 are used, otherwise this parameter is ignored, and its value is preserved. This contains a bit for each memory plane to be written in: bit 0 denotes the first 16K block of screen memory, bit 1 denotes the second 16K block (in 4-colour and 8-colour sytems), and bit 2 denotes the third block used in the 8-colour system. Bits higher than appropriate for a particular system will be ignored: for example, bits 1 and 2 will be ignored on monochrome hardware.

Any program which does not make use of colour (i.e. which only uses colours 0 and 1) should use the value 1 for the "colour plane mask parameter"; this will prevent writing in the second (or third) screen planes of a colour system, if the XOR or COM functions are used.

On the other hand, programs which do use colours other than 0 and 1 should use values 3 (bits 0 and 1) for a 4-colour system, and 7 (bits 0, 1, and 2) for an 8-colour system (actually, 7 may be used for all systems, in this case, the apparent effect of certain logical functions will vary between different types of display).

If the logical function is 0, 2 or 4, ScrollText will obey the same convention regarding the number of screen memory planes written as the screen text and graphics driver: e.g. if the foreground colour is 1 and the background is 0, only the first screen memory plane will be written in.

The range of a column parameter is from 1 to the width of the current window, and the range of a row parameter is from 1 to the number of text lines in a window, i.e. :

1 <= Column + Column_count -1 <= width of window, and

1 <= Row + Row_count - 1 <= number of text lines in the window.

Errors

The ranges of the above parameters are checked by these system calls; an error is returned if the specified rectangles are not entirely within the window. No clipping is done the rectangles specified must be entirely within the window.

119 GetVol

Returns the current default volume number.

Input/Output Parameters

Input:	RR12	←	pointer to volume identifier buffer
	R6	←	buffer size
Output:	R7	→	size of volume identifier
	R5	→	error status

Characteristics

This call returns the current default volume identifier in the buffer pointed to by RR12.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) will be returned.

120 New

Allocates a block of bytes from heap.

Input/Output Parameters

Input: RR8 ← address of block pointer
R10 ← length

Output: R5 → error status
@RR8 → block pointer

Characteristics

This call allocates a block of bytes from the heap, returning a pointer to the location of the first byte of the block. The input "address of block pointer" is the address of a long (4byte) memory location, that is, the address where 'New' stores the block. The input 'length' is the number of bytes to be allocated.

EXAMPLE:

```
                .
                .
addptr          DSL 1
length          ASSIGN ...
                .
                .
LDA             RR8,addptr
LD              R10,#length
SC              #120
LDL             RR6,@RR8
                .
                .
```

In this example, RR6 contains the block starting address. If the block cannot be allocated,@RR8 contains a nil pointer (hex FFFFFFFF), but no error will be returned in R5.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) is returned.

121 BrandNewAbsolute

Allocates a block at a specified address.

Input/Output Parameters

Input:	RR8 ←	address of block pointer
	R10 ←	length
	@RR8 ←	block pointer
Output:	R5 →	error status

Characteristics

This call is similar to a New (SC 120) except that the block allocated is at a specified address.

The input address (RR8) is the address of a long (4-byte) memory location; this is where the desired address is stored. The input to R10 is the number of bytes requested, and must be even.

On exit from this call, the memory location that RR8 points to contains a 32-bit address of the actual block allocated. If the space requested is not available, a nil-pointer (hex FFFFFFF) is returned in the memory location pointed to by RR8, but no error is returned in R5.

It is important to remember that RR8 does not contain the memory address specified.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) is returned.

122 NewLargestBlock

Allocates the largest block of bytes from heap.

Input/Output Parameters

Input:	RR8 ←	address of block pointer
Output:	@RR8 →	block pointer
	R10 →	length
	R5 →	error status

Characteristics

This procedure allocates a the largest free block in memory, returning a pointer to the location of the first byte of the block and the length of that block.

The input pointer should be the address of a long (4byte) memory location; that is the address where 'NewLargestBlock' stores the block start address.

If the block cannot be allocated,@RR8 contains a nil (hex FFFFFFFF) pointer but no error is returned in R5.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) is returned.

123 StickyNew

Allocates a block of bytes from heap that remains allocated after the program doing this call terminates.

Input/Output Parameters

Input:	RR8 ←	address of block pointer
	R10 ←	length
Output:	@RR8 →	block pointer
	R5 →	error status

iH 4 "Characteristics" This call allocates a block of bytes from the heap, returning a pointer to the location of the first byte of the block.

The input "address of block pointer" is the address of a long (4byte) memory location, that is, the address where the block start address is stored. The input 'length' is the number of bytes to be allocated.

This call is just like "New", but is used for those rare occasions when the allocated block is not to be de-allocated when the "calling" program terminates.

Errors

If there are any errors, the status code is returned in R5. If there are no errors, a zero (0) is returned.

9. INTRODUCTION TO GRAPHICS

ABOUT THIS CHAPTER

This chapter is an introduction to the graphics facilities available in the M20 Graphics Package. It includes a summary of features and an explanation of graphics concepts; the graphics routines are listed in functional groups. A list of the default conditions for the M20 is given and error reporting is explained.

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INTRODUCTION

The M20 Graphics Package is implemented in the form of a library. This M20 Graphics Library is available in the file "graph.lib", which is an integrated package of over forty routines offering a set of functionalities for two dimensional graphics applications. This library may be called by the PASCAL and Assembly programming languages (for more detail see Chapter 6). Chapter 10 contains a detailed description of each routine, in alphabetical order.

SUMMARY OF FEATURES

The M20 Graphics Package presents a consistent and easily comprehensible structure that reflects proposed international standards for such packages.

Besides the full complement of standard output primitives, including lines, polylines, markers, etc., there are several added features:

- line drawings and move operations may be optionally specified as an offset from the current position
- circle, ellipse and rectangle functions are available
- output primitives may be drawn in any of eight colours (on eight-colour systems) or four colours (on four-colour systems)
- polygons, circles and ellipses may be solid filled
- intercharacter spacing for text may be adjusted.

The screen may be subdivided into rectangular regions called view areas. View areas are independent from one another and there may be a maximum of 16 on the screen. If the user tries to draw a picture which does not fit within the view area then only the visible portion of the drawing is displayed and the rest is discarded (clipped).

Pictures, or parts of pictures, may be stored and redrawn when necessary. For every feature that may be set by the M20 Graphics Package, there is an inquiry function which permits the user to request its current state. The inquiry functions return:

- the colour, logic operator and line class for the current view area
- the number of the current view area
- the position and blink rate of the graphics cursor for the current view area

- the location at which graphics output will begin
- the colour number of the pixel which is nearest to a specified point
- the device coordinates of a given point expressed in world coordinates
- the next text entry point and the text cursor blink rate for the current view area
- the size and text parameters of the current view area
- the world coordinate space for the current view area.

The M20 Graphics Package defaults to an operating mode that automatically makes all format decisions (see Default Conditions). The user may change these default conditions to other values which will better suit the specific problem.

CONCEPTS

Graphical output generated by the M20 Graphics Package comprises two general classes of functions: **output primitives** and **primitive attributes.**

Output primitives are abstractions of basic actions that graphics devices can perform, like drawing lines and locating cursors. Output primitives are defined in a two-dimensional user coordinate space (known as world coordinates, see below). The units and the coordinates of the user coordinate space are established by the application program.

Primitive attributes determine the characteristics that an output primitive will possess when displayed on an output device; e.g., line class, colour, intercharacter spacing, etc. Primitive attributes are set modally; i.e., they establish a current value that is assigned to subsequently generated output primitives.

Coordinate data is subjected to transformations that perform a mapping between two coordinate systems, namely:

- **world coordinates,** defined by the user that establish the scaling basis on which the graphical output is described. The world coordinate space definition determines how the coordinates from the application program shall be placed within a view area. When a new view area is created, it will have the same world coordinate space definition as the parent view area, but since the proportions of the two view areas have changed, the shape of subsequent output to those view areas will change too. The world coordinate space defines a view area within the Cartesian plane. DivideViewArea defines a rectangular surface on which the scale of two axes (the x axis and the y axis) is determined. The view area may or may not contain the plane's origin, that is the point of crossing of the two axes at which the coordinates are (0, 0);

- **device coordinates** range from 0 to 511 pixels on the x axis (pixel = picture element, the smallest visible entity on the screen) and from 0 to 255 scanlines on the y axis (scanline = a row of pixels), where each coordinate pair addresses only one specific pixel.

Output primitives and attributes are automatically mapped from the user's world coordinate space to the device coordinates via a transformation which need not concern the user.

The M20 Graphics Package maintains **two current positions,** one for text and one for graphics, and **two cursors,** one for text and one for graphics. Only one of the two cursors (or neither, if so specified) is displayed at any one time. The text current position and the text cursor are always at the same logical location: the point at which the next text output will appear. The graphics current position (the point from which the next graphics output will begin) and the graphics cursor do not coincide. The graphics cursor may be used as an echo symbol to indicate a position on the screen that reflects the values entered by an input device. The current graphics position is used in many but not all graphics output routines, e.g., Polyline will establish its own starting point, but moves the current position along as it draws, leaving it at the final point. The circle and ellipse routine (GDP) leaves the current position unaffected.

Some graphics routines use **absolute coordinates**, others use **relative coordinates.** The distinction is that absolute coordinates are distances along the x and y axes from the origin of the Cartesian plane, while relative coordinates are distances along the x and y axes from the current point.

Most of the output routines are affected by the current **colour attributes** and the colour **logic-operator attribute.** There is a foreground colour which determines the colour of text output, and a background colour. There is a graphics colour which determines the colour of graphic output (lines, circles, dots, etc.). These attributes are selected from the range of colours available on the specific M20 configuration. The colours available on the M20 eight-colour system are: black, red, green, yellow, blue, magenta, cyan and white. The colours available on the M20 four-colour system are four colours chosen from the eight just mentioned. The monochrome system provides two colours, black and white.

The eight colours are numbered from 0 to 7. On four-colour systems, the colours chosen in the range 4 to 7 map to a value in the range 0 to 3 via a logical operation. Bits 0 and 2 of the binary representation are OR'd, e.g. the values 4 (100 binary) and 5 (101 binary) give 1 OR 0 = 1 and 1 OR 1 = 1 respectively. This sets the least significant bit (bit 0) and bit 1 remains unchanged. Thus, the values 4 and 5 will become 1 after the logical operation (4 decimal = 100 binary which becomes 01 binary = 1 decimal and 5 decimal = 101 binary which becomes 01 binary = 1 decimal) and the colour is green (if the default value has not been changed). The values 6 and 7 will become 3 after the logical operation (6 decimal = 110 binary which becomes 11 binary = 3 decimal and 7 decimal = 111 binary which becomes 11 binary = 3 decimal) and the colour is red.

The logic-operator attribute determines the resultant output colour, considering the type of graphics routine (text or graphics), the setting of the foreground, background or graphics colour attribute and the colour of the target pixels in the view area. There are six logic operators and each one acts on all pixels in determining what the final colour shall be. The action occurs one pixel at a time, using the colour of the target pixel and that of the new graphics output as operands.

FUNCTIONAL GROUPS

The functional capabilities of the M20 Graphics Package may be divided into four general classes, as follow.

- Transformation and control.

ClearViewArea	:	clears the specified view area.
CloseGraphics	:	closes the graphics session.
CloseViewTrans	:	closes the specified view area.
DivideViewArea	:	creates a new view area.
Escape	:	colours an area.
OpenGraphics	:	opens the graphics session.
SelectViewTrans	:	activates the selected view area.
SetWorldCoordSp	:	defines the world coordinate space.

- Graphics Output.

GDP	:	Generalised Drawing Primitive, creates a circle or an ellipse.
GraphCursorAbs	:	moves the graphics cursor to a specified absolute position.
GraphCursorRel	:	moves the graphics cursor to a specified relative position.
GraphPosAbs	:	redefines the current graphics position (absolute).
GraphPosRel	:	redefines the current graphics position (relative).
LineAbs	:	draws a line from the current graphics position to a specified absolute position.
LineRel	:	draws a line from the current graphics position to a specified relative position.

MarkerAbs	: displays a point at a specified absolute position.
MarkerRel	: displays a point at a specified relative position.
PixelArray	: transfers an image onto the screen.
Polyline	: draws a connected sequence of lines.
Polymarker	: displays the specified points.
TextCursor	: moves the text cursor.

- Graphics Attributes.

SelectCursor	: chooses which cursor (if any) is to be displayed.
SelectGrColour	: selects the colour for subsequent graphics output.
SelectTxColour	: selects the colours for subsequent text output.
SetColourLogic	: defines a logic operator that influences the output colour.
SetColourRep	: sets one of the four colour indices to one of the eight M20 colours (four-colour systems only).
SetGrCsrBlnkrate	: sets the blink rate for the graphics cursor.
SetGrCsrShape	: defines the graphics cursor shape.
SetLineClass	: determines the graphics output for the LineAbs, LineRel and Polyline routines.
SetTextline	: sets the character width and text line height.
SetTxCsrBlnkrate	: sets the blink rate for the text cursor.
SetTxCsrShape	: defines the text cursor shape.

