Pascal-M

M-code documentation V 2K1

Summary

This document describes the M-code machine
How to implement, loader, objectcode, instructions.

Authors

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Revisions:

V1.0	9 september 1978	(Mark D. Rustad),
V1.3	1986	Hans Otten
V1.4	August 2020	Hans Otten
V 2k1	October 2021	Hans Otten Work In Progress

M-code machine

The Pascal-M compiler produces objectcode for the virtual M-code machine. This is a variant of the P-code machine that is defined in the design of the Px interpreters (see the Pascal P4 source, books, design articles).

The M-code machine can be executed by implementing an interpreter

At the moment several interpreters of M-code interpreters are available (others have existed but are lost for now):

- V1 KIM-1 6502 code interpreter in assembler
- V1 Pascal interpreter
- V1.3 VAX/VMS Pascal interpreter
- V1.4 Freepascal interpreter
- 2K1 6502 and Freepascal

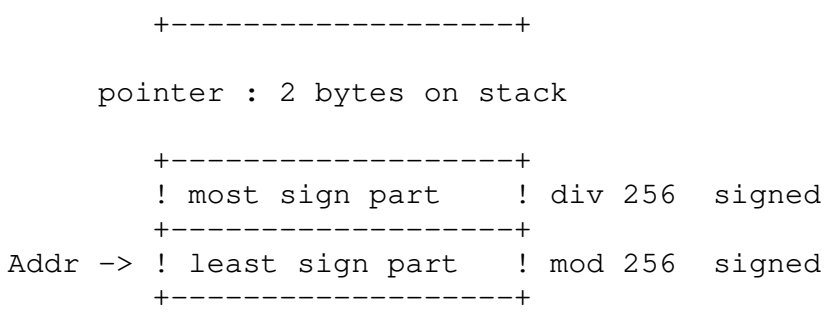
V1.0 of the M-code machine is defined in Preliminary M-code description 1978 .doc

Changes between V1.0 and V1.4 are:

- New instructions C2, SFA – Set file address C3 GFA Get File Address
- New standard procedures OD 0E, RSFRWW, 0F STT , 10 CLS
- Changes to RDI RLN WRI WLN etc read/write instructions to handle file address.
- New standard procedures RMEM and WMEM read and write physical memory locations

Data-representation :

```
     character : 1 byte on stack

        +------------------+
Addr -> ! ascii code char  !
        +------------------+

     boolean : 2 bytes on stack

        +------------------+
        !         0        !
        +------------------+
Addr -> !  true or false   ! true = 1, false = 0
        +------------------+

     integer : 2 bytes on stack

        +------------------+
        ! most sign part   ! div 256  signed
        +------------------+
Addr -> ! least sign part  ! mod 256  signed
```

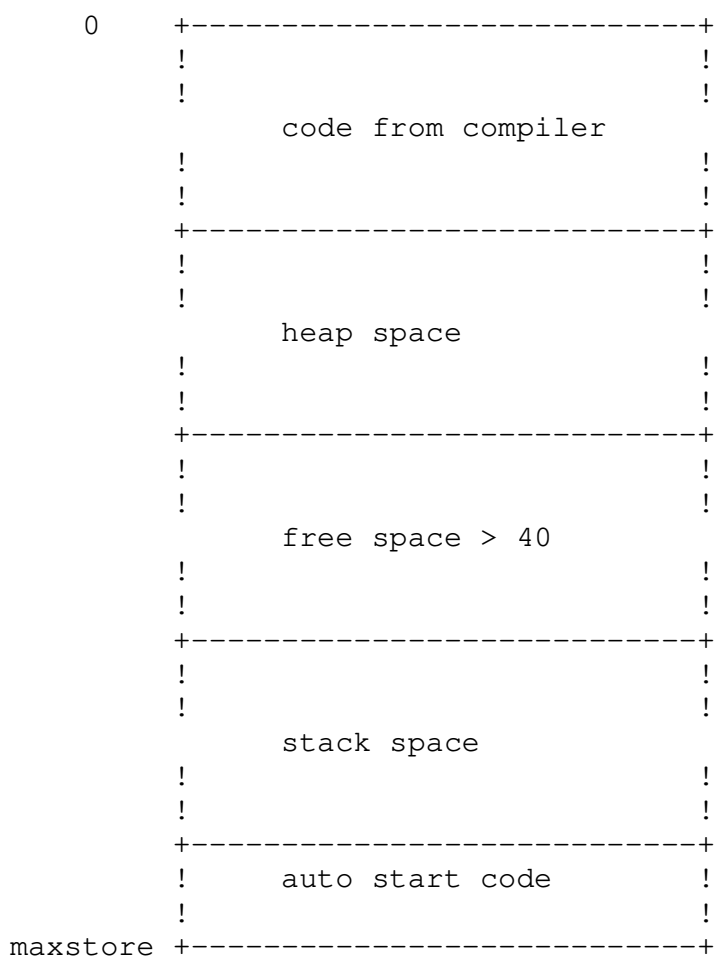


Addresses, pointers such as stackpointer, markpointer etc always point to the least significant byte of the data-item.

Examples are given above.

Stack layout as given in the interpreting procedures gives an impression before and after the instruction execution. The stack is actually growing from high addresses to low addresses. For example, reserving space on the stack requires decrementing of the stackpointer.

Memory layout :



M-code machine

The M-code machine is a strict stack computer.following the P-code design (see the book by Pemberton for example, chapter 10)

Registers are:

Program counter
Stackpointer
Heap pointer
Markpointer

Memory is 64Kbyte, byte addressable.

At start of the M-code machine:

Heappointer starts after the last byte loaded from objectcode
Program counter := maxstore - 4 ;
Stackpointer = maxstore - 5 ;
markpointer := stackpointer

```
Main program fixed in upper memory
MST0
CUP1 0
CSP STOP

Stored as:
    store [maxstore - 4] := 48  ; (* MST0      *)
    store [maxstore - 3] := 190 ; (* CUP1      *)
    store [maxstore - 2] := 0   ; (* proc nr 0 *)
    store [maxstore - 1] := 189 ; (* CSP       *)
    store [maxstore    ] := 11  ; (* Standard proc Stop
*)
;
```

Object code

The compiler produces objectcode in Px record format.

The object code produced by the PASCAL-M compiler is composed of lines of standard ASII characters. In most cases, the characters should be interpreted as hexadecimal digits. Though there are several types of records used in M-code, each type starts with an ASCII uppercase “P” and ends with the checksum of the record coded as two hexadecimal digits.

The type of the P-record is determined by the character immediately following the P. The exact format of each of the different record types is given below.

The P1 record

The P1 record is used to load object code into the interpreter’s program area. The two hex digits following the P1 P1 indicate how many bytes of object code are in this record (two hex digits per byte). After the last object code byte is this record’s checksum byte, again, two hex digits. No load address is specified in this record since the M-code loader maintains its own current loading address which is automatically incremented as P1 records are loaded.
A typical P1 record could appear as
P10B09600F9E100902BD0CA159

The P2 record

The P2 record is used for “satisfying” forward references by going back to a previously loaded area in the program and inserting an address. In this case, the four hex digitis appearing after the P2 specify the byte address to be modified (relative to the beginning of the code) and the next four hex digits specify the value to be inserted into that location and the following one (since the planted addresses are always two bytes in length).
A typical P2 record could appear as:
P20001000AFA

The P4 record

The P4 record is used to declare procedure/function entry addresses and specify the name and number of the procedure. The two hex digits immediately following the P4 specify this procedure’s number and the next 8 ASCII characters are the first 8 characters of the procedure’s name (space-filled if necessary). The procedure name specification in this case is an exception to the general rule that m-code consists of hex digits. The checksum of this record does include the ASCII characters added in according to their ASCII values.
A P4 record could appear as:
P401OUT 66

The P9 record

The P9 record signifies the end of loading. At some point, the P9 record should include the number of object records loaded (for error detection purposes) but does not at this time.
A P9 record appears as:
P9

M-code operators

In the code examples:

- PC is Program counter, pointing at byte following current instruction in M-code
- Stack is current stackpointer
- Level is call level
- Store is the memory array of stack and M-code

Calculation BaseAddres:

returns base-address of stackframe of level by following baseaddress linkpointers :
Note that all addresses are the address of the least significant byte of the item.

```
              +-----------------------+
      mp -->  ! link markpointer high ! --> previous frame
              +-----------------------+
              ! link markpointer low  !
              +-----------------------+   *
```

```
temp := markp ;
while level > 0 do
  begin
     temp := store[temp] * 256 + store[temp - 1] ;
     level := level - 1
   end ;
BaseAddress := temp + 1 ;
```

The M-code interpreter executes the instruction set of a stack computer. Although the design of m-code was based on the p-code produced by the P2 compiler, numerous changes have been made. Following is a description of each of the M-code operators.