- Inquiry.

ErrorInquiry	: returns the error status for the most recently called graphics routine other than the inquiry routines.
InqAttributes	: returns the colour, logic operator and line attributes for the current view area.
InqCurTransNmbr	: returns the number of the current view area.
InqGraphCursor	: returns the position and blink rate of the graphics cursor for the current view area.
InqGraphPos	: returns the location at which new graphics output will begin.
InqPixel	: returns the colour number of the pixel which is nearest to the specified point.
InqPixelArray	: retrieves a rectangular image from the current view area and stores it.
InqPixelCoords	: returns the device coordinates of a given (x,y) pair of world coordinates.
InqTextCursor	: returns the next text entry point and the text cursor blink rate for the current view area.
InqViewArea	: returns the size and text parameters of the current view area.
InqWorldCoordSp	: returns the world coordinate space parameters for the current view area.

ERRORS

Error reporting is handled in two ways. For all routines, an error status is reported; the value zero means no error. If an error has occurred, a value in the range 1 to 255 inclusive is returned. The code numbers used are the standard PCOS error codes with the same meanings (see Appendix E).

For most routines, this status value is transferred to an error status variable maintained by the M20 Graphics Package. There is a routine (ErrorInquiry) which returns the current value of this variable (that is, the error status of the most recent Graphics Package routine called other than the inquiry routines).

The inquiry group of routines handles error reports differently. These never touch the error status variable (except for ErrorInquiry which retrieves its value). They report any error directly through an error parameter, and they do not generate an error status.

DEFAULT CONDITIONS

The following is a list of the default conditions that will be assumed unless otherwise specified:

- world coordinates range from 0.0 to 511.0 on the X axis and from 0.0 to 255.0 on the Y axis, coinciding with the device coordinates except that the latter are integer values
- view area number 1 is the full screen, with device coordinates ranging from 0 to 511 on the X axis and from 0 to 255 on the Y axis
- colour depends on the system configuration

    a) the monochrome system sets the background colour to 0 = black and the text and graphics colours to 1 = white

    b) the four-colour system sets the background colour to 0 = black; the text and graphics colours to 1 = green; 2 = blue; 3 = red

    c) the eight-colour system sets 0 = black to the background colour, 1 = green to the text and graphics colour, 2 = blue, 3 = cyan, 4 = red, 5 = yellow, 6 = magenta, 7 = white

- the logic operator is PSET, which displays graphics output in the chosen colour
- the line class is solid line

- no cursor is displayed
- there is one cursor blink per second (one blink includes two changes of state, one from ON to OFF and one from OFF to ON)
- the text cursor shape is 7 pixels wide x 11 scanlines high (within an 8x12 space) and is displayed as a rectangle having alternate pixels set
- the graphics cursor shape is 2 pixels wide x 2 scanlines high
- the graphics position is (0.0, 0.0)
- the graphics cursor is at the centre of the screen, i.e. the upper left hand corner of the graphics cursor is at (255, 127)
- there are 16 scanlines per text line and 8 pixels per character
- there are 16 textlines (rows) and 64 characters (columns) per screen.

10. THE M20 GRAPHICS ROUTINES

ABOUT THIS CHAPTER

This chapter describes in alphabetical order all the routines provided by the M20 Graphics Package.

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ClearViewArea

Clears the specified view area.

Input/Output Parameters

Input: R4 ← view area number (in the range 1 to 16, integer)

Output: R5 → error code (integer)

Characteristics

This function clears the specified view area, created via DivideViewArea. The view area is not closed, this call merely removes all its current contents. The background colour is unchanged and fills the whole view area.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

CloseGraphics

Closes the graphics session.

Input/Output Parameters

none

Characteristics

If this routine is called it must be the last graphics package call. Calls to graphics routines must be bracketed by the OpenGraphics/CloseGraphics pair, otherwise results are far from guaranteed.

View area definitions and graphics package tables are cleared. The initial default conditions are reset (for these conditions see OpenGraphics).

CloseViewTrans

Closes the specified view area.

Input/Output Parameters

Input: R8 ← view area number (in the range 0 to 16, integer)

Output: none

Characteristics

This routine closes the specified view area created via DivideViewArea. The view area is joined to the one(s) next to it and takes on the same background colour(s) as the adjacent view area(s). The resulting view areas must be rectangular. The enlarged view area(s)' coordinate definitions are adjusted to map the view area's new dimensions.

If the current view area is closed then view area number 1 becomes the current view area. If register R8 is loaded with the value zero then all the view areas are closed and view area number 1 becomes the current one, filling the entire screen.

View area number 1 cannot be closed. If the input parameter specifies the value 1, the value of a view area which has not been opened, or a value not within the range Ø to 16, no error message is generated and the attempt to close the view area has no effect.

Errors

No error messages are returned from this routine.

DivideViewArea

Creates a new view area.

Input/Output Parameters

Input: R8 ← division/orientation (in the range 0 to 3, integer)
R9 ← division point (integer)

Output: R7 → view area number (in the range 2 to 16, integer)
R5 → error code (integer)

Valid Input Values

R8: defines which part of the view area will become the new view area

0: horizontal split; the upper view area is the new one
1: horizontal split; the lower view area is the new one
2: vertical split; the left view area is the new one
3: vertical split; the right view area is the new one.

R9: defines the division point

- if R8 is loaded with the value 0 or 1 (horizontal split) then R9 is loaded with the number of scanlines (min = 1, max = current view area height - 1) counting from the top scanline of the current view area

- if R8 is loaded with the value 2 or 3 (vertical split), then R9 is loaded with the required view area width expressed as a number of characters, in the range 1 to 63 or 1 to 79, counting from the left side of the current view area.

  Characters may be six or eight pixels wide, but the width in pixels of the left view area must be a multiple of 8 and is calculated from the following formula:

  left_view_area=truncate[(num_of_chars*char_width+3)/8]*8

  where "num_of_chars" is equal to the number of characters specified by R9 and "char_width" is the current character width in pixels (6 or 8).

  When the character width is eigth pixels, this calculation will always give exactly sufficient pixels to contain the number of characters specified in R9, as the formula reduces to left_view_area = num_of_chars * 8

However, when the character width has been set (via Set-Textline) to 6 pixels, there is nearly always a right margin (of the left view area) of less than six pixels, and this formula does not round up the view area width to allow space for the final character. Hence, in this case, the number of characters allowed will be one less than the value specified in R9, i.e. one less than required unless the user has added one to his input to cover this eventuality.

- if R9 is loaded with the value -1, then the current view area is divided as equally as possible.

Output Values

R7: this register contains the number of the new view area. The value is within the range 2 to 16.

Characteristics

This routine creates a new view area by splitting the current one as specified by the values loaded in R8 and R9. R7 contains the number of the new view area.

The new view area inherits the following attributes from its parent view area: text spacing, colour, and world coordinate space definition.

The initial state is the full screen defined as view area number 1. This can be split into other view areas; adjacent view areas may be closed and joined with it, as long as the resultant view area is rectangular. View area number 1 always exists, it can not be closed. There may be a maximum of 16 view areas at a time. A new view area is assigned the lowest available number in the range 2 to 16 (e.g., if 6 view areas are created and view area number 3 is closed, 3 will be assigned to the view area next created).

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

ErrorInquiry

Returns the error status for the most recently called graphics routine.

Input/Output Parameters

Input: none

Output: R5 → error code (in the range 0 to 255, integer)

Output Values

The output value of this function may be:

0: no error for the most recently called graphics routine

1 to 255: an error has occured in the most recently called graphics routine. The code numbers used are the standard PCOS error codes, with the same meanings.

Characteristics

This routine returns the error status for the most recently called graphics routine other than the Inquiry (Inq ...) routines.

The Inquiry class of routines does not alter or test the error status variable: each one has its own error parameter, through which it transmits error messages.

Routines, other than the Inquiry routines, clear the error status variable before execution, and upon completion this variable reflects the error status of the routine. If the value is zero, then no error has occurred.

Errors

This routine does not generate errors.

Colours an area.

Input/Output Parameters

Input: R1 ⟵ function number (1)
RR2 ⟵ data structure pointer

Output: R5 ⟶ error code (integer)

Characteristics

This routine paints an area in accordance with the parameters in the data structure pointed to by the input value.

The data structure (e.g., array, record, etc.) must contain the following information:

- an x coordinate (two 16-bit words, IEEE single-precision real number, high-order word first)
- a y coordinate (two 16-bit words, IEEE single-precision real number, high-order word first)
- two colour numbers, one for painting the area identified by the point (x, y) and one for the border (each colour number is a 16-bit word, integer, high-order first).

The area surrounding the point (x, y) is painted with the colour specified in the data structure, within a contiguous border. No colouring will occur if the point happens to fall on the border. The border must be of only one colour.

The colour numbers have different effects on the monochrome, four-colour and eight-colour systems. However, integers in the range 0 to 7 will work for both colour parameters without generating errors on all three types of systems. On the monochrome system, 0=black and a value in the range 1 to 7=white. On four-colour systems, the two colour numbers are indices into a table of four pre-selected colours (see SetColourRep). On eight-colour systems, the values in the range 0 to 7 have the following meanings : 0=black, 1=green, 2=blue, 3=cyan, 4=red, 5=yellow, 6=magenta, 7=white.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

Generalised Drawing Primitive, creates a circle or an ellipse.

Input/Output Parameters

Input: RR6 ← X array pointer
RR2 ← Y array pointer
R4 ← 1 (circle) or
2 (ellipse)

Output: R5 → error code (integer)

Characteristics

The application program must declare and allocate the two coordinate arrays. Each array contains single-precision numbers; the high order word must precede the low order word. The size of each array must be at least large enough to store as many double-word numbers as there are points (2 points for the circle and 3 for the ellipse).

Default values will be assumed for colour, world coordinate space definition, and logic operator.

This function does not affect the current graphics position.

Circle: This routine draws a circle if R4 is loaded with the value 1.

The world coordinates of the centre point must be stored in the first element of the two arrays X[1] and Y[1]. The second element of the two arrays X[2] and Y [2] is the world coordinate of a point on the circumference. The GDP circle function determines the radius by calculating the distance from the centre of the circle to this absolute location X [2] and Y [2].

The output generated by this function is always a circle, regardless of the coordinate space definition.

If the coordinates generate a circle larger than the view area then the portions that lie outside the view area are clipped.

Ellipse: This routine draws an ellipse (parallel to the x or y axis) if R4 is loaded with the value 2.

The world coordinates of the centre point must be stored in the first element of the two arrays X [1] and Y [1]. The second and third elements contain the world coordinates of one end of the minor axis (either one will do), and of one end of the major axis. (It does not matter which axis point comes first.)

If the coordinates generate an ellipse larger than the view area then the portions that lie outside the view area are clipped.

The exact shape of the ellipse may vary depending on the coordinate space definition.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

Moves the graphics cursor to the specified absolute position.

Input/Output Parameters

Input: RR0 ← x (single-precision real)
RR2 ← y (single-precision real)

Output: R5 → error code (integer)

Characteristics

This routine moves the graphics cursor to the absolute position specified in world coordinates. The graphics cursor is displayed only if the SelectCursor routine has been previously invoked with R8 loaded with the value 1.

If the coordinates specify a point which is outside the current view area then the current position of the graphics cursor remains unchanged and an error code is generated.

The current graphics position is not associated with the position of the graphics cursor. The position of the graphics cursor coincides with that of the current graphics position only when both are assigned the same coordinates. This separation allows the application program to use the graphics cursor as an echo symbol to indicate a position on the screen that reflects the values entered by an input device.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

GraphCursorRel

Moves the graphics cursor to a specified relative position.

Input/Output Parameters

Input: RR0 ← dx (single-precision real)
RR2 ← dy (single-precision real)

Output: R5 → error code (integer)

Characteristics

This routine moves the graphics cursor to a new position which is obtained by adding the input values dx, dy (which specify the distance between the old position and the new one in world coordinates) to the old graphics cursor position. The resulting position must fall within the user's word coordinate space definition.

The graphics cursor is displayed only if the SelectCursor routine has been previously invoked with R8 loaded with the value 1.

If the resulting position is outside the current view area then the current position of the graphics cursor is unchanged and an error code is generated.

The current graphics position is not associated with the position of the graphics cursor. The position of the graphic cursor coincides with that of the current graphics position only when both are assigned the same coordinates. This separation allows the application program to use the graphics cursor as an echo symbol to indicate a position on the screen that reflects the values entered by an input device.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

Redefines the current graphics position (absolute).