0x, LDCIS – Load small integer constant
The LDCIS instruction pushes a small integer constant in the range of [0..15] onto the stack in standard integer form (16 bit representation). The constant is in the lower 4 bits of the instruction byte itself, allowing the entire operation to only require a single byte of M-code.

```
store[stack  ] := 0     ;   (* high byte zero *)
store[stack-1] := level ;
 stack := stack - 2
```

1X YY, LDAS – Load short address
The LDAS instruction loads the absolute address of the Yyth byte at the Xth level onto the stack. This instruction is only generated for offsets less than 256 bytes from a base address.

```
temp := BaseAddress( level ) - store[ pc ] ;
store[stack    ] := temp div 256 ; (* high byte of address *)
store[stack - 1] := temp mod 256 ; (*  low byte of address *)
```

```
stack := stack - 2 ;
pc := pc + 1
```

2X YY YY, LDA – Load Address
The LDA instruction pushes the absolute address of the YYYYth byte at the Xth level onto the stack.

```
 temp := BaseAddress(level) - store[pc] * 256 - store [pc + 1]
;
 store[stack    ] := temp div 256 ; (* high byte of address *)
 store[stack - 1] := temp mod 256 ; (*  low byte of address *)
 stack := stack - 2 ;
  pc := pc + 2
```

3X, MSTO – Mark stack at Xth level without return bytes
The MSTO instruction marks the stack in preparation for a procedure call. The MSTN instruction is used for a function call.

4X, MSTN YY – Mark stack at Xth level with return bytes
The MSTN instruction marks the stack in preparation for a function call.

5X YY, LOD1 – Load 1-byte item on stack
The LOD1 instruction loads the byte YYth at the Xth level on the stack. Before pushing the item onto the stack, it is expanded to 16 bits.

6X YY, LDO2 – Load 1-byte item on stack
The LOD1 instruction loads the byte YYth and YY=1th bytes at the Xth level on the stack.

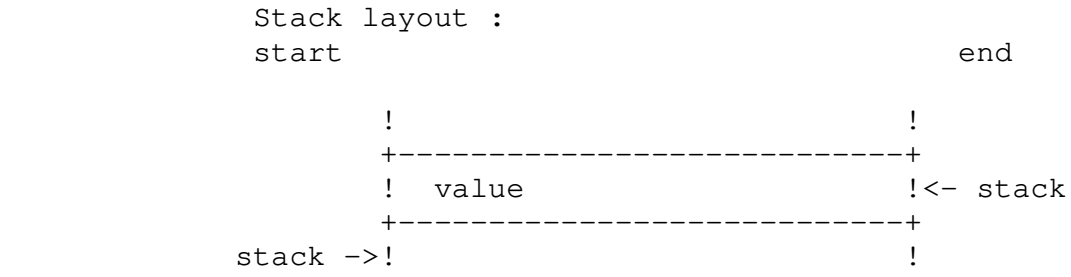
7X YY, STR1 – Store 1-byte data into memory
The STR1 instruction pulls one 16-bit item off the stack and stores the least significant byte into the YYth level

pulls word from stack and stores least significant byte at level at offset following opcode

```
     Stack layout :
     start                                    end

            !                              !
            +------------------------------+
            !  value                       !<- stack
            +------------------------------+
        stack ->!                          !
```

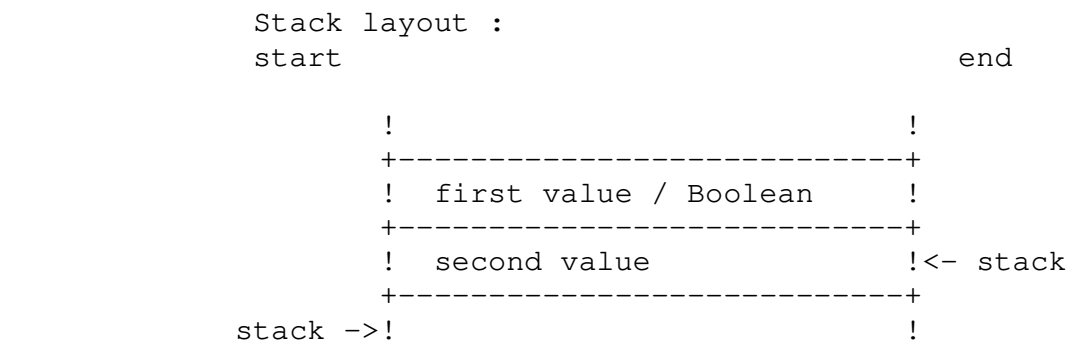
8X YY. STR2 - Store 2-byte data item into memory
The STR2 instruction pulls one 16-bit item off the stack and stores the bytes into the YYth bytes at the Xth level.

pulls word from stack and stores word
at level at offset following opcode



90, LEQ2 – 2-byte Less than or equal test
The LEQ2 instruction pulls two 2-byte items off the stack and pushes a Boolean item into the stack. The Boolean item will be a one (true) whenever the item next to the top of the stack is less than or equal to the item at the top of the stack is less than or equal to the item at the top of the stack. Otherwise, the Boolean item will be zero (false).

compares for less or equal
condition tested : first value =< second value
result : Boolean 1 if less or equal else Boolean 0



91, MFOR – For loop processing instruction
The FOR instruction is placed at the end of every loop. The instruction both initializes the loop and does the end check dependent upon data on the stack. For this reason, it is necessary that there are no goto in the language and that no extraneous data be left on the stack as a result of going through the loop.

implements the FOR statement.
Controls the loop with information on the stack.
Stored are
- the address off the loop variable
- the beginvalue
- the endvalue
- a flag word

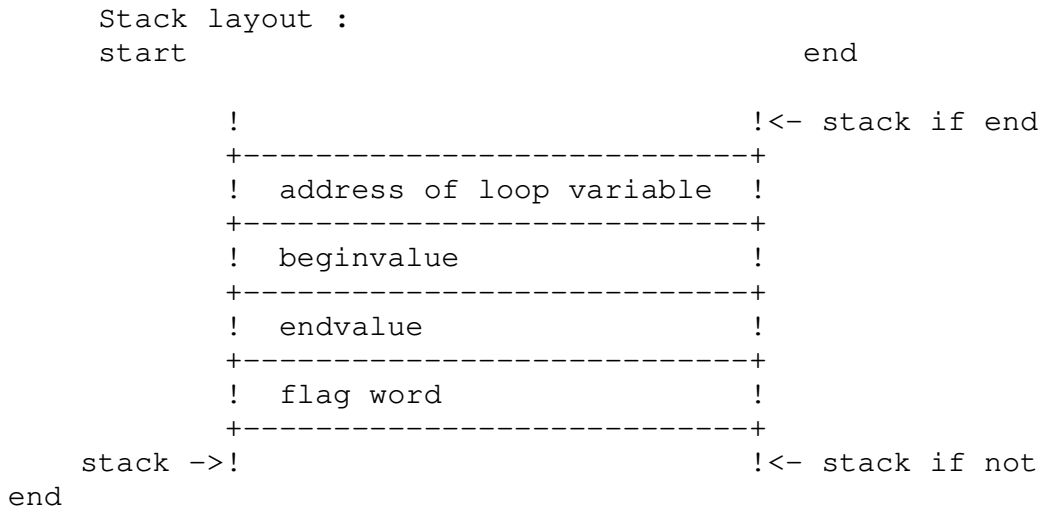
The FOR instruction implements a jump-instruction,

the jump is taken as long as the end-condition is
not reached.

The stack is cleaned up if the end-condition is reached.