Input/Output Parameters

Input: RR0 ← x (single-precision real)
RR2 ← y (single-precision real)

Output: R5 → error code (integer)

Characteristics

This routine redefines the current graphics position for subsequent graphics output. The input values specify an absolute location in world coordinates. Any subsequent graphics output that uses the current graphics position as a starting point will use this redefined position.

The current graphics position not associated with the position of the graphics cursor. The position of the graphic cursor coincides with that of the current graphics position only when both are assigned the same coordinate. This separation allows the application program to use the graphics cursor as an echo symbol to indicate a position on the screen that reflects the values entered by an input device.

The specified point becomes the current graphics position even if it is not within the current view area.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

GraphPosRel

Redefines the current graphics position (relative).

Input/Output Parameters

Input: RR0 ← dx (single-precision real)
RR2 ← dy (single-precision real)

Output: R5 → error code (integer)

Characteristics

This routine redefines the current graphics position for subsequent graphics output. The new graphics position is obtained by adding the input values dx,dy (which specify a distance in world coordinates) to the previous graphic position. The next graphics output that uses the current graphics position as a starting point will use this redefined position.

The current graphics position is not associated with the position of the graphics cursor. The position of the graphic cursor coincides with that of the current graphics position only when both are assigned the same coordinate point. This separation allows the application program to use the graphics cursor as an echo symbol to indicate a position on the screen that reflects the values entered by an input device.

The specified point becomes the current graphics position even if it is not within the current view area.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

InqAttributes

Returns the colour, logic operator and line attributes for the current view area.

Input/Output Parameters

Input: none

Output:
R5 → error code (integer)
R7 → logic operator (in the range 0 to 5, integer)
R8 → line class (in the range 0 to 2, integer)
R9 → current graphics colour (in the range 0 to 7, integer)
R10 → text foreground colour (in the range 0 to 7, integer)
R11 → background colour (in the range 0 to 7, integer)

Characteristics

This routine returns the following information for the current view area:

- current graphics colour (see SelectGrColour)
- text foreground colour (see SelectTxColour)
- background colour (see SelectTxColour and ClearViewArea)
- line class (see SetLineClass)
- logic operator for colour (see SetColourLogic).

If the view area is undefined (see DivideViewArea) an error code is returned.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

InqCurTransNmbr

Returns the number of the current view area.

Input/Output Parameters

Input: none

Output: R5 → error code (integer)
R7 → view area number (integer, in the range 1 to 16)

Characteristics

This routine returns the identification number of the current view area. This number may be used for:

- selecting a different view area
- redefining the view area's world coordinate space
- clearing the view area's contents
- closing the view area
- retrieving information about the view area (e.g., colour, coordinates).

Errors

The only value returned in R5 is 0, no error.

InqGraphCursor

Returns the position and blink rate of the graphics cursor for the current view area.

Input/Output Parameters

Input: none

Output: RR0 → X (single-precision real)
RR2 → Y (single-precision real)
R5 → error code (integer)
R9 → blink rate (in the range 0 to 20, integer)

Characteristics

This routine returns the location (X,Y) in world coordinates of the graphics cursor and its blinkrate expressed in state changes per second (from OFF to ON or from ON to OFF), rounded to the nearest 50 milliseconds. See SetGrCsrBlnkrate.

The graphics cursor is placed with its upper left hand corner of its 8x12 pixel shape at this (X,Y) position.

The graphics cursor position and the graphics position are generally not the same; the graphics cursor merely marks a position within the view area.

The graphics cursor position and the text cursor position are entirely independent of each other. Only one of these two cursors (or neither, if so specified) appears at any one time.

Errors

The only value returned in R5 is 0, no error.

InqGraphPos

Returns the location at which new graphics output will begin.

Input/Output Parameters

Input: none

Output: RR2 → Y (single-precision real)
R5 → error code (integer)
RR6 → X (single-precision real)

Characteristics

This routine returns the location (X,Y), in world coordinates, within the current view area at which new graphics output will begin (e.g., a LineRel call would generate a line with the first end at this point).

Errors

The only value returned in R5 is 0, no error.

InqPixel

Returns the colour number of the pixel which is nearest to the specified point.

Input/Output Parameters

```
Input:  RR0 ◄── X world coordinate
                (single-precision real)
        RR6 ◄── Y world coordinate
                (single-precision real)

Output: R3  ──► colour number (in the range 0 to 7, integer)
        R5  ──► error code (integer)
```

Output Values

R3 : this register contains the colour number.

On monochrome systems:

colour number	colour
0	black
1	white

On four-colour systems, R3 returns a value in the range 0 to 3 (see SetColourRep). The default values are:

colour number	colour
0	black
1	green
2	blue
3	red

On eight-colour systems:

colour number	colour
0	black
1	green
2	blue
3	cyan
4	red
5	yellow
6	magenta
7	white

Characterisitcs

This routine returns the colour number of the pixel which is nearest to the specified world coordinate (X,Y) , in the current view area.

In the monochrome and eight-colour systems, the colour numbers are pre-defined; in four-colour systems, the value is an index into a table (see SetColourRep) of pre-selected colours (four colours selected from the eight available).

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

InqPixelArray

Retrieves a rectangular image from the current view area and stores it.

Input: RR0 ← X width (single-precision real)
RR2 ← Y height (single-precision real)
RR6 ← array pointer

Output: R4 → invalid code (0 or 1, integer)
R5 → error code (integer)

Valid Input Values

RR0: width of the rectangle to be retrieved, expressed in world coordinates, single-precision real

RR2: height of the rectangle to be retrieved, expressed in world coordinates, single-precision real.

Output Values

R4: this register reports discovery of invalid pixel colour values if it is set to 1; if all pixel values are valid this register is set to 0.

Characteristics

This routine retrieves a rectangular image from the current view area, and stores it in the array pointed to by RR6 to be displayed later. The inverse function is accomplished by PixelArray.

The upper left-hand corner of the rectangle to be retrieved from the screen is placed at the current graphics position.

The two registers RR0 and RR2 specify the rectangle's dimensions in world coordinates. These dimensions are transformed into device coordinates (pixels). The size of the storage array depends on the total number of pixels in the rectangle. The user may calculate this total number of pixels by:

1. retrieving the device coordinates for each corner of the rectangle (via InqPixelCoords) only if the default world coordinates have been changed

3. applying the "array size" formula (see below).

The application program is responsible for knowing the required array size and allocating space for it.

The array contains the bit images of the scanlines within the rectangle, packed 16 bits for array entry. Each scanline image will begin with the first bit of the scanline in bit 15 of the first array entry (left-justified). The size of the array (in words) may be calculated according to the following formula:

array size=truncate[(pixel_width+15)/16]*pixel_height*colour_planes+3

where "colour_planes" is the number of colour planes in the system configuration. Each colour plane provides one bit (i.e. two states) per pixel. With two colour planes, each pixel is represented by two bits and thus four states are possible. By extension, three colour planes provide eight states. Therefore, monochrome has 1 colour plane, four-colour has 2 colour planes and eight-colour has 3 colour planes.

The extra 3 words in the array (at the beginning) contain the rectangle's width, height and special codes related to the conditions in which the array was created (number of colour planes, etc.). The array is one dimensional. The maximum size of the array is that needed for a full screen rectangle, assuming that there is sufficient memory in the system configuration for an array that large.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

InqPixelCoords

Returns the device coordinates (expressed in pixels) of a given point expressed in world coordinates.

Input/Output Parameters

```
Input:  RR0 <--- X world coordinate
                 (single-precision real)
        RR2 <--- Y world coordinate
                 (single-precision real)

Output: R5  ---> error code (integer)
        R6  ---> X device coordinate (in the range 0 to 511, integer)
        R7  ---> Y device coordinate (in the range 0 to 255, integer)
```

Characterisitcs

This routine returns the device coordinates, expressed in pixels, for the input world coordinates. The device coordinates are calculated with respect to the borders of the current view area.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

InqTextCursor

Returns the next text entry point and the text cursor blink rate for the current view area.

Input/Output Parameters

Input: none

Output: R5 ⟶ error code (integer)
R7 ⟶ blink rate (in the range 0 to 20, integer)
R8 ⟶ text column (in the range 1 to 64 or 1 to 80, integer)
R9 ⟶ text row (in the range 1 to 16 or 1 to 25, integer)

Characterisitcs

This routine returns the next text entry point, which coincides with the location of the text cursor, and the text cursor blink rate for the current view area. See SetTxCsrBlnkrate.

The text cursor position is given in number of columns (e.g., number of characters) from the view area's left edge and of rows (e.g., number of text lines) from the view area's top edge.

The cursor blink rate is expressed in state changes per second (from OFF to ON or from ON to OFF), rounded to the nearest 50-milliseconds.

If the information is not available it is because the view area is too small to contain text. An error code is returned and the other output parameters remain undefined.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

InqViewArea

Returns the current view area's size definition and text parameters.

Input/Output Parameters

Input: none

Output:
- R5 → error code (integer)
- R8 → view area width (in the range 1 to 64 bytes, integer)
- R9 → view area height (in the range 1 to 256 scanlines, integer)
- R10 → text character width (6 or 8 pixels, integer)
- R11 → text line height (in the range 10 to 16 scanlines, integer)

Characteristics

This routine returns the current view area's width (in bytes) and height (in scanlines) and the current character's width (in pixels) and height (in scanlines).

Errors

The only value returned in R5 is 0, no error.

InqWorldCoordSp

Returns the world coordinate space parameters for the current view area.

Input/Output Parameters

Input: none

Output:

R5	→	error code (integer)
RR6	→	X0 (single-precision real)
RR8	→	Y0 (single-precision real)
RR10	→	X1 (single-precision real)
RR12	→	Y1 (single-precision real)

Characteristics

This routine returns the world coordinates of the lower left-hand corner (X0,Y0) and of the upper right-hand corner (X1,Y1) respectively, of the current view area.

These coordinates do not determine the proportions of the view area; they determine how points in world coordinates will map to the current view area.

Errors

The only value returned in R5 is 0, no error.

LineAbs

Draws a line from the current graphics position to the specified absolute position.

Input/Output Parameters

Input: RR0 ← x (single-precision real)
RR2 ← y (single-precision real)

Output: R5 → error code (integer)

Characteristics

This routine draws a line from the current graphic position to the absolute (x,y) position which is specified in world coordinates.

Default values will be assumed for coordinate space, colour, logic operator, and line class.

If the (x,y) coordinates specify a point which is outside the view area but within the range of a single-precision floating-point number, then a line is drawn in the direction of the specified point but is clipped on the view area boundary.

The specified point becomes the current graphics position, even if it is outside the view area.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

LineRel

Draws a line from the current graphics position to a specified relative position.

Input/Output Parameters

Input: RR0 ⟵ dx (single-precision real)
RR2 ⟵ dy (single-precision real)

Output: R5 ⟶ error code (integer)

Characteristics

This routine draws a line, the length and direction of which are specified in world coordinates by the dx and dy input parameters, starting from the current graphics position.

Default values will be assumed for coordinate space, colour, logic operator, and line class.

If the point, resulting from the input distances, is outside the view area but within the range of a single-precision floating-point number, then a line is drawn in the specified direction but is clipped on the view area boundary.

The resulting point becomes the current graphic position, even if it is outside the view area.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

MarkerAbs

Displays a point at the specified absolute position.

Input/Output Parameters

Input: RR0 ← x (single-precision real)
RR2 ← y (single-precision real)

Output: R5 → error code (integer)

Characteristics

This routine displays a point at the absolute (x,y) position which is specified in world coordinates.

Default values will be assumed for coordinate space, colour, and logic operator.

If the (x,y) coordinates specify a point which is outside the view area but within the range of a single-precision floating-point number, then no point is displayed. The resulting point becomes the current graphic position, even if it is outside the view area.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

MarkerRel

Displays a point at a specified distance from the current graphics position.

Input/Output Parameters

Input: RR0 ⟵ dx (single-precision real)
RR2 ⟵ dy (single-precision real)

Output: R5 ⟶ error code (integer)

Characteristics

This routine displays a point at a specified (dx,dy) distance from the current graphics position. The distance is specified in world coordinates.

Default values will be assumed for coordinate space, colour, and logic operator.

If the point, resulting from the input distances, is outside the view area but within the range of a single-precision floating-point number, then no point is displayed. The resulting point becomes the current graphic position.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

OpenGraphics

Sets up the M20 for creating graphics.

Input/Output Parameters

none

Characteristics

This procedure must be the first graphics call. The default conditions are set:

- a single view area, labelled 1
- world coordinates coincide with device coordinates (0.0-511.0 pixels x 0.0-255.0 scanlines)
- black as the background colour
- white as the foreground and text colours for the black and white system and green for the colour system
- no cursor displayed
- a blank screen.

It may also be used to reinitialise the graphics environment, thus clearing the effects of all the preceding graphics calls. The application program handles subsequent graphics functions and procedures and their output as if starting afresh.

PixelArray

Transfers an image onto the screen.

Input/Output Parameters

Input: RR0 ← X width (single-precision real)
RR2 ← Y height (single-precision real)
RR10 ← array pointer

Output: R5 → error code (integer)

Characteristics

This routine retrieves a rectangular image stored into a one-dimensional array pointed to by RR10 and displays it on the screen. The rectangular image stored in memory is part of (or all) a picture previously displayed on a view area.

The size of the rectangular image to be displayed is loaded in RR0 and RR2. These two values are in world coordinates.

The image is displayed with the rectangle's upper left-hand corner at the current graphics position.

The two values X width and Y height loaded in RR0 and RR2 need not correspond to the full size of the image implied by the array. If the rectangular image stored in the array is relatively large compared to this routine's arguments X width, Y height, then only part of the stored image is displayed. The right and bottom edge of the image are clipped.

If the rectangular image stored in the array is smaller than that implied by the arguments X width and Y height of this routine, then the full picture will appear. This will not extend to the right and bottom borders implied by the two arguments.

If the current graphics position is too close to the right and/or bottom edge of the screen for the entire image to be displayed, then only part of the image is displayed and the rest of it is clipped at the screen edge.

The default value for logic operator is assumed.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

Polyline

Draws a connected sequence of lines.

Input/Output Parameters

```
Input:  RR6 <-- X array pointer
        RR2 <-- Y array pointer
        R4  <-- number of points (integer, equal to or greater than 2)

Output: R5  --> error code (integer)
```

Characteristics

This routine draws lines connecting the points specified by the two arrays. The two arrays are the same size and contain single-precision real numbers. A coordinate is made up of element X[J] of the first array and element Y[J] of the second array. Register R4 contains an integer specifying the number of points to be connected. The points are absolute locations in world coordinates.

Default values will be assumed for coordinate space, colour, logic operator, and line class.

The application program must declare and allocate the two coordinate arrays. Each array contains single-precision real numbers; the high order word must precede the low-order word. The size of each array must be at least large enough to store as many double-word numbers as there are points.

The figure will not be a closed polygon unless the first and last points specified by the arrays coincide.

If the coordinates specify points that are not within the view area, then the figure will be clipped on the view area boundary. If the last point is outside the view area, it nevertheless becomes the current graphics position.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

Polymarker

Displays the specified points.

Input/Output Parameters

Input: RR6 ← X array pointer
RR2 ← Y array pointer
R4 ← number of points (integer, equal to or greater than 1)

Output: R5 → error code (integer)

Characteristics

This routine displays the number of points specified by R4; each one is identified by the coordinates specified by the two arrays. A coordinate is made up of element X[J] of the first array and element Y[J] of the second array. The two arrays are the same size and contain single-precision real numbers. The points are absolute locations in world coordinates.

Default values will be assumed for coordinate space, colour, and logic operator.

The application program must declare and allocate the two coordinate arrays. Each array contains single-precision real numbers; the high order word must precede the low order word. The size of each array must be at least large enough to store as many double-word numbers as there are points.

The coordinates which specify points that are outside the view area will not be displayed and no error message is generated. However, the current graphics position will track these non-visible points and if the last point is outside the view area it nevertheless becomes the current graphics position.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SelectCursor

Chooses which cursor is to be displayed.

Input/Output Parameters

Input: R8 ← 0 (neither cursor) or
1 (graphics cursor) or
2 (text cursor)

Output: R5 → error code (integer)

Characteristics

This routine chooses which cursor (if any) is to be displayed.

If selected, the text cursor is displayed and text will be displayed starting from that position.

If selected, the graphics cursor is displayed with its upper left hand corner at the current cursor coordinates. However, subsequent graphics output will not start from this point unless the current graphics position has been updated to this same position.

The text and graphics cursor do not usually occupy the same position. The two cursors cannot be displayed simultaneously.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SelectGrColour

Selects the colour for subsequent graphics output.

Input/Output Parameters

Input: R8 ← colour code (in the range 0 to 7, integer)

Output: R5 → error code (integer)

Valid Input Values

On monochrome systems, R8 (colour code) selects either black or white to be the graphics colour attribute:

colour code	graphics colour attribute
0	black
1 to 7	white

On four-colour systems, R8 (colour code) selects the colour attribute indirectly by acting as an index into a table of four colours preselected from the eight possible colours (see SetColourRep):

colour code	graphics colour attribute
0 to 3	the colour attribute associated with each one of the four values 0, 1, 2 and 3, depends on the values set by default or via SetColourRep.
4 to 7	The values in this range map to a value in the range 0 to 3 via a logical operation (see the following note).

Note: Bits 0 and 2 of the binary representation are OR'd, e.g., the values 4 (100 binary) and 5 (101) give 1 OR 0 = 1 and 1 OR 1 = 1 respectively. This sets the least significant bit (bit 0) and bit 1 remains unchanged. Thus, the values 4 and 5 will become 1 after the logical operation (4 decimal = 100 binary which becomes 01 binary = 1 decimal and 5 decimal = 101 binary which becomes 01 binary = 1 decimal) and the colour is green (if the default value has not been changed). The values 6 and 7 will become 3 after the logical operation (6 decimal = 110 binary which becomes 11 binary = 3 decimal and 7 decimal = 111 binary which becomes 11 binary = 3 decimal) and the colour is red.

On eight-colour systems, R8 (colour code) selects the colour attribute directly, according to the following table:

colour code	graphics colour attribute
0	black
1	green
2	blue
3	cyan
4	red
5	yellow
6	magenta
7	white

Characteristics

This routine selects the specified colour for subsequent graphics output. There are different effects on monochrome, four-colour and eight-colour systems.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SelectTxColour

Selects the colours for subsequent text output.

Input/Output Parameters

Input: R8 ← foreground colour code (in the range 0 to 7, integer)
R9 ← background colour code (in the range 0 to 7, integer)

Output: R5 → error code (integer)

Valid Input Values

On monochrome systems, if the foreground colour is set to black (0), the background colour may be set to any value in the range 1 to 7 (white). The default value for the background colour is black.

On four colour systems, each parameter selects the colour attribute indirectly by acting as an index into a table of four colours preselected from the eight possible colours (see SetColourRep):

background colour code and foreground colour code	text colour attribute
0 to 3	the colour attribute, associated with each one of the four values 0, 1, 2 and 3, depends on the values set via SetColourRep.
4 to 7	the colours selected are not easily predictable.

On eight colour systems, each parameters selects the colour attribute directly, according to the following table:

Background colour code and foreground colour code	text colour attribute
0	black
1	green
2	blue
3	cyan
4	red
5	yellow
6	magenta
7	white

Characteristics

This routine specifies the colours to be used as the foreground and background of the text output. Text is displayed in the foreground colour. The background colour also affects the ClearViewArea routine and the "PRESET" logic operator (see SetColourLogic).

The values set by this function hold until it is called again.

There are different effects on monochrome, four-colour and eight-colour systems.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SelectViewTrans

Activates the selected view area.

Input/Output Parameters

Input: R8 ⟵ view area number (in the range 1 to 16, integer)

Output: R5 ⟶ error code (integer)

Characteristics

This routine activates the specified view area which has previously been defined via DivideViewArea. All text and graphics output will be displayed on this view area and is entered in accordance with its attributes (colour, world coordinate space, text spacing, current text and graphics positions, etc.).

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetColourLogic

Defines a logic operator that influences the output colour.

Input/Output Parameters

Input: R10 ← logic operator code (in the range 0 to 5, integer)

Output: R5 → error code (integer)

Valid Input Values

0 PSET:	graphics output is displayed in the default colour or in the colour specified via the last SelectGrColour call.
1 XOR:	the graphics colour and the colour of the target pixel are logically XOR'd. Graphics output is drawn in the resulting colour, e.g., if the current graphics colour is blue (010 binary) and the pixels on which the geometrical output will be drawn are yellow (101 binary), then the resulting colour is white (010 XOR 101 = 111).
2 AND:	the graphics colour and the colour of the target pixel are logically AND'd. Graphics output is drawn in the resulting colour, e.g., if the current graphics colour is blue (010 binary) and the pixels on which the geometrical output will be drawn are yellow (101 binary), then the resulting colour is black (010 AND 101 = 000).
3 NOT:	this is a unary operator that complements the colour of the target pixel (the current graphics colour is irrelevant), e.g., if the target pixel is yellow (101 binary) then the resulting colour is blue (010 binary).
4 OR:	the graphics colour and the colour of the target pixel are logically OR'd. Graphics output is drawn in the resulting colour, e.g., if the current graphics colour is blue (010 binary) and the pixels on which the geometrical output will be drawn are yellow (101 binary) then the resulting colour is white (010 OR 101 = 111).
5 PRESET:	the graphics colour is set to the background colour which is black on the monochrome and eight colour systems if the default values remain unchanged; it is also black on the four-colour system if the default values remain unchanged.

Characteristics

This routine specifies a logic operator that will influence the output colour (for all subsequent output except text) on a pixel-by-pixel basis.

When new output is displayed the logic operation is applied one pixel at a time. The logic operations deal with the numbers in the range 0 to 7, as three-bit binary quantities.

The specific results vary depending on the system configuration. Monochrome systems transform the numbers in the range 2 to 7 to the value 1, thus the only operands are 0 and 1, which are the colours black and white respectively.

Eight colour systems make no transformation and deal with the numbers directly as colours, with corresponding results.

Four colour systems treat the numbers not directly as colours but as indices into the four-colour table. Predicting the final result is possible but requires some calculation.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetColourRep

Sets one of the four colour indices to one of the eight M20 colours.

Input/Output Parameters

Input: R1 ← colour index (in the range 0 to 3, integer)
R2 ← colour code (in the range 0 to 7, integer)

Output: R5 → error code (integer)

Valid Input Values

The following table shows the corresponding colour attributes for the colour code (R2):

colour code	graphics colour attribute
0	black
1	green
2	blue
3	cyan
4	red
5	yellow
6	magenta
7	white

Characteristics

This routine is used on four-colour systems and has no effect on monochrome and on eight-colour systems. It sets one of the four colour indices to one of the eight M20 colours.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetGrCsrBlnkrate

Sets the blink rate for the graphics cursor.

Input/Output Parameters

Input: R8 ← blink rate (in the range 0 to 20, integer)

Output: R5 → error code (integer)

Valid Input Values

R8 is loaded with a value in the range 0 to 20

0:	the cursor is left ON continuously
1 to 20:	the cursor blinks n/2 times per second.

Characteristics

This routine sets the blink rate for the graphics cursor, from the steady state to the specified state changes per second (from OFF to ON or from ON to OFF). The specified value is truncated to the nearest 50 milliseconds.

This routine does not affect which cursor is to be displayed. The SelectCursor routine does this.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetGrCsrShape

Defines the graphics cursor shape.

Input/Output Parameters

Input: RR8 ←— array pointer

Output: R5 —→ error code (integer)

Characteristics

This routine defines the graphics cursor shape according to the contents of the array pointed to by the array pointer. This array consists of 6 one-word (2 bytes) elements, each containing a 16-bit unsigned integer. Each byte is a bit-map of a scanline of the cursor. The first element's high-order byte is the top scanline of the new cursor; the sixth's element low-order byte is the last scanline of the new cursor.

This routine does not effect which cursor is to be displayed. The SelectCursor routine does this.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetLineClass

Determines the graphic output for the LineAbs and LineRel routines.

Input/Output Parameters

Input: R3 ← 0 (line) or
1 (hollow rectangle) or
2 (solid rectangle)

Output: R5 → error code (integer)

Characteristics

This routine determines whether the graphic output for the LineAbs and LineRel routines will be a line, a hollow rectangle or a solid rectangle. In the latter two cases, the world coordinates specified in the LineAbs and LineRel routines constitute the end points of the diagonal of the rectangle.

The graphics output will be displayed in the current graphics colour.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetTextline

Sets the character width and text line height.

Input/Output Parameters

Input: R10 ← line height (in the range 10 to 16, integer)
R12 ← character width (6 or 8, integer)

Output: R5 → error code (integer)

Characteristics

This routine sets the width (in pixels) and the text line height (in scanlines) of the character space. It is the space around each character which grows or shrinks, the individual character size remaining unchanged.

The values set by this routine hold for the current view area and all subdivisions of it, or until the routine is called again.

This setting influences the width of subsequent view area definitions. In fact, DivideViewArea's second parameter "division point" establishes the division point of the view area. For vertical divisions, "division point" expresses the number of characters from the old view area's left edge. If the character width is of 6 pixels rather than 8, then the left view area will be smaller than it would have been with 8 pixel characters.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetTxCsrBlnkrate

Sets the blink rate for the text cursor.