The flag word has the following meaning

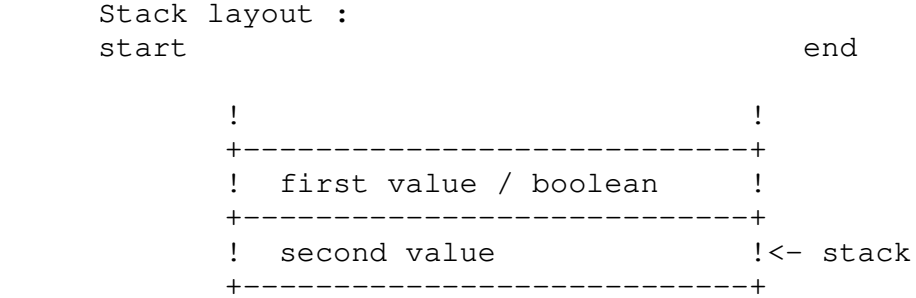
Bit 0 = 0 : the loop variable is a one byte location
Bit 0 = 1 : the loop variable is a two byte location
Bit 2 = 0 : to loop
Bit 2 = 1 : downto loop
Bit 8 = 0 : loop not initialized
Bit 8 = 1 : loop initialized



92 XX XX, LEQM – Less than or equal for arrays and records.
See 95 – LESM for description

93, LES2 – less than test for 2-byte data items
The LES2 instruction is similar to the LQ2 instruction except it does a “less than“ test.

compares for less or equal
condition tested : first value < second value
result : boolean 1 if less or equal else boolean 0



```
stack ->!                              !
```

94, LEQ8 – less or equals test for sets
this is the Is contained in test for sets. It pulls 2 8-byte sets off the stack and compares them for at least the common bits.

checks if all elements of first set are present
in second set. Leaves boolean result on the stack.

```
Stack layout
begin                                    end
       !                              !
       +------------------------------+
       !  first set / result boolean!
       +------------------------------+
       !  second set                  ! <- stack
       +------------------------------+
stack ->!                              !
```

95 XX XX, LESM - Less than test for arrays and records
The LESM instruction pulls two addresses off the stack and compares XXXXth bytes. If the first area is less in value than the area pointed by the second address then a 1 (true) is pushed onto the stack, otherwise a 0 (false) is pushed.

compares for equality of arrays or records
condition tested : first value < second value
result : boolean 1 if equal else boolean 0
size of structure follows opcode

```
Stack layout :
start                                      end

       !                              !
       +------------------------------+
       !  first address / boolean     !
       +------------------------------+
       !  second address              !<--stack
       +------------------------------+
stack ->!                              !
```

96, EQU2 – Equal test for 2-byte data items
The EQU2 instruction pulls two 2-byte data items off the stack and pushes a Boolean item onto the stack. The Boolean item will be a 1 (true) when the items compared are equal and a 0 (false) otherwise.
compares for equality
condition tested : first value = second value
result : boolean 1 if equal else boolean 0

```
Stack layout :
```

```
 start                                    end

        !                            !
        +----------------------------+
        !  first value / boolean     !
        +----------------------------+
        !  second value              !<- stack
        +----------------------------+
stack ->!                            !
```

97, GEQ8 – Greater than or equal test for sets
This is the Contains test for sets. See 94 instruction. If true it sends a false on the stack and visa versa due to the generation of a AC – Not instruction following this one by the Pascal-M compiler.

checks if all elements of second set are present
in first set. Leaves boolean result on the stack.

```
 Stack layout
 begin                                  end
        !                            !
        +----------------------------+
        !  first set / result boolean!
        +----------------------------+
        !  second set                ! <- stack
        +----------------------------+
stack ->!                            !
```

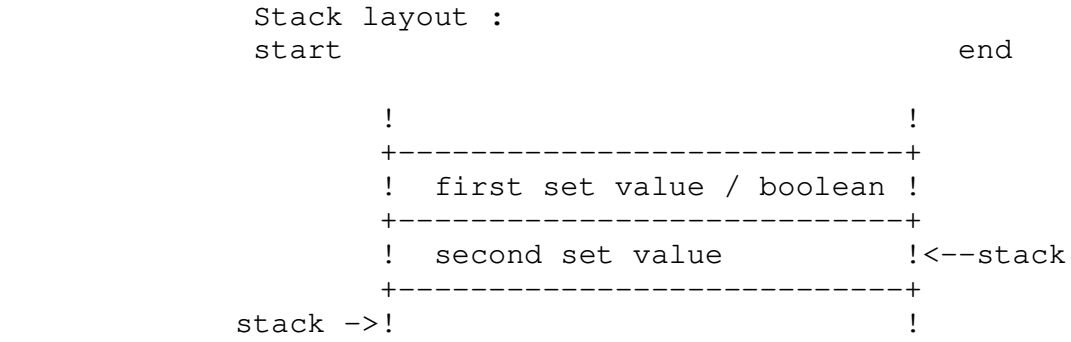
98 XX XX, EQUM – Equal test for arrays and records
The EQUM instruction pulls two addresses off the stack and compares XXXX bytes. If the two areas are equal a 1 (true) is pushed onto the stack, otherwise a 0 (false) is pushed on the stack.

compares for equality of arrays or records
condition tested : first value = second value
result : boolean 1 if equal else boolean 0
size of structure follows opcode

```
 Stack layout :
 start                                    end

        !                            !
        +----------------------------+
        !  first address / boolean   !
        +----------------------------+
        !  second address            !<--stack
        +----------------------------+
stack ->!                            !
```

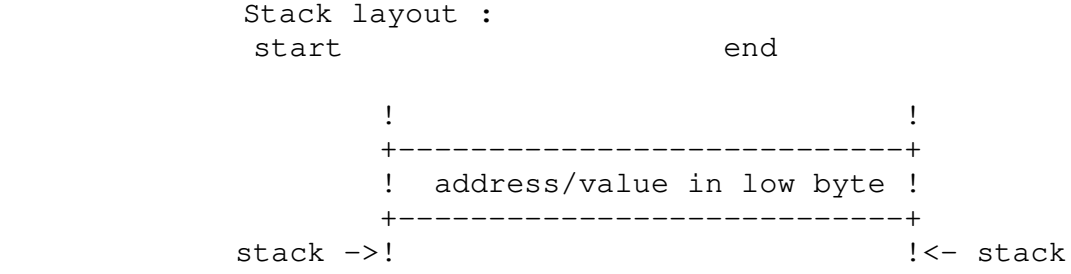
99, EQU8 – Equal test for sets
The EQU8 instruction pulls two byte sets off the stack and compares them. If they are equal a 1 (true) is pushed onto the stack, otherwise a 0 (false) is pushed on the stack.

compares for equality of sets
  condition tested : first value = second value
  result : boolean 1 if equal else boolean 0

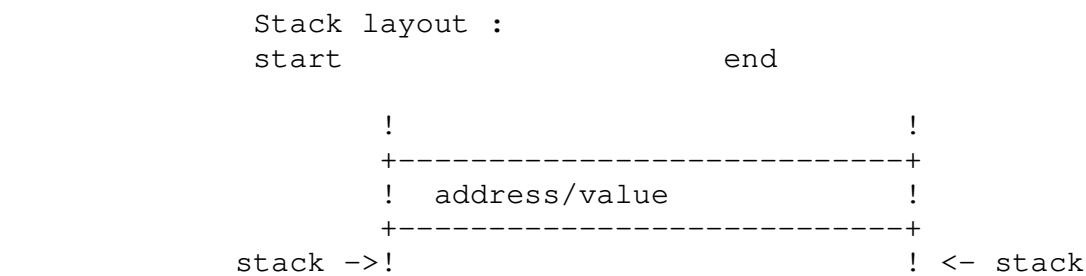


9A, IND1 – indirectly load 1-byte data item
The IND1 instruction pulls an address off the stack and pushes the byte at that location onto the stack after expanding it to two bytes(as with the LOD1 instruction).

loads one byte value on stack from address on stack

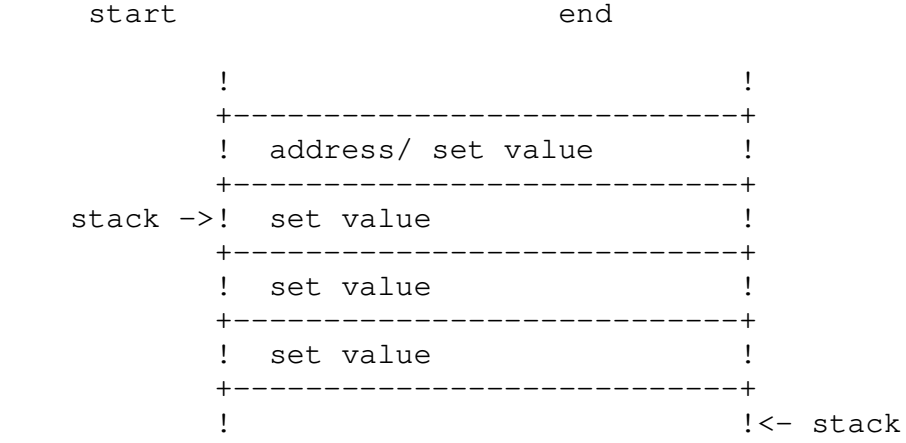


9B, IND2 – Indirectly load 2-byte data item
The IND2 instruction pulls an address off the stack and pushes the byte at the location and the folling one onto the stack.
loads two byte value on stack from address on stack



9C, IND8 – indirectly load 8-byte data item
The IND8 instruction pulls an address off the stack and pushes that byte and the following 7 onto the stack.

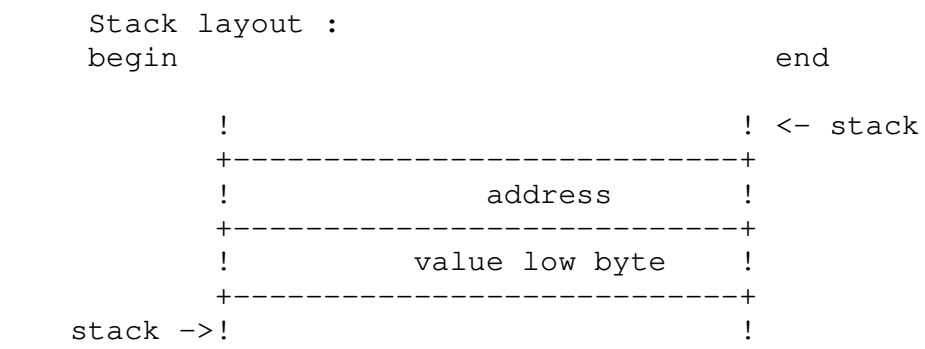
(* loads two byte value on stack from address on stack



9D, STO1 – Indirectly store 1-byte data item

The STO1 instruction pulls 2-bytes of data off the stack and an address. The least significant byte of data is stored at the address that was pulled off the stack.

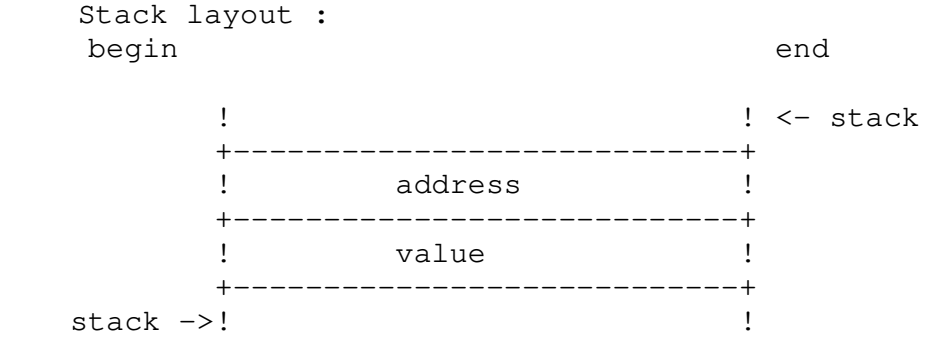
indirectly stores 1 byte from stack at address on stack



9E, STO2 Indirectly store 2-byte data item

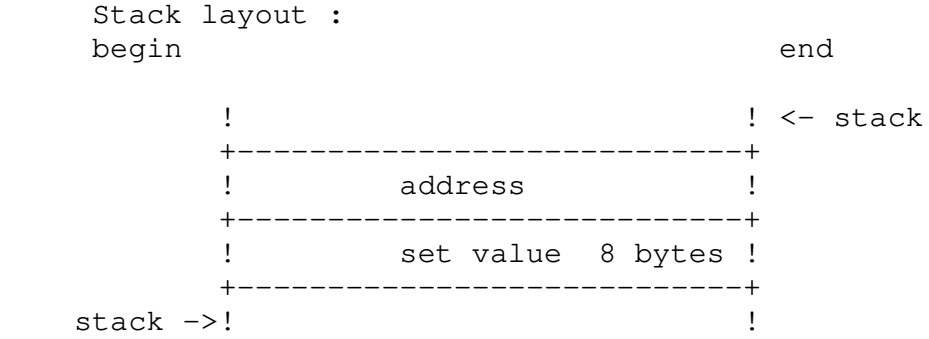
The STO2 instruction pulls 2-bytes data off the stack and an address. The 2 bytes of data are stored into memory starting at the address that was pulled off the stack.

indirectly stores 2 bytes from stack at address on stack



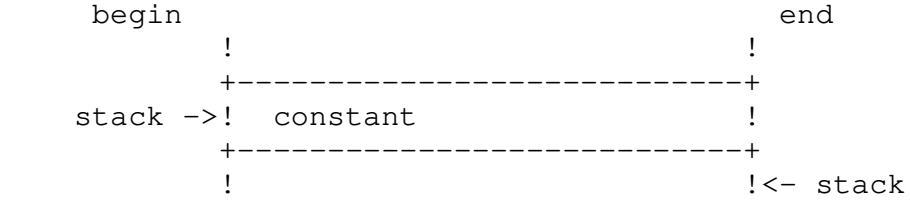
9F, STO8 – Indirectly store 8-byte data item.
The STO8 instruction pulls 8-bytes of data off the stack and an address. The 8 bytes of data are stored into memory starting at the address that was pulled off the stack.

indirectly stores 2 bytes from stack at address on stack



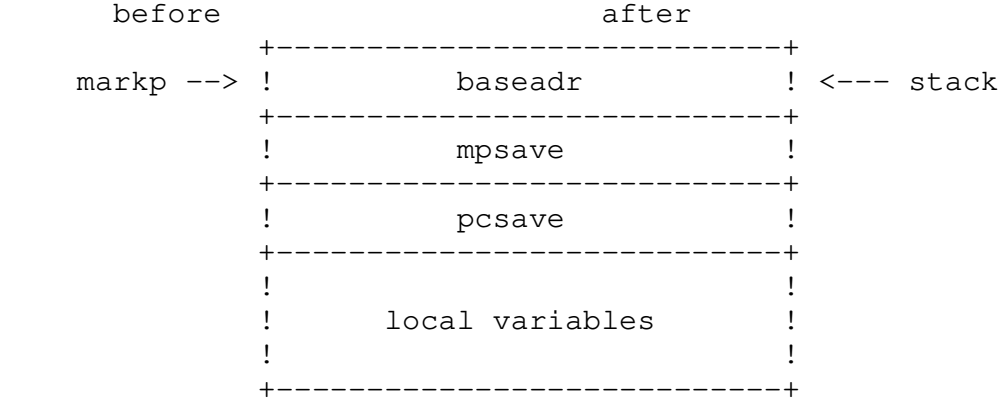
A0 XX XX, LDC – Load 2-byte constant
The LDC instruction pushes the 2-byte constant, XXXX onto the stack.

loads constant following opcode on the stack



A1, RETP – Return from procedure (or function)
The RETP instruction returns from the current procedure, cleaning up the stack appropiately.

Returns from procedure/function, cleans up
stack by removing local variables and
linkframe
Situation before :



```
  stack --> !
```

The DVI instruction pulls two 2-byte integers off the stack adds them together and pushes the result onto the stack.

adds two integers on stack, leaves integer
result on stack.
evaluates expression :
result := first value / second value

```
Stack layout :
start                                    end
       !                              !
       +------------------------------+
       !  first  value / result       !
       +------------------------------+
       !  second value                ! <- stack
       +------------------------------+
stack ->!                             !
```

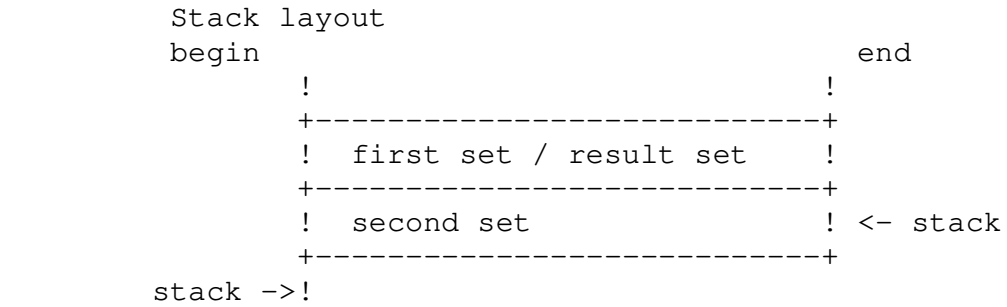
A3, MAND – Boolean AND
The MAND instruction pulls two Boolean items off the stack, logical AND-s them together and pushes the result into the stack.