Input/Output Parameters

Input: R8 ← blink rate (in the range 0 to 20, integer)

Output: R5 → error code (integer)

Valid Input Values

R8 is loaded with a value in the range 0 to 20

0:	the cursor is left ON continuoulsy
1 to 20:	the cursor blinks n/2 times per second.

Characteristics

This function sets the blink rate for the text cursor, from the steady state to the specified state changes per second (from OFF to ON or from ON to OFF), e.g., if R8 is loaded with the value 8, then there are 8 states per second, 4 ON states and 4 OFF states. The specified value is truncated to the nearest 50 milliseconds.

This function does not select which cursor is to be displayed, the SelectCursor function does this.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetTxCsrShape

Defines the text cursor shape.

Input/Output Parameters

Input: RR8 ← array pointer

Output: R5 → error code (integer)

Characteristics

This routine defines the text cursor shape according to the contents of the array pointed to by the input value. This array consists of 6 one-word (2 bytes) elements, each containing a 16-bit unsigned integer. Each byte is a bit-map of a scanline of the cursor. The first element's high-order byte is the top scanline of the new cursor; the sixth element's low-order byte is the last scanline of the new cursor.

If the most significant bit of each byte is set then the leftmost column of pixels will touch the character preceding it.

This routine does not effect which cursor is to be displayed. The SelectCursor routine does this.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

SetWorldCoordSp

Defines the world coordinate space.

Input/Output Parameters

Input: RR0 ← X0 (single-precision real)
RR2 ← Y0 (single-precision real)
R4 ← view area number (integer, in the range 1 to 16)
RR6 ← X1 (single-precision real)
RR8 ← Y1 (single-precision real)

Output: R5 → error code (integer)

Characteristics

This routine defines the user coordinate space, known as the world coordinate space. The routine may be called again to refined the user's world coordinate space when required.

The input coordinates determine the scaling interpretation within the specified view area and not the view area's size which is determined via the DivideViewArea routine.

All subsequent graphic coordinates within the view area will be scaled by a transformation routine using the input coordinates (X0, Y0) and (X1, Y1), which define the endpoints of a diagonal of the entire view area. (X0, Y0) are the coordinates of the lower left-hand corner and (X1, Y1) are those of the upper right-hand corner of the view area.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

TextCursor

Moves the text cursor.

Input/Output Parameters

Input: R8 ← text column (integer, in the range 1 to 64 or 1 to 80)

R9 ← text row (integer, in the range 1 to 16 or 1 to 25)

Output: R5 → error code (integer)

Characteristics

This function moves the text cursor and thereby determines the next screen position at which text will be displayed in the current view area. The text cursor is displayed only if the SelectCursor function has been previously invoked, loading R8 with the value 2.

R8 is loaded with a number in the range 1 to 64 or 1 to 80, depending on whether the character's width is 8 or 6 pixels respectively. R9 is loaded with a number in the range 1 to 16 or 1 to 25, depending on the character's height (see SetTextline).

A full-screen view area may be 64 columns wide and 16 rows high or 80 columns wide and 25 rows high. The dimension which is current determines the position of anything specified in terms of character counts. If the current view area is smaller than full-screen then the amount of text that it may contain depends on the dimensions of the view area.

If the coordinates specify a point which is outside the current view area then the current position of the text cursor is unchanged.

Errors

If there are any errors, the status code is returned in R5. The code numbers correspond to the standard PCOS error codes, with the same meanings. See APPENDIX E for the error descriptions. If there are no errors, a zero is returned.

APPENDICES

A. RESERVED WORDS

The following symbols are recognized for their specific meanings by the assembler. They cannot be used by the programmer as variable names. If the programmer uses one of these symbols by mistake, the assembler flags its occurrence with error 86, Multiple Definition.

Reserved Word	Use
ADC	mnemonic
ADCB	mnemonic
ADD	mnemonic
ADDB	mnemonic
ADDL	mnemonic
AND	mnemonic
ANDB	mnemonic
ASSIGN	directive
AT	directive
BIT	mnemonic
BITB	mnemonic
C	condition code
CALL	mnemonic
CALR	mnemonic
CLR	mnemonic
CLRB	mnemonic
COM	mnemonic
COMB	mnemonic
COMFLG	mnemonic
COMMON	directive
CP	mnemonic
CPB	mnemonic
CPD	mnemonic
CPDB	mnemonic
CPDR	mnemonic
CPDRB	mnemonic
CPI	mnemonic
CPIB	mnemonic
CPIR	mnemonic
CPIRB	mnemonic
CPL	mnemonic
CPSD	mnemonic
CPSDB	mnemonic
CPSDR	mnemonic
CPSDRB	mnemonic
CPSI	mnemonic
CPSIB	mnemonic
CPSIR	mnemonic
CPSIRB	mnemonic
DAB	mnemonic
DBJNZ	mnemonic
DD	directive

Reserved Word	Use
DDB	directive
DDL	directive
DEC	mnemonic
DECB	mnemonic
DI	mnemonic
DIV	mnemonic
DIVL	mnemonic
DJNZ	mnemonic
DS	directive
DSB	directive
DSL	directive
EI	mnemonic
ENDIF	directive
EQ	condition code
EX	mnemonic
EXB	mnemonic
EXTERNAL	directive
EXTS	mnemonic
EXTSB	mnemonic
EXTSL	mnemonic
FALSE	condition code
FCW	control word
FLAGS	control word
GE	condition code
GLOBAL	directive
GT	condition code
HALT	mnemonic
IF	directive
IN	mnemonic
INB	mnemonic
INC	mnemonic
INCB	mnemonic
INCLUDE	directive
IND	mnemonic
INDB	mnemonic
INDR	mnemonic
INDRB	mnemonic
INI	mnemonic
INIB	mnemonic
INIR	mnemonic
INIRB	mnemonic
IRET	mnemonic
JP	mnemonic
JR	mnemonic
LD	mnemonic
LDA	mnemonic
LDAR	mnemonic
LDB	mnemonic
LDCTL	mnemonic
LDCTLB	mnemonic
LDD	mnemonic
LDDB	mnemonic
LDDR	mnemonic

Reserved Word	Use
LDDRB	mnemonic
LDI	mnemonic
LDIB	mnemonic
LDIR	mnemonic
LDIRB	mnemonic
LDK	mnemonic
LDL	mnemonic
LDM	mnemonic
LDPS	mnemonic
LDR	mnemonic
LDRB	mnemonic
LDRL	mnemonic
LE	condition code
LISTOFF	directive
LISTON	directive
LT	condition code
MBIT	mnemonic
MI	condition code
MODULE	directive
MREQ	mnemonic
MRES	mnemonic
MSET	mnemonic
MULT	mnemonic
MULTL	mnemonic
NC	condition code
NE	condition code
NEG	mnemonic
NEGB	mnemonic
NONSEGMENTED	module type
NOP	mnemonic
NOV	condition code
NSP	control word
NSPOFF	control word
NSPSEG	control word
NVI	interrupt
NZ	condition code
OR	mnemonic
ORB	mnemonic
OTDR	mnemonic
OTDRB	mnemonic
OTIR	mnemonic
OTIRB	mnemonic
OUT	mnemonic
OUTB	mnemonic
OUTD	mnemonic
OUTDB	mnemonic
OUTI	mnemonic
OUTIB	mnemonic
OV	condition code
P	flag
PAGE	directive
PE	condition code
PL	condition code

Reserved Word	Use
PO	condition code
POP	mnemonic
POPL	mnemonic
PSAP	control word
PSAPOFF	control word
PSAPSEG	control word
PUSH	mnemonic
PUSHL	mnemonic
R0	word register
R1	word register
R10	word register
R11	word register
R12	word register
R13	word register
R14	word register
R15	word register
R2	word register
R3	word register
R4	word register
R5	word register
R6	word register
R7	word register
R8	word register
R9	word register
REFRESH	control word
RES	mnemonic
RESB	mnemonic
RESFLG	mnemonic
RET	mnemonic
RH0	byte register
RH1	byte register
RH2	byte register
RH3	byte register
RH4	byte register
RH5	byte register
RH6	byte register
RH7	byte register
RL	mnemonic
RL0	byte register
RL1	byte register
RL2	byte register
RL3	byte register
RL4	byte register
RL5	byte register
RL6	byte register
RL7	byte register
RLB	mnemonic
RLC	mnemonic
RLCB	mnemonic
RLDB	mnemonic
RQ0	quad register
RQ12	quad register
RQ4	quad register

Reserved Word	Use
RQ8	quad register
RR	mnemonic
RR0	long register
RR10	long register
RR12	long register
RR14	long register
RR2	long register
RR4	long register
RR6	long register
RR8	long register
RRB	mnemonic
RRC	mnemonic
RRCB	mnemonic
RRDB	mnemonic
S	flag
SBC	mnemonic
SBCB	mnemonic
SC	mnemonic
SDA	mnemonic
SDAB	mnemonic
SDAL	mnemonic
SDL	mnemonic
SDLB	mnemonic
SDLL	mnemonic
SECTION	directive
SEGMENTED	module type
SET	mnemonic
SETB	mnemonic
SETFLG	mnemonic
SIN	mnemonic
SINB	mnemonic
SIND	mnemonic
SINDB	mnemonic
SINDR	mnemonic
SINDRB	mnemonic
SINI	mnemonic
SINIB	mnemonic
SINIR	mnemonic
SINIRB	mnemonic
SLA	mnemonic
SLAB	mnemonic
SLAL	mnemonic
SLL	mnemonic
SLLB	mnemonic
SLLL	mnemonic
SOTDR	mnemonic
SOTDRB	mnemonic
SOTIR	mnemonic
SOTIRB	mnemonic
SOUT	mnemonic
SOUTB	mnemonic
SOUTD	mnemonic
SOUTI	mnemonic
SOUTIB	mnemonic

Reserved Word	Use
SRA	mnemonic
SRAB	mnemonic
SRAL	mnemonic
SRL	mnemonic
SRLB	mnemonic
SRLL	mnemonic
SUB	mnemonic
SUBB	mnemonic
SUBL	mnemonic
TCC	mnemonic
TCCB	mnemonic
TEMPLATE	directive
TEST	mnemonic
TESTB	mnemonic
TESTL	mnemonic
TITLE	directive
TRDB	mnemonic
TRDRB	mnemonic
TRIB	mnemonic
TRIRB	mnemonic
TRTDB	mnemonic
TRTDRB	mnemonic
TRTIB	mnemonic
TRTIRB	mnemonic
TRUE	condition code
TSET	mnemonic
TSETB	mnemonic
UGE	condition code
UGT	condition code
ULE	condition code
ULT	condition code
V	flag
VI	interrupt
XOR	mnemonic
XORB	mnemonic
Z	condition code

B. ASM ERRORS AND WARNINGS

The following is a complete list of codes of errors and warnings that can be returned by the ASM command during assembly time. The code meaning refers to the source file line number in the context of the program.

Bad Statement:

Code	Meaning
1	Bad Line
2	Bad Label/Mnemonic Field or Context
3	Bad IF/ENDIF
4	Bad Directive or Context
5	Bad Labelled Directive or Context
6	Bad Module/Section or Context
7	Bad Argument or Context
8	Bad Byte-Data Context
9	Bad Word-Data Context
10	Bad Long-Data Context
11	Source line truncated
12	IF not terminated by ENDIF
13	ENDIF with no matching IF

Bad Character, Identifier or Constant:

Code	Meaning
14	Identifier Too Long
15	Single-Quoted Text Too Long or bad use of %
16	Quote Not Closed or bad use of %
17	Illegal Number
18	Illegal Character
19	Illegal base specification in number
20	Illegal Keyword
21	End of Line in number
22	Keyword in label field
23	Mnemonic not in mnemonic field

Bad Expression:

Code	Meaning
24	Bad Parenthesis Use
25	Segment/Section/External mismatch in relational expression
26	Illegal relational operands
27	Illegal Type Combination in Expression
28	Illegal operator in address term
29	Segment/Section/External mismatch in additive term
30	Illegal additive operand
31	Address type mismatch in additive term
32	Illegal multiplicative operand
33	Illegal unary operand
34	Absolute segment number out of range
35	Illegal type in segment/offset of absolute address

Bad Operand:

Code	Meaning
38	Bad Use of Short Address
39	Bad Argument or Context
40	Invalid Address Register
41	DD, DDB or DDL operand, Wrong Size
42	Index Register is Invalid
43	DD Repeat Nesting Error
44	Wrong Register Type
45	Indirect Register is Zero
46	Immediate Operand Wrong Size
47	Base Register zero not allowed
48	Index Register zero not allowed
49	Even address required
50	Invalid Relative Address
51	Relative out of Range
52	Invalid Short Extraction
53	Absolute Address too Large for Short Extraction
54	Invalid Segment or Offset Extraction
55	Invalid Small Immediate
56	Extra Operands Ignored
57	Illegal Operand
58	Truncation Warning

59	Section or Module Name out of place
60	Invalid Address
61	DD overflows 64K
62	No prior Section for SECTION *
63	Page size specified is too small
64	Undefined or non-numeric page size
65	Unexpected end of line
66	Bad Operator/Value

Undefined Symbol:

Code	Meaning
70	Undefined Symbol (Second pass only)

Bad Location or Definition:

Code	Meaning
72	Symbol not defined until second pass
73	Symbol redefined in second pass
74	Location Counter overflowed 64K
75	Warning: Address incremented to even value

First Pass Errors:

Code	Meaning
86	Multiple Definition (First pass error)
88	IF Value Not Defined (First pass error)
89	Invalid ATparm, DSparm or DD Repeat Count
90	Undefined ATparm, DSparm Template Base or DD

Fatal Errors:

Code	Meaning
93	Symbol Table Full - Terminate
94	Unknown Character in file
95	Internal Object Table full
96	Internal Object Table full
97	Too many INCLUDEs
98	Binary data file absent or improper

C. FUNCTIONAL LIST OF SYSTEM CALLS

ABOUT THIS APPENDIX

This appendix lists the M20 System Calls in functional groups.