Performs AND on two booleans on the stack,
leaves boolean result on stack.
Booleans placed on stack as two bytes,
low byte contains 0 if false.
evaluates expression :
result := first boolean AND second boolean.
(true is 1 if first and second true)

```
Stack layout :
start                                    end
       !                              !
       +------------------------------+
       !  first  boolean/ result      !
       +------------------------------+
       !  second boolean              ! <- stack
       +------------------------------+
stack ->!                             !
```

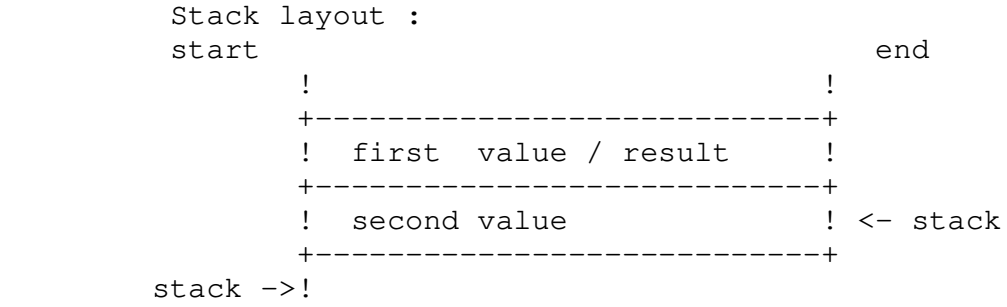
A4, DIF – Set difference
The DIF instruction pulls two 8-byte sets off the stack, finds the difference between the two by logically AND-ing and Exclusive-OR-ing each byte and pushes the result onto the stack.

gives the difference of two sets on the stack,
leaves result on the stack. Collects in result
all elements present in first set and not in second set.



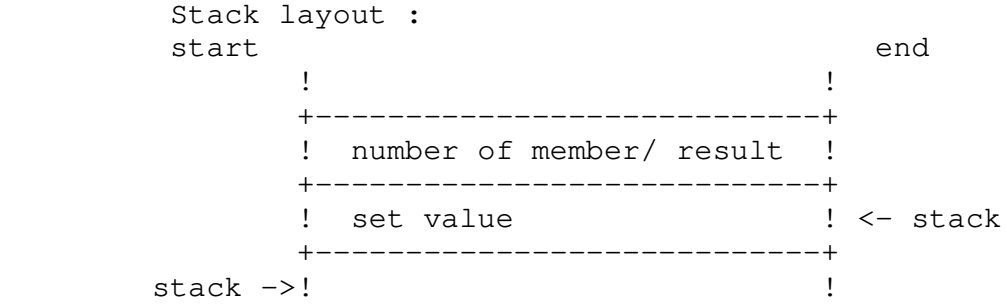
A5, DVI -- Divide integer
The DVI instruction pulls two 2-byte integers off the stack and divides the top of the stack into the second and pushes the result onto the stack.

divides two integers on stack, leaves integer
result on stack. Signed division.
evaluates expression :
result := first value / second value



A6, INN – Test if element in set
The INN instruction pulls an 8-byte set off the stack and a 2-byte integer. If the set element indicated by the integer is in the set, a 1 (true) will be pushed on the stack, otherwise a 0 (false) will be pushed on the stack.

The is member of test for sets is implemented
with this instruction. Leaves boolean true
on stack if member in set.



A7, INT – Set interaction
The INT instruction pulls tw0 8-byte sets off the stack and finds the intersection by logically AND-ing each byte together. The intersection is then pushed onto the stack.

gives the intersection of two sets on the stack,
leaves result on the stack. Collects in result
all elements present in first and in second set.

```
Stack layout
begin                                  end
       !                             !
       +-----------------------------+
       !  first set / result set     !
       +-----------------------------+
       !  second set                 ! <- stack
       +-----------------------------+
stack ->!                            !
```

A8, IOR – Inclusive OR
The IOR instruction pulls two Boolean items off the stack, logically OR-s them together and pushes the result on the stack.

Performs OR on two booleans on the stack,
leaves boolean result on stack.
Booleans placed on stack as two bytes,
low byte contains 0 if false.
evaluates expression :
result := first boolean OR second boolean.
(true is 1 if first or second true)

```
Stack layout :
start                                   end
       !                             !
       +-----------------------------+
       !  first  boolean/ result     !
       +-----------------------------+
       !  second boolean             ! <- stack
       +-----------------------------+
stack ->!                            !
```

A9, MMOD – Modulus function
The MMOD isntruction pulls two integers off the stack, and finds the modulus by taking the remainder of dividing the top of the stack into the second. The resulting remainder is then pushed onto the stack.

modulus of two integers on stack, leaves integer
result on stack. Signed division.
evaluates expression :
result := first value mod second value

```
     Stack layout :
     start                                    end
            !                              !
            +------------------------------+
            !  first  value / result       !
            +------------------------------+
            !  second value                ! <- stack
            +------------------------------+
    stack ->!                              !
```

AA, MPI – Multiply integer
The MPI instruction pulls two integers off the stack, multiplies them and pushes the result onto the stack.

multiplies two integers on stack, leaves integer
result on stack. Signed division.
evaluates expression :
result := first value * second value

```
     Stack layout :
     start                                    end
            !                              !
            +------------------------------+
            !  first  value / result       !
            +------------------------------+
            !  second value                ! <- stack
            +------------------------------+
    stack ->!                              !
```

AB, NGI – Negate integer
The NGI instruction pulls the integer off the stack, changes its sign and pushes it back onto the stack.

```
changes sign of integer on stack
     evaluates expression :
         result := - result

     Stack layout :
     start                                    end
            !                              !
            +------------------------------+
            !     result                   !
            +------------------------------+
    stack ->!                              !<- stack
```

AC, MNOT – negate Boolean
The MNOT instruction pulls one Boolean item of the stack, logically complements it and pushes it back onto the stack.

* complements boolean value on stack

evaluates expression :
result := not result

```
Stack layout :
start                                    end
       !                              !
       +------------------------------+
       !     result                   !
       +------------------------------+
stack ->!                              !<- stack
```

AD, SBI – Subtract Integer
The DVI instruction pulls two 2-byte integers off the stack and subtracts the top of the stack from the next and pushes the difference onto the stack.

subtracts two integers on stack, leaves integer
result on stack.
evaluates expression :
result := first value - second value

```
Stack layout :
start                                    end
       !                              !
       +------------------------------+
       !  first  value / result       !
       +------------------------------+
       !  second value                ! <- stack
       +------------------------------+
stack ->!                              !
```

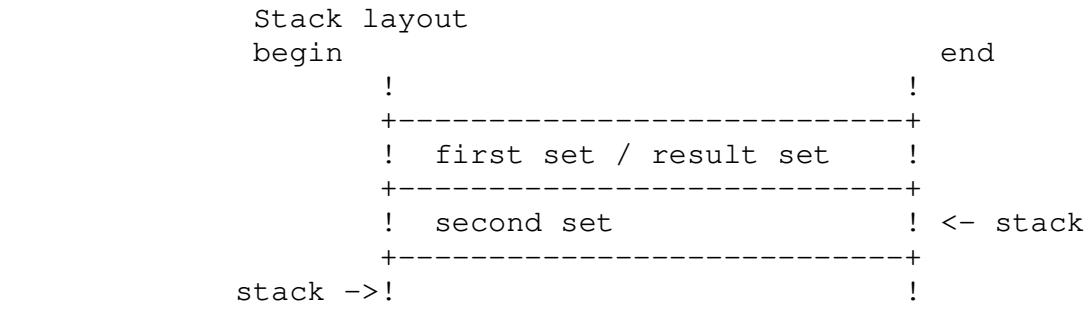
AE, SGS – Generate singleton set
The SGS instruction pulls an integer off the stack, generates a SET with that integer as its only element and pushes the generated set onto the stack.

Generate singleton set on stack.
On stack number is present as integer
of set member to be set, other set members
not present.

```
Stack layout :
start                                    end
       !                              !
       +------------------------------+
stack ->!  setnumber / set             !<-- stack
       +------------------------------+
       !                              !
```

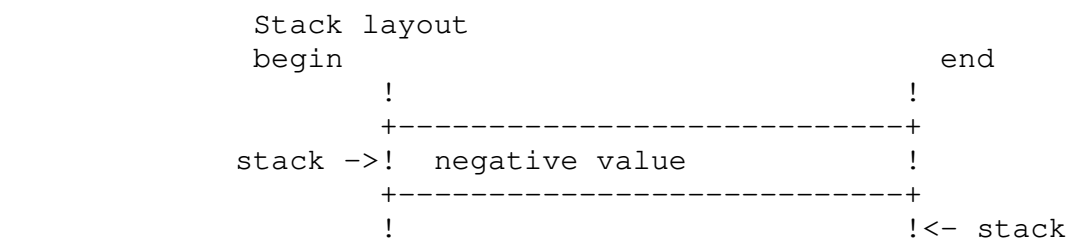
AF, UNI – Set union
The UNI instruction pulls two sets of the stack, logically O-s them together and pushes the resulting set onto the stack.

gives the union of two sets on the stack,
leaves result on the stack. Collects in result
all elements present in either input set.