CONTENTS

BYTESTREAM CALLS	C-1
BLOCK TRANSFER CALLS	C-3
STORAGE ALLOCATION CALLS	C-4
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BYTESTREAM CALLS

Name	System Call	Parameter	Register
LookByte	9	DID returned byte buffer status(00 or FF) error status	R8 RL7 RH7 R5
GetByte	10	DID returned byte error status	R8 R7 R5
PutByte	11	DID input byte value error status	R8 RL7 R5
ReadBytes	12	DID input count input ptr to memory returned count error status	R8 R9 RR10 R7 R5
WriteBytes	13	DID input count input ptr to memory returned count error status	R8 R9 RR10 R7 R5
ReadLine	14	DID input count input ptr to memory count returned error status	R8 R9 RR10 R6 R5
Eof	16	DID returned status error status	R8 R9 R5
ResetByte	18	DID error status	R8 R5

Name	System Call	Parameter	Register
Close	19	DID error status	R8 R5
SetControlByte	20	DID input word number input word error status	R8 R9 R10 R5
GetStatusByte	21	DID input word number returned word read error status	R8 R9 R10 R5
OpenFile (files)	22	DID input extent length input mode input file id. length input ptr to addr error status	R8 R6 R7 R9 RR10 R5
OpenFile (RS-232-C)	22	DID error status	R8 R5
DSeek	23	DID input position error status	R8 RR10 R5
DGetLen (files)	24	DID returned length error status	R8 RR10 R5
DGetLen (RS-232-C)	24	DID returned zero status returned number of bytes error status	R8 R10 R11 R5
DGetPosition	25	DID returned position error status	R8 RR10 R5
DRemove	26	input length input ptr to name error status	R9 RR10 R5

Name	System Call	Parameter	Register
DRename	27	input old address input old length input new address input new length error status	RR6 R8 RR10 R9 R5
DDirectory	28	input file id. length input address error status	R9 RR10 R5

BLOCK TRANSFER CALLS

Name	System Call	Parameter	Register
BSet	29	input n (byte value) input ptr to memory input length error status	RL7 RR8 R10 R5
BWSet	30	input n (word value) input ptr to memory input length error status	R7 RR8 R10 R5
BClear	31	input ptr to memory input length error status	RR8 R10 R5
BMove	32	input length input ptr to old memory input ptr to new memory error status	R7 RR8 RR10 R5

STORAGE ALLOCATION CALLS

Name	System Call	Parameter	Register
NewSameSegment	33	address of block pointer input length error status returned block pointer	RR8 R10 R5 RR8
Dispose	34	address of block pointer input length error status Hex FFFFFFFF	RR8 R10 R5 RR8
MaxSize	99	returned size error status	R8 R5
NewAbsolute	104	address of block pointer input length input block pointer error status	RR8 R10 RR8 R5
New	120	address of block pointer input length error status returned block pointer	RR8 R10 R5 RR8
BrandNewAbsolute	121	address of block pointer input length input block pointer error status	RR8 R10 RR8 R5
NewLargestBlock	122	address of block pointer returned block pointer returned length error status	RR8 RR8 R10 R5
StickyNew	123	address of block pointer input length error status returned block pointer	RR8 R10 R5 RR8

GRAPHICS SYSTEM CALLS

Name	System Call	Parameter	Register
Cls	35	(no parameters)	
ChgCur0	36	input column input row error status	R8 R9 R5
ChgCur1	37	input x input y	R8 R9
ChgCur2	38	input blink rate	R8
ChgCur3	39	input blink rate	R8
ChgCur4	40	input ptr to array	RR8
ChgCur5	41	input ptr to array	RR8
ReadCur0	42	input ptr to array output blink rate output column output row error status	RR10 R7 R8 R9 R5
ReadCur1	43	input ptr to array output blink rate output x-position output y-position error status	RR10 R7 R8 R9 R5
SelectCur	44	input select	R8
GrfInit	45	output colour flag output ptr to m-box	R8 RR10
PaletteSet	46	input colour A input colour B input colour C input colour D error status	R8 R9 R10 R11 R5

Name	System Call	Parameter	Register
DefineWindow	47	input quadrant input position input vert-spacing input horz-spacing output window number error status	R8 R9 R10 R12 R11 R5
SelectWindow	48	input window number error status	R8 R5
ReadWindow	49	output window number output x-size output y-size output foreground colour output background colour error status	R7 R8 R9 R10 R11 R5
ChgWindow	50	input foreground colour input background colour error status	R8 R9 R5
CloseWindow	51	input window number	R8
ScaleXY	52	input x-position input y-position return_value	R8 R9 R10
MapXYC	53	input x-position input y-position	R8 R9
MapCXY	54	returned x-position returned y-position	R8 R9
FetchC	55	returned C-value	RR8
StoreC	56	input C-value	RR8
UpC	57	(no parameters)	
DownC	58	(no parameters)	
LeftC	59	(no parameters)	

Name	System Call	Parameter	Register
RightC	60	(no parameters)	
SetAtr	61	input colour error status	R8 R5
SetC	62	input operation	R8
ReadC	63	returned colour	R8
NSetCX	64	input hor. line count input operation	R8 R9
NSetCY	65	input vertical line count input operation	R8 R9
NRead	66	input width (count) input height (count) input ptr to array always cleared returned addr. of array	R8 R9 RR10 R5 RR10
NWrite	67	input logical function input width (count) input height (count) input ptr to array always cleared	R7 R8 R9 RR10 R5
PntInit	68	input paint colour input border colour error status	R8 R9 R5
TDownC	69	returned check value	R8
TUpC	70	returned check value	R8
ScanL	71	returned count-l returned margin flag returned painted flag	R9 R10 R11
ScanR	72	input maxcount returned C-type returned maxcount returned count-r returned margin flag returned painted flag	R8 RR6 R8 R9 R10 R11

Name	System Call	Parameter	Register
CloseAllWindows	113	(no parameters)	
ClearText	115	input column input row input column count input row count error status	R10 R11 R12 R13 R5
ScrollText	116	input color plane mask input logical function input source column input source row input destination column input destination row input column count input row count error status	R6 R7 R8 R9 R10 R11 R12 R13 R5

TIME AND DATE CALLS

Name	System Call	Parameter	Register
SetTime	73	input addr of data input length of string error status	RR8 R10 R5
SetDate	74	input addr of data input length of string error status	RR8 R10 R5
GetTime	75	input addr of data input length of string error status	RR8 R10 R5

Name	System Call	Parameter	Register
GetDate	76	input addr of data input length of string error status	RR8 R10 R5

USER CODE CALLS

Name	System Call	Parameter	Register
CallUser	77	input pointer (system stack has a pointer to 2-character symbol, list of parameter pointers, number of parameters) error status	RR14 R5

IEEE-488 CALLS

Name	System Call	Parameter	Register
IBSrQ0	78	error status	R5
IBSrQ1	79	error status	R5
IBPoll	80	input talker addr returned ptr to status error status	R8 RR10 R5

Name	System Call	Parameter	Register
IBISet	81	input operand	R8
		error status	R5
IBRSet	82	error status	R5
IBPrnt	83	input buffer addr	RR6
		input listener addr	R8
		input buffer length	R9
		input delimiter	R10
		error status	R5
IBWByt	84	input numval addr	RR6
		input comlist addr	R8
		input numval length	R9
		input comlist addr	RR10
		error status	R5
IBInpt	85	input buffer length	R7
		input talker addr	R8
		input listener addr	R9
		input buffer addr	RR10
		returned buffer length	R7
		error status	R5
IBLinpt	86	input buffer length	R7
		input talker addr	R8
		input listener addr	R9
		input buffer addr	RR10
		returned buffer length	R7
		error status	R5
IBRByt	87	input buffer addr	RR6
		input comlist length	R8
		input buffer length	R9
		input comlist addr	RR10
		error status	R5

MISCELLANEOUS SYSTEM CALLS

Name	System Call	Parameter	Register
Error	88	input parameter num input error code	RH5 RL5
DString	89	input addr of string error status	RR12 R5
CrLf	90	error status	R5
DHexByte	91	input byte error status	R12 R5
DHex	92	input word error status	R12 R5
DHexLong	93	input long word error status	RR12 R5
DNumW	94	input integer input field width error status	R12 R13 R5
DLong	95	input long integer error status	RR12 R5
DisectName	96	input string length input string addr input names record addr error status returned volume number returned names record	R9 RR10 RR12 R5 R7 RR12
CheckVolume	97	error status	R5

Name	System Call	Parameter	Register
Search	98	input drive	R6
		input search mode	R7
		input length	R9
		input file pointer	RR10
		input file name pointer	RR12
		returned length	R9
		returned file pointer	RR10
		modified	RR12
		error status	R5
SetVol	102	input volume number	R7
		error status	R5
StringLen	105	input pointer	RR12
		returned length	R7
		error status	R5
DiskFree	106	input volume number	R7
		returned num of sectors	RR10
		error status	R5
BootSystem	107	error status	R5
SetSysSeg	108	error status	R5
SearchDevTab	109	input ptr device name	RR10
		input dev name length	R9
		returned entry number	RL5
		returned device type	RH5
		returned ptr table entry	RR8
		error status	R5
CtlCharDisp	111	on/off (nonzero/zero)	R8
KbSetLock	114	input integer flag	R6
		returned previous state	R7
		error status	R5
GetVol	119	input ptr vol. id. buffer	RR12
		input buffer size	R6
		returned size	R7
		error status	R5

D. FUNCTIONAL LIST OF GRAPHICS ROUTINES

ABOUT THIS APPENDIX

This appendix gives a functional list of graphics routines, subdivided into their logical groups. The list comprises the name, the parameters and the registers used by each graphics routine.

CONTENTS

TRANSFORMATION AND CONTROL	D-1
GRAPHICS OUTPUT	D-2
GRAPHICS ATTRIBUTES	D-3
INQUIRY	D-4

TRANSFORMATION AND CONTROL

Name	Parameter	Register
ClearViewArea	view area number	R4
	error code	R5
CloseGraphics	(no parameters)	
CloseViewTrans	view area number	R8
DivideViewArea	division/orientation	R8
	division point	R9
	view area number	R7
	error code	R5
Escape	function number (1)	R1
	data structure pointer	RR2
	error code	R5
OpenGraphics	(no parameters)	
SelectViewTrans	view area number	R8
	error code	R5
SetWorldCoordSp	X0	RR0
	Y0	RR2
	view area number	R4
	X1	RR6
	Y1	RR8
	error code	R5

GRAPHICS OUTPUT

Name	Parameter	Register
GDP	X array pointer	RR6
	Y array pointer	RR2
	1 (circle) or	R4
	2 (ellipse)	
	error code	R5
GraphCursorAbs	x	RR0
	y	RR2
	error code	R5
GraphCursorRel	dx	RR0
	dy	RR2
	error code	R5
GraphPosAbs	x	RR0
	y	RR2
	error code	R5
GraphPosRel	dx	RR0
	dy	RR2
	error code	R5
LineAbs	x	RR0
	y	RR2
	error code	R5
LineRel	dx	RR0
	dy	RR2
	error code	R5
MarkerAbs	x	RR0
	y	RR2
	error code	R5
MarkerRel	dx	RR0
	dy	RR2
	error code	R5
PixelArray	X width	RR0
	Y height	RR2
	array pointer	RR10
	error code	R5

Name	Parameter	Register
Polyline	X array pointer Y array pointer number of points error code	RR6 RR2 R4 R5
Polymarker	X array pointer Y array pointer number of points error code	RR6 RR2 R4 R5
TextCursor	text column text row error code	R8 R9 R5