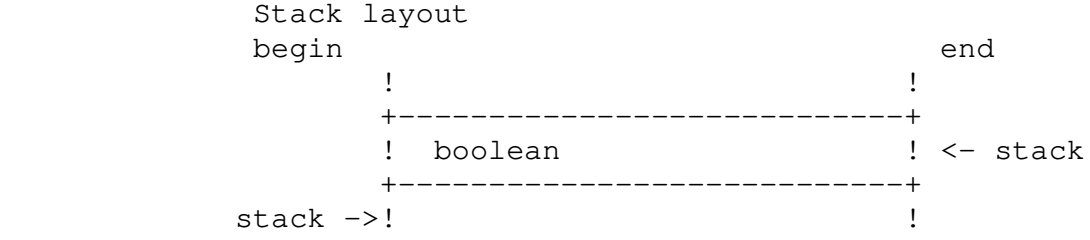
B0 X X, LNC – Load negative constant
The LNC instruction loads the negative of XXXX onto the stack.

loads negative value on stack with value after opcode



B1 X X, FJP – False jump
The FJP instruction pulls one Boolean off the stack. If the item is zero (false), control will transfer to the XXXXth byte of the current procedure, otherwise control passes to the next instruction in sequence.

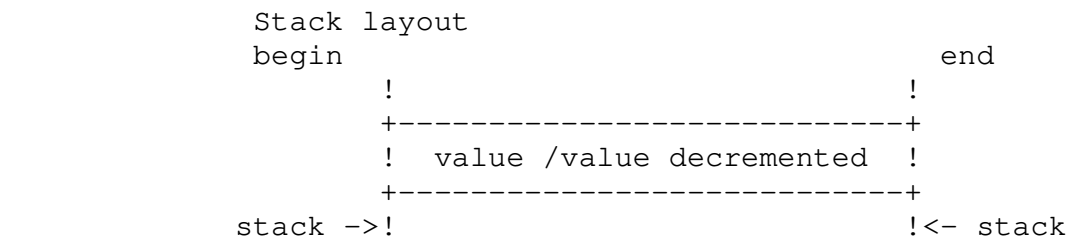
false jump, taken if value on stack is false, zero
jump performed with UJP



B2 X X, UJP – unconditional jump
The UJP instruction always transfers control to the XXXXth byte of the procedure,

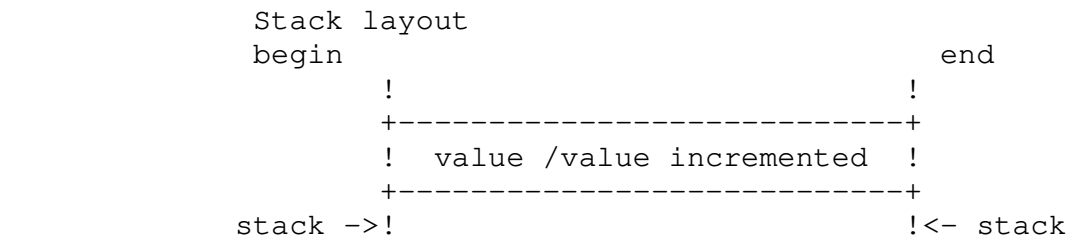
B3 X X, DEC – Decrement
The INC instruction pulls one 2-byte integer off the stack, detracts XX from it and pushes the result back onto the stack.

decrement value on stack with value after opcode and
leave result in same stack position



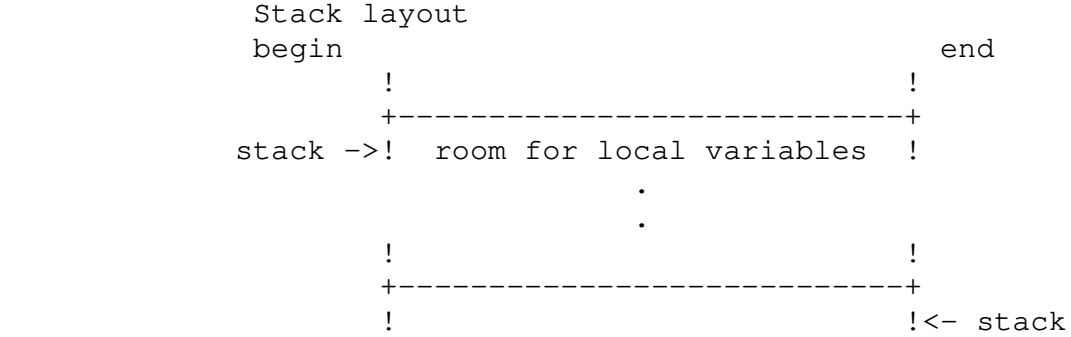
B4 X X, INC – Increment
The INC instruction pulls one 2-byte integer off the stack, adds XX to it and pushes the result back onto the stack.

increment value on stack with value after opcode and
leave result in same stack position



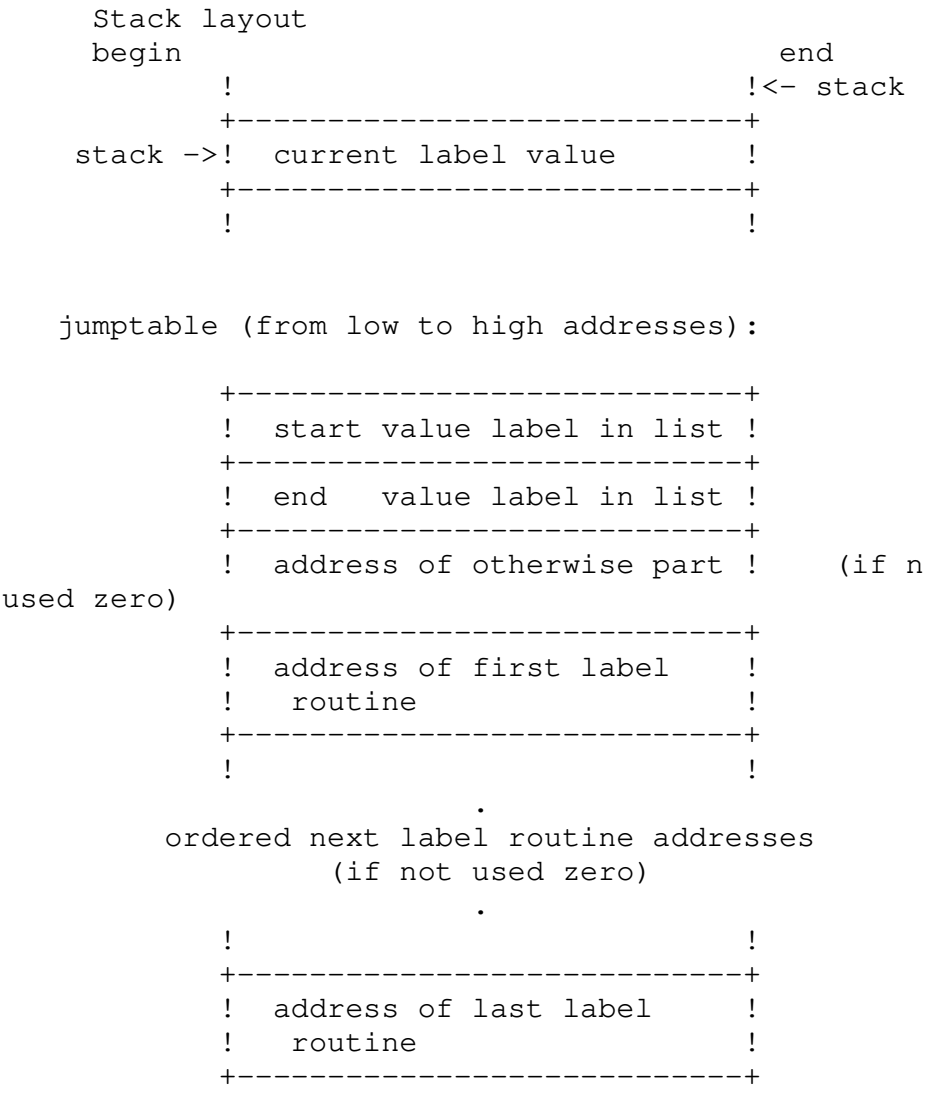
B5 X X, ENT – Enter block
The ENT instruction is always generated as the first instruction of the procedure. It reserves stack space for all variables local to the procedure.

Reserve stack space for all variables local
to procedure.
PC (high), PC + 1 (low) contain nr of bytes to reserve.



B6 -----, CAS – Case statement procedure
The CAS instruction does most of the processing for the case statement. It occupies a variable amount of memory because the instruction includes the complete jumptable for the case statement.