GRAPHICS ATTRIBUTES

Name	Parameter	Register
SelectCursor	0 (neither cursor) or 1 (graphics cursor) or 2 (text cursor) error code	R8 R5
SelectGrColour	colour code error code	R8 R5
SelectTxColour	foreground colour code background colour code error code	R8 R9 R5
SetColourLogic	logic operator code error code	R10 R5

Name	Parameter	Register
SetColourRep	colour index	R1
	colour code	R2
	error code	R5
SetGrCsrBlnkrate	blink rate	R8
	error code	R5
SetGrCsrShape	array pointer	RR8
	error code	R5
SetLineClass	0 (line) or	R3
	1 (hollow rectangle) or	
	2 (solid rectangle)	
	error code	R5
SetTextline	line height	R10
	character width	R12
	error code	R5
SetTxCsrBlnkrate	blink rate	R8
	error code	R5
SetTxCsrShape	array pointer	RR8
	error code	R5

INQUIRY

Name	Parameter	Register
ErrorInquiry	error code	R5
InqAttributes	error code	R5
	logic operator	R7
	line class	R8
	current graphics colour	R9
	text foreground colour	R10
	background colour	R11

Name	Parameter	Register
InqCurTransNmbr	error code	R5
	view area number	R7
InqGraphCursor	X	RR0
	Y	RR2
	error code	R5
	blinkrate	R9
InqGraphPos	Y	RR2
	error code	R5
	X	RR6
InqPixel	X	RR0
	Y	RR2
	colour number	R3
	error code	R5
InqPixelArray	X width	RR0
	Y height	RR2
	array pointer	RR6
	invalid code	R4
	error code	R5
InqPixelCoords	X world coordinate	RR0
	Y world coordinate	RR2
	error code	R5
	X device coordinate	R6
	Y device coordinate	R7
InqTextCursor	error code	R5
	blink rate	R7
	text column	R8
	text row	R9
InqViewArea	error code	R5
	view area width	R8
	view area height	R9
	text character width	R10
	text line height	R11
InqWorldCoordSp	error code	R5
	X0	RR6
	Y0	RR8
	X1	RR10
	Y1	RR12

E. SYSTEM ERRORS

ERROR CODE (Decimal)		ERROR Description	Error code in hexadecimal (returned in R5)
0		no error	00
2		syntax error	02
3		invalid termination of input bytestream	03
5		illegal function call	05
6		overflow	06
7		out of memory	07
9	EITHER	invalid listener or talker address - when returned by an IEEE-488 system call	09
	OR	out of range - otherwise	
10	EITHER	no IEEE board - when returned by an IEEE-488 system call	0A
	OR	duplicate definition - otherwise	
11		time out error	0B
13		type mismatch	0D
15		string too long	0F
18		undefined function	12
22		missing operand	16
23		buffer overflow	17
35		window not open	23

ERROR CODE (Decimal)	ERROR Description	Error code in hexadecimal (returned in R5)
36	unable to create window	24
38	parameter out of range	26
53	file not found	35
54	bad file mode	36
55	file already open	37
57	disk i/o error	39
58	file already exists	3A
59	disk type mismatch	3B
60	disk not initialized	3C
61	disk filled	3D
62	end of file	3E
63	invalid record number	3F
64	invalid file name	40
67	too many files	43
68	internal error	44
69	volume name not found	45
70	rename error	46
71	invalid volume number	47

ERROR CODE (Decimal)	ERROR Description	Error code in hexadecimal (returned in R5)
72	volume not enabled	48
73	invalid password	49
74	illegal disk change	4A
75	write protected file	4B
76	error in parameter	4C
77	invalid number of parameters	4D
78	file not open	4E
79	printer error	4F
80	copy protected file	50
81	paper empty	51
82	printer fault	52
92	command not found	5C
99	bad load file	63
101	error in time or date	65
108	call user error	6C
110	time out	6E
111	invalid device	6F

F. M20 I/O PORT ADDRESSES

ABOUT THIS APPENDIX

This appendix provides a list of M20 I/O Port Addresses which can be specified when using the two PDEBUG commands, PORT I/O READ and PORT I/O WRITE.

CONTENTS

MAIN MOTHERBOARD PORTS	F-1
IEEE EXPANSION BOARD PORTS	F-2
HARD DISK UNIT EXPANSION BOARD PORTS	F-3
RS-232-C TWIN EXPANSION BOARD PORTS	F-3

M 20 I/O ADDRESSES

8251 (TTY PRT)	4ØCØ	DATA
	4ØC2	CONTROL
8253 (PRT/TIMING)	412Ø	PRINTER
	4122	KEYBOARD
8251 SERIAL PORTS		
	48Ø2	CONTROL P Ø
	48ØØ	DATA " "
	4822	CONTROL P 1
	482Ø	DATA P 1
BAUD RATE (8253)	4866	CONTROL
	486Ø	REGISTER Ø
	4862	REGISTER 1
	4864	REGISTER 2
INTERRUPT COMMAND	484Ø	REGISTER
	4842	DATA REGISTER
MODEM STATUS PORT	488Ø	

Port Addresses are here listed in 4 groups:

1. Main Motherboard Ports

2. IEEE Expansion Board Ports

3. Hard Disk Unit Expansion Board Ports

4. RS-232-C Twin Expansion Board Ports

MAIN MOTHERBOARD PORTS

DEVICE	ADDRESS	COMMENT
FDC	%001 %003 %005 %007	Status/Command Track Sector Data
TTL Latch	%021	
CRTC (Video)	%061 %063	Address Data
8255A (Centronics Parallel Interface)	%081 %083 %085 %087	Port A Port B Port C Control
8251 (Keyboard)	%0A1 %0A3	Data Status/Control
8251 (TTY/PRTR)	%0C1 %0C3	Data Status/Control

8253	%121	Ctr 0 (TTY/printer timing)
	%123	Crt 1 (Keyboard timing)
	%125	Crt 2 (Real time clock-NVI)
	%127	Control register
8259 (Master)	%140-1	
	%142-3	
REG FILE (4 colours)	%181	Loc 1
	%183	Loc 2
	%185	Loc 3
	%187	Loc 4

IEEE EXPANSION BOARD PORTS

DEVICE	ADDRESS	COMMENT
8292 (GPIB CTLER)	%101	A0 = 0
	%103	A0 = 1
8291 (GPIB Talker/ Listener)	%161	Data in / Data out
	%163	Interrupt status / Mask 1
	%165	Interrupt status / Mask 2
	%167	Serial poll status / Mode
	%169	Address status / Mode
	%16B	Cmd pass through / Aux mode
	%16D	Address 0 / Address 0/1
	%16F	Address 1 / EOS
8259 (IEEE)	%1A0	
	%1A2	

HARD DISK UNIT EXPANSION BOARD PORTS

DEVICE	ADDRESS	COMMENT
cyl_hi	%1cb	cylinder address high register
cyl_lo	%1c9	cylinder address low register
head	%1cd	head select register (also contains drive select and bytes per sector)
sector	%1c7	sector for operation
command	%1cf	command status register address
error	%1c3	contains error information
wr_prcomp	%1c3	value * 4 = cylinder to start write precompensation
data	%1c1	data port to the interface board
sec_cnt	%1c5	sector count for the format command

RS-232-C TWIN EXPANSION BOARD PORTS

DEVICE	ADDRESS	COMMENT
	for the modem interface	
modem_prt	%881	modem status port
	for the interrupt sub-system	
exp_int	%841	8259 interrupt command register
	%843	8259 data register
	for the serial ports	
tp_0	%803	8251a 0 control port
	%801	8251a 0 data port

tp_1	%823	8251a 1 control port
	%821	8251a 1 data port
exp_baud	%867	8253 control port
	%861	8253 out 0 register
	%863	8253 out 1 register
	%865	8253 out 3 register

G. MAILBOX

A mailbox area (8 bytes), used by the IEEE driver, is declared globally by PCOS. The first 6 bytes comprise the array "IEEE"; the next byte is the flag "srq_488" (see also section on IEEE calls and system calls 78 through 87). The next byte indicates which carriage return key, /S1/, /S2/ or the standard /CR/, was pressed last (it should be noted that a zero is returned for any key except /S1/ or /S2/).

On calling GrfInit (SC 45), the interpreter will be passed the address of this area in RR10.

Format of Mailbox Area

bytes	description
0-5	"IEEE" Array; values set by IEEE driver for use by BASIC interpreter.
6	" srq_488 " flag; value set by IEEE interrupt service routine " ibsrq92 ", tested by the BASIC interpreter. This indicates that a service request has been received.
7	S1 and S2 key depression flag. Set in keyboard driver; (0 = neither key depressed, 1 =/S1/ depressed, 2 =/S2/ depressed)

H. M20-RS-232-C DEVICE PARAMETER TABLE

This appeandix details the structure of the Device Parameter Table used by System Calls 20 and 21. These system calls are used for reading and writing device parameters for devices connected to the RS-232-C interfaces.

A knowledge of the hardware in question is useful for a deeper comprehension of this appendix (see M20 hardware literature).

WORD NUMBER	DESCRIPTION	
0-1	Ring buffer address	(long word)
2	Ring buffer input address	(word)
3	Ring buffer output address	(word)
4	Ring buffer count	(word)
5	Ring buffer size	(word)
6	75% of ring buffer size	(word)
7	50% of ring buffer size	(word)
8	8251A USART control port address	(word)
9	8251A USART state and error flags	(word)
10	8251A USART time out for data output	(word)
11 (high)	8251A USART mode	(byte)
11 (low)	8253 timer command	(byte)
12	8253 timer control port address	(word)
13	8253 timer baudrate data port address	(word)
14	8253 timer baud rate count	(word)
15	8259A PIC port A address	(word)
16	8259A PIC SEOI command word	(word)
17	8259A PIC - master interrupt mask bit	(word)
18	8259A U - slave interrupt mask bit	(word)

Word numbers 0 to 7 contain the state of the ring buffer. Words 8 to 11 (high) contain information relative to the 8251A (Programmable Communication Interface).

Word 8 contains the control port address. This can assume the following values:

%00C3 : USART motherboard control port.

%0803 : USART expansion board 1 control port.

%0823 : USART expansion board 2 control port.

Word 9 represents the status and the error flags for the 8251 and is organised in the following way:

STATUS	BIT POSITION	LEGAL VALUES	MEANING
Duplex mode	15	1	full echoing of all input
		0	No echoing of input
(reserved)	14	0	(not used)
Framing Error	13	1	a valid stop bit has not been detected at the end of each character. (Reported from 8251A)
		0	No Framing Error
Overrun Error	12	1	a character has not been read before the next one becomes available. (Reported from 8251A)
		0	No Overrun Error
Parity Error	11	1	a change in parity value has been detected. (Reported from 8251A)
		0	No Parity Error
Timeout Error	10	1	a timeout has occured while waiting for the Transmit Ready line on the 8251A
		0	No Timeout Error
Memory Error	9	1	driver failed to open to open buffer - no Open Port call or insufficient memory.
		0	No Memory Error
Buffer Error	8	1	interrupt routine tried to overwrite the buffer.
		0	No Buffer Error

STATUS	BIT POSITION	LEGAL VALUES	MEANING
(reserved)	7	0	(not used)
Free-running protocol	6	1 0	free-running protocol, Handshake protocol using XON/XOFF
XOFF/XON Flag (M20 previously acted as transmitter)	5	1	XOFF character, sent in previous transmission. Buffer is 75% full. XOFF is sent from M20 i.e. other sender should stop.
		0	XON character, sent in previous transmission. Input buffer is ready to receive characters (default state.) XON is sent from M20 i.e. other sender should start again.
Hardware State	4	1 0	hardware present and 8259A passed interrupt mask test. No hardware or failed test
XOFF/XON	3	1	XOFF character, detected in current reception. XOFF character is received from outside. No characters will be transmitted.
		0	XON character, detected in current reception. XON received from outside. Characters will be transmitted (default state).
(reserved)	2	0	(not used)
(reserved)	1	0	(not used)
(reserved)	0	0	(not used)

Word 10 contains the time-out value for the transmission of data.