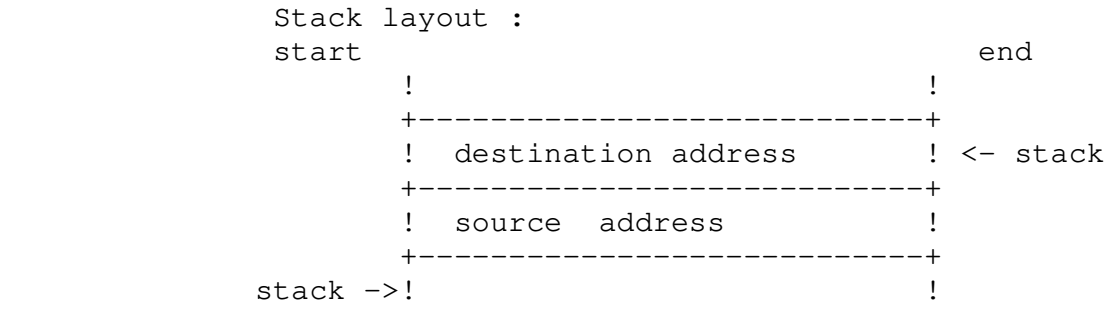
processes case - statement.
Following the opcode the complete jump-table
is present including the otherwise part
and the beginning and endvalue of the label:



B7 X X, MOV
C4 X X X X MOVMVB – Move storage
The MOV instruction is used for moving arrays and records around in memory The address of the sending field is pulled off the stack and the address of the receiving field is pulled off next, XXXX bytes are then transferred from the sending to the receiving field.

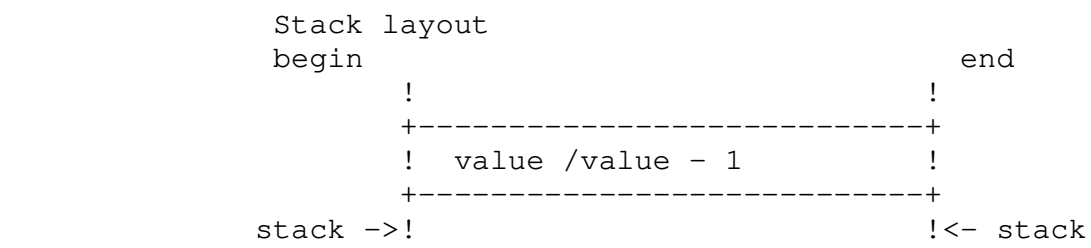
moves structures in memory

Size to move follows opcode as word.
If MVB then blanks to pad follows size as word.
Source and destination address are on the stack.



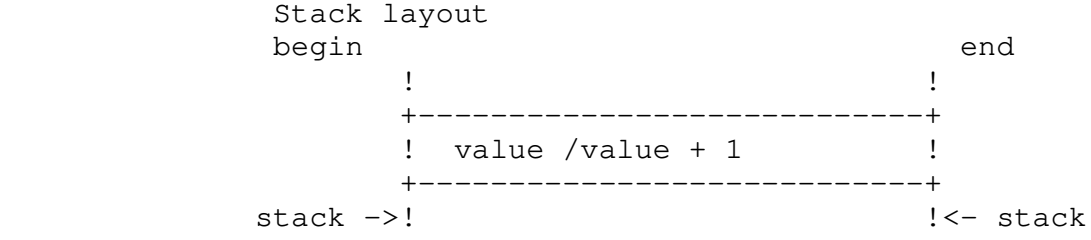
B8, DEC1 – decrement by 1
The INC1 instruction pulls one 2-byte integer off the stack, subtracts 1 from it and pushes the result back onto the stack.

decrement first value on stack with one and
leave result in same stack position



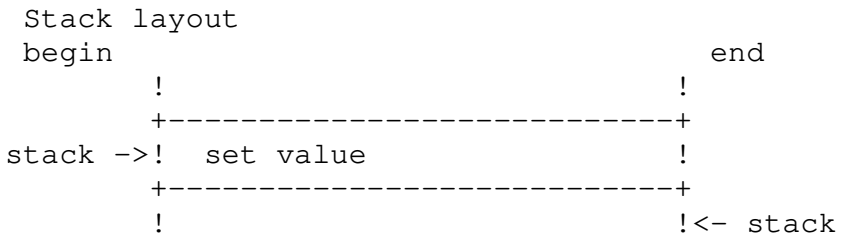
B9, INC1 – increment by 1
The INC1 instruction pulls one 2-byte integer off the stack, adds 1 to it and pushes the result back onto the stack.

increment first value on stack with one and
leave result in same stack position

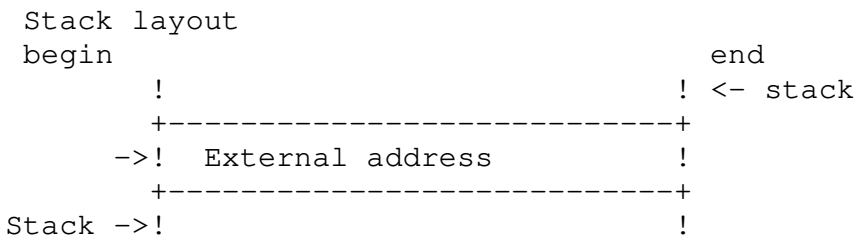


BA X X X X X X X X, LDCS – Load set constant
The LDCS instruction loads the 8-byte set, X X X X X X X X, onto the stack.

loads constant set following opcode on the
stack.



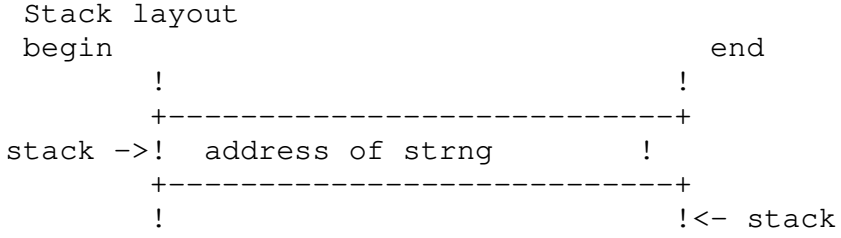
BB X X, CAP – Call assembly procedure
The CAP instruction is used to call an assembly-language routine previously loaded into a specified address.
The actual action of this instruction may be considered to be system-dependent.
Local parameters are stored at the stack with LDCI



See the chapter CAP for more information.

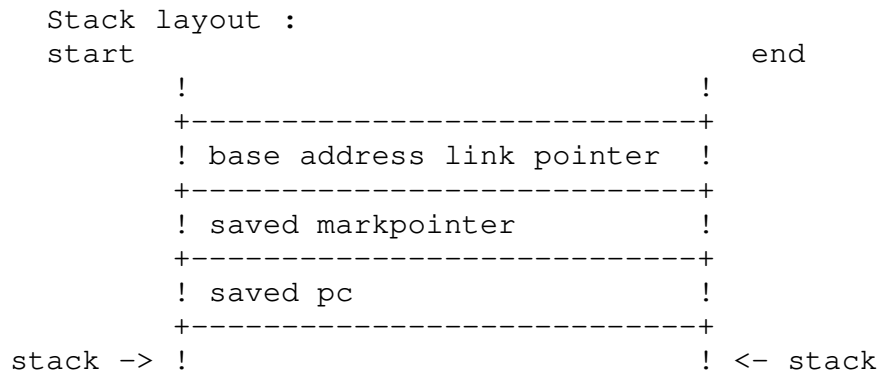
BC X ---===, LCA – Load constant address
The LCA instruction pushes the address of the string starting 2 bytes after the instruction code onto the stack. The length of the string is specified by XX. For this reason, all addresses used within the Pascal-M system, whether pointer or array bases, must refer to the actual hardware address of the item.

Load address of strngfollowing opcode on stack
pc incremented up to opcode following strng



BD X, CSP – Call standard procedure X
The CSP instruction is used for calling standard procedures that exist within the interpreter itself. XX is a numeric index that determines which procedure is to be executed. Since a large number of possible instruction codes have not been used, it may be desirable at some point to eliminate this instruction and incorporate all standard procedures as instructions.

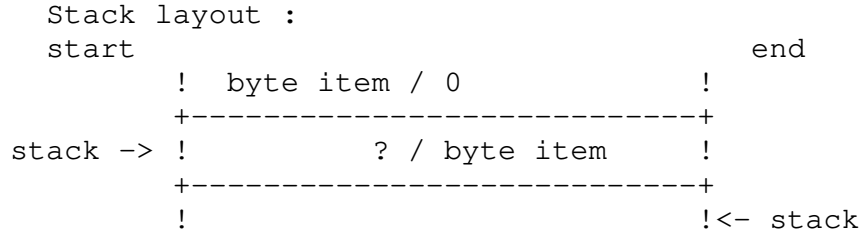
BE XX, CUP1 –simple call user procedure
The CUP1 instruction is used to call procedures whenever the parameter list of the call does itself not include a function call. XX is a numeric index that determines the procedure to be called. The compiler assigns a number to each procedure at compile time. The number is then associated with an address at load time.



BF X, CUP2 – Complex Call user procedure
The CUP2 instruction is used to call procedures whenever the parameter list of the call does include a call to a function. One 2-byte integer is pulled off the stack, which indicates how many bytes of parameters are being passed. In all other respects, CUP2 functions the same as CUP1.

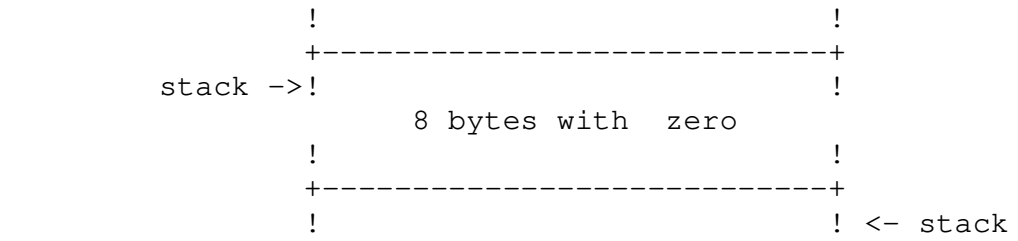
C0, FIX21 – cleanup stack after call to single-byte function
The FIX21 instruction pushes a single byte of zero onto the stack. This operation is used to standardize the return value of single-byte-valued functions (such as Boolean functions). This action then makes the single byte value occupy two bytes on the stack as is usual.

Transfers one byte item on stack into two byte item,
byte item moved to low byte of two byte item,
high byte filled with zero



C1, LNS – Load null set
The LNS instruction pushes 8 bytes of zero onto the stack for use a a null set.

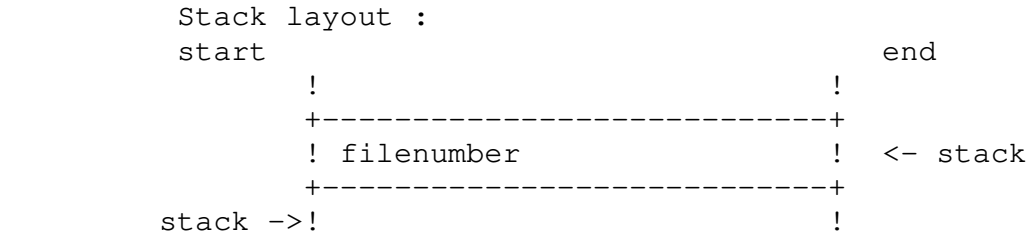
```
Load null set on stack : 8 bytes of zero
```



Additions for V1.1 and up:

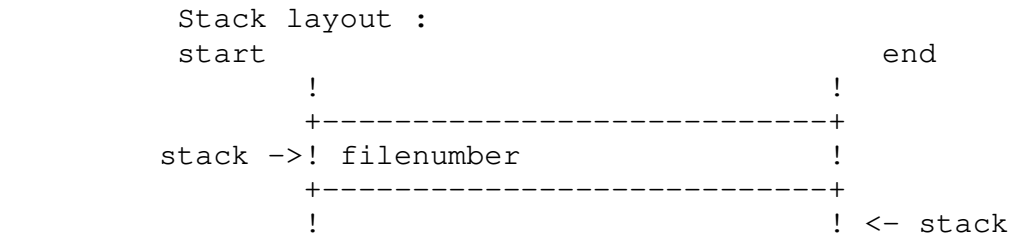
C2, SFA – Set file address
The SFA instruction pulls one 2-byte address of the stack and places it in a location internal to the interpreter for use by all subsequent I/O operations. The address pulled off the stack is the address of a pointer to the file buffer.

Set file address for all file operations to follow
filenumber in least sign byte on stack



C3, GFA – Get file address
The GFA instruction pushes the value of the internal file address on the stack.

Get file address for all file operations to follow
filenumber in least sign byte on stack



Standard procedures

00, WRI – Write integer
The WRI procedure writes one integer onto output.

writes integer on stack in specified field width.

```
Stack layout
begin                                   end
       !                              !
       +------------------------------+
       !  char code                   !<- stack
       +------------------------------+
       ! field width                  !
       +------------------------------+
stack ->!                              !
```

01, WRC – Write character to output
The WRC procedure writes one character to output.

writes character on stack in specified field width.

```
Stack layout
begin                                   end
       !                              !
       +------------------------------+
       !  char code                   ! <- stack
       +------------------------------+
       ! field width                  !
       +------------------------------+
stack ->!                              !
```

02, WRS – Write string to output
The WRS procedure writes a packed array of characters onto output.

prints strngto output,

```
Stack layout
begin                    end
    !              !
    +--------------------------+
    !  address              !<- stack
    !  of strng           !
    +--------------------------+
    ! specified            !
    ! field width           !
    +--------------------------+
    ! actual             !
```

```
        ! field width           !
        +-------------------------+
   stack ->!                     !
```

03, RDI – Read integer
The RDI procedure reads an integer from input

reads integer
if terminal then
if CR entered then endofline becomes true
and a space returned
if CTRL-Z entered then endoffile and endofline
become true
at least the value zero is returned,
also for illegal characters

```
Stack layout :
start                                   end
       !                              !
       +------------------------------+
       !  address for integer         !<- stack
       +------------------------------+
stack ->!                             !
```

04. RLN – Read to end of line on input
The RLN reads skips to end of line on input.

05, RDC – Read character from input
The RDC procedure reads a single character from input.

reads character from input file

```
Stack layout :
start                                   end
       !                              !
       +------------------------------+
       !  address for char            !<- stack
       +------------------------------+
stack ->!                             !
```

06, WLN – Write end of line
The WLN procedure writes an end of line

07, NEW – Allocate space on the heap
The NEW procedure pulls a 2-byte integer off the stack which specifies the size of the area to be allocated and a 2-byte address which specifies the pointer varaible to be set. Space is then allocated on the heap and the pointer variable set to the address of that storage.

(* Reserves space in the heap for variable
pointer address and size to reserve on the stack
heap pointer updated

```
Stack layout :
start                                  end
       !                             !
       +-----------------------------+
       !  address of pointer         !<- stack
       +-----------------------------+
       !  size to reserve on heap    !
       +-----------------------------+
stack ->!                             !
```

08, EOF – End of file test
The EOF procedure pushes a Boolean item on the stack which is true if an end of file condition exists.

enters boolean end of file on stack

```
Stack layout :
start                                  end
       !                             !
       +-----------------------------+
stack ->!  boolean (1 if endoffile)  !
       +-----------------------------+
       !                             !<- stack
```

09, RST – Reset heap pointer
The RST procedure sets the heap pointer to the value pulled off the stack.

Restores heap pointer to value in pointer
address of pointer on the stack

```
Stack layout :
start                                  end
       !                             !
       +-----------------------------+
       !  address of pointer         !<- stack
       +-----------------------------+
stack ->!                             !
```

0A, ELN – Test for end of line
The ELN procedure pushes a Boolean item on the stack which is true if an end of line condition exists.

(* enters boolean end of line on stack

```
Stack layout :
```

```
 start                                    end
        !                             !
        +-----------------------------+
stack ->!  boolean (1 if endofline)   !
        +-----------------------------+
        !                             !<- stack
```

0B, STP – Stop
The STP procedure halts execution.

0C, ODD – Test integer for odd.
The ODD procedure pulls a 2-byte integer off the stack and pushes a Boolean item onto the stack which is true if the integer is odd.

enters boolean true on stack if value on stack is odd

```
 Stack layout :
 start                                    end
        !                             !
        +-----------------------------+
stack ->!  value/ result (1 if odd)   !<-stack
        +-----------------------------+
        !                             !
```

OD : RSFRWW ;
OE: RSFRWW reset rewrite file

resets or rewrites file
filename as string on stack

```
 Stack layout :
 start                                    end
        !                             !
        +-----------------------------+
        ! address of strng            !<-- stack
        +-----------------------------+
        ! length of strng             !
        +-----------------------------+
stack ->!                             !
```

OF : STT status I/O

enters status of file on stack for current filenumber

```
 Stack layout :
 start                                    end
        !                             !
        +-----------------------------+
stack ->!  value/ result (1 if odd)   !
        +-----------------------------+
```

```
          !                                !<-stack
```

10 : CLS closefile

11 RDMEM read byte from physical memory address

Address XX on stack on entry, byte Y returned

```
 Stack layout :
 start                                    end
        !                               !
        +-------------------------------+
stack ->!  Address / byte from memory!<-  stack