The high byte in word 11 is the 8251A Mode byte and is described below:

7	6	5	4	3	2	1	Ø
S2	S1	EP	PEN	L2	L1	B2	B1

Number of Stop Bits:	S2	S1		
	0	1	1 stop bit	
	1	0	1.5 stop bits	
	1	1	2 stop bits	(default)
	0	0	ILLEGAL	
Even Parity/ Parity Enable:	EP	PEN		
	0	0	Disable Parity/Odd Parity	(default)
	0	1	Enable Parity/Odd Parity	
	1	1	Enable Parity/Even Parity	
	1	0	Disable Parity/Even Parity	
Character Length:	L2	L1		
	0	0	5 Data bits	
	0	1	6 Data bits	
	1	0	7 Data bits	(default)
	1	1	8 Data bits	
Baud Rate Factor:	B2	B1		
	1	0	Asynchronous Mode 16 x	(default)
	0	0	Synchronous Mode	
	0	1	Asynchronous Mode 1 x	
	1	1	Asynchronous Mode 64 x	

The low byte in word 11, and words 12 to 14 concern the 8253 timer (Programmable interval timer). The low byte in word 11 is the 8253 command byte described below:

7	6	5	4	3	2	1	Ø
SC1	SCØ	RL1	RLØ	M2	M1		BCD

Counter Select:		SC1	SC0	
		0	0	Select Counter 0
		0	1	Select Counter 1
		1	0	Select Counter 2
		1	1	ILLEGAL
Read/Load Instruction:		RL1	RL0	
		0	0	Counter Latching Operation
		0	1	Read/Load most sig. byte only (msb)
		1	0	Read/Load least sig. byte only (lsb)
		1	1	Read/Load lsb first, then msb
Mode:	M2	M1	M0	
	0	0	0	Mode 0: Interrupt on Terminal Count
	0	0	1	Mode 1: Programmable One-Shot
	x	1	0	Mode 2: Rate Generator
	x	1	1	Mode 3: Square Wave Rate Generator
	1	0	0	Mode 4: Software Triggered Strobe
	1	0	1	Mode 5: Hardware Triggered Strobe
4 BCD's/ Binary Word		BCD		
		0		Binary Counter (16 bits)
		1		BCD Counter (4 decades * 4 bits/ decade)

Word 12 contains the 8253 control port address; this can be either

%0127 motherboard timer control port

%0867 expansion board timer control port

Word 13 contains a channel address of an 8253 timer. The address can be one of the following:

%0121 channel 0 motherboard timer

%0123 channel 1 motherboard timer

%0125 channel 2 motherboard timer

%0861 channel 0 expansion board timer

%0863 channel 1 expansion board timer

%0865 channel 2 expansion board timer

Word 14 sets the transmission baud rate as follows:

1538	baud count for baud rate of 50
699	baud count for baud rate of 110
256	baud count for baud rate of 300
128	baud count for baud rate of 600
64	baud count for baud rate of 1200
32	baud count for baud rate of 2400
16	baud count for baud rate of 4800
8	baud count for baud rate of 9600
4	baud count for baud rate of 19200

Word 15 contains the 8259 control port address (Prgrammable Interrupt Controller (PIC)). These can be:

%0140	mother board PIC control port address
%0840	expansion board PIC control port A address

Note that even addresses for programmable interrupt controller B data port addresses are assumed to be 2 more than A control port addresses.

Word 16 contains the SEOI (Specific End Of Interrupt) command to be issued before exiting the interrupt routine. The SEOI is calculated using the formula:

SEOI = %C0 + (2* IR No.)

where IR No.is an interrupt routine number from 0 - 7.

The RS-232-C SEOI's are the following:

%00C6	master 8259A pic SEOI for IR3 (tty mother)
%00CE	master 8259A pic SEOI for IR7 (expansion)
%00C0	slave 8259A pic SEOI for IR0 (port 1)
%00C4	slave 8259A pic SEOI for IR2 (port 2)

The following table gives all the M20 interrupt assignments.

Master 8259A PIC Mother Board Interrupt Assignments:

IR0:	Floppy Disk Controller		
IR1:	External Daisy Chain Request		(potentially a slave 8259A)
IR2:	External Daisy Chain Request		(potentially a slave 8259A)
IR3:	RxD: DTE TTY/Remote	8251A	
IR4:	RxD: keyboard	8251A	
IR5:	TxD: DTE/TTY/Remote	8251A	(not used)
IR6:	Parallel 8255A PC0 or PC3		
IR7:	External Daisy Chain Request		(used w/ RS-232-C Expansion Board)

Slave 8259A PIC Expansion Board Interrupt Assignments:

IR0:	RxD: DTE/TTY port 1/Remote	8251A	
IR1:	TxD: DTE/TTY port 1/Remote	8251A	(not used)
IR2:	RxD DTE/TTY port 2/Remote	8251A	
IR3:	TxD: DTE/TTY port 2/Remote	8251A	(not used)
IR4:	grounded (not used)		
IR5:	grounded (not used)		
IR6:	grounded (not used)		

Words 17 and 18 contain the masks relative to the interrupt levels. The mask values are the following:

8259A PIC Interrrupt Assignments (by bit with data bus shift):

%0100	IR7 interrupt mask
%0080	IR6 interrupt mask
%0040	IR5 interrupt mask
%0020	IR4 interrupt mask
%0010	IR3 interrupt mask
%0008	IR2 interrupt mask
%0004	IR1 interrupt mask
%0002	IR0 interrupt mask

I. DEVICE ID (DID) ASSIGNMENTS

The following table describes the allocation of DID's to various functions. Some of these DID's represent devices which are always open, others are assigned by system calls.

1	BASIC files
2	.
.	.
.	.
15	.
17	Console
18	Printer
19	Communications RS-232-C
20	System Disk Files (not accessible to BASIC)
.	.
.	.
.	.
24	.
25	Com1 (RS-232-C)
26	Com2 (RS-232-C)

J. ASCII CODE

This table shows decimal, hexadecimal, and binary representation of the ASCII code. (Boxed characters are different on national keyboards.)

a	b	c	d	a	b	c	d	a	b	c	a	b	c
0	00	0000 0000	NUL	64	40	0100 0000	@	128	80	1000 0000	192	C0	1100 0000
1	01	0000 0001	SOH	65	41	0100 0001	A	129	81	1000 0001	193	C1	1100 0001
2	02	0000 0010	STX	66	42	0100 0010	B	130	82	1000 0010	194	C2	1100 0010
3	03	0000 0011	ETX	67	43	0100 0011	C	131	83	1000 0011	195	C3	1100 0011
4	04	0000 0100	EQT	68	44	0100 0100	D	132	84	1000 0100	196	C4	1100 0100
5	05	0000 0101	ENQ	69	45	0100 0101	E	133	85	1000 0101	197	C5	1100 0101
6	06	0000 0110	ACK	70	46	0100 0110	F	134	86	1000 0110	198	C6	1100 0110
7	07	0000 0111	BEL	71	47	0100 0111	G	135	87	1000 0111	199	C7	1100 0111
8	08	0000 1000	BS	72	48	0100 1000	H	136	88	1000 1000	200	C8	1100 1000
9	09	0000 1001	HT	73	49	0100 1001	I	137	89	1000 1001	201	C9	1100 1001
10	0A	0000 1010	LF	74	4A	0100 1010	J	138	8A	1000 1010	202	CA	1100 1010
11	0B	0000 1011	VT	75	4B	0100 1011	K	139	8B	1000 1011	203	CB	1100 1011
12	0C	0000 1100	FF	76	4C	0100 1100	L	140	8C	1000 1100	204	CC	1100 1100
13	0D	0000 1101	CR	77	4D	0100 1101	M	141	8D	1000 1101	205	CD	1100 1101
14	0E	0000 1110	SO	78	4E	0100 1110	N	142	8E	1000 1110	206	CE	1100 1110
15	0F	0000 1111	SI	79	4F	0100 1111	O	143	8F	1000 1111	207	CF	1100 1111
16	10	0001 0000	DLE	80	50	0101 0000	P	144	90	1001 0000	208	D0	1101 0000
17	11	0001 0001	DC_1	81	51	0101 0001	Q	145	91	1001 0001	209	D1	1101 0001
18	12	0001 0010	DC_2	82	52	0101 0010	R	146	92	1001 0010	210	D2	1101 0010
19	13	0001 0011	DC_3	83	53	0101 0011	S	147	93	1001 0011	211	D3	1101 0011
20	14	0001 0100	DC_4	84	54	0101 0100	T	148	94	1001 0100	212	D4	1101 0100
21	15	0001 0101	NAK	85	55	0101 0101	U	149	95	1001 0101	213	D5	1101 0101
22	16	0001 0110	SYN	86	56	0101 0110	V	150	96	1001 0110	214	D6	1101 0110
23	17	0001 0111	ETB	87	57	0101 0111	W	151	97	1001 0111	215	D7	1101 0111
24	18	0001 1000	CAN	88	58	0101 1000	X	152	98	1001 1000	216	D8	1101 1000
25	19	0001 1001	EM	89	59	0101 1001	Y	153	99	1001 1001	217	D9	1101 1001
26	1A	0001 1010	SUB	90	5A	0101 1010	Z	154	9A	1001 1010	218	DA	1101 1010
27	1B	0001 1011	ESC	91	5B	0101 1011	[	155	9B	1001 1011	219	DB	1101 1011
28	1C	0001 1100	FS	92	5C	0101 1100	\	156	9C	1001 1100	220	DC	1101 1100
29	1D	0001 1101	GS	93	5D	0101 1101	]	157	9D	1001 1101	221	DD	1101 1101
30	1E	0001 1110	RS	94	5E	0101 1110	↑	158	9E	1001 1110	222	DE	1101 1110
31	1F	0001 1111	US	95	5F	0101 1111	—	159	9F	1001 1111	223	DF	1101 1111
32	20	0010 0000	SPACE	96	60	0110 0000	`	160	A0	1010 0000	224	E0	1110 0000
33	21	0010 0001	!	97	61	0110 0001	a	161	A1	1010 0001	225	E1	1110 0001
34	22	0010 0010	"	98	62	0110 0010	b	162	A2	1010 0010	226	E2	1110 0010
35	23	0010 0011	#	99	63	0110 0011	c	163	A3	1010 0011	227	E3	1110 0011
36	24	0010 0100	$	100	64	0110 0100	d	164	A4	1010 0100	228	E4	1110 0100
37	25	0010 0101	%	101	65	0110 0101	e	165	A5	1010 0101	229	E5	1110 0101
38	26	0010 0110	&	102	66	0110 0110	f	166	A6	1010 0110	230	E6	1110 0110
39	27	0010 0111	'	103	67	0110 0111	g	167	A7	1010 0111	231	E7	1110 0111
40	28	0010 1000	(	104	68	0110 1000	h	168	A8	1010 1000	232	E8	1110 1000
41	29	0010 1001	)	105	69	0110 1001	i	169	A9	1010 1001	233	E9	1110 1001
42	2A	0010 1010	*	106	6A	0110 1010	j	170	AA	1010 1010	234	EA	1110 1010
43	2B	0010 1011	+	107	6B	0110 1011	k	171	AB	1010 1011	235	EB	1110 1011
44	2C	0010 1100	,	108	6C	0110 1100	l	172	AC	1010 1100	236	EC	1110 1100
45	2D	0010 1101	-	109	6D	0110 1101	m	173	AD	1010 1101	237	ED	1110 1101
46	2E	0010 1110	.	110	6E	0110 1110	n	174	AE	1010 1110	238	EE	1110 1110
47	2F	0010 1111	/	111	6F	0110 1111	o	175	AF	1010 1111	239	EF	1110 1111
48	30	0011 0000	0	112	70	0111 0000	p	176	B0	1011 0000	240	F0	1111 0000
49	31	0011 0001	1	113	71	0111 0001	q	177	B1	1011 0001	241	F1	1111 0001
50	32	0011 0010	2	114	72	0111 0010	r	178	B2	1011 0010	242	F2	1111 0010
51	33	0011 0011	3	115	73	0111 0011	s	179	B3	1011 0011	243	F3	1111 0011
52	34	0011 0100	4	116	74	0111 0100	t	180	B4	1011 0100	244	F4	1111 0100
53	35	0011 0101	5	117	75	0111 0101	u	181	B5	1011 0101	245	F5	1111 0101
54	36	0011 0110	6	118	76	0111 0110	v	182	B6	1011 0110	246	F6	1111 0110
55	37	0011 0111	7	119	77	0111 0111	w	183	B7	1011 0111	247	F7	1111 0111
56	38	0011 1000	8	120	78	0111 1000	x	184	B8	1011 1000	248	F8	1111 1000
57	39	0011 1001	9	121	79	0111 1001	y	185	B9	1011 1001	249	F9	1111 1001
58	3A	0011 1010	:	122	7A	0111 1010	z	186	BA	1011 1010	250	FA	1111 1010
59	3B	0011 1011	;	123	7B	0111 1011	{	187	BB	1011 1011	251	FB	1111 1011
60	3C	0011 1100	<	124	7C	0111 1100			188	BC	1011 1100	252	FC	1111 1100
61	3D	0011 1101	=	125	7D	0111 1101	}	189	BD	1011 1101	253	FD	1111 1101
62	3E	0011 1110	>	126	7E	0111 1110	~	190	BE	1011 1110	254	FE	1111 1110
63	3F	0011 1111	?	127	7F	0111 1111	DEL	191	BF	1011 1111	255	FF	1111 1111

NOTICE

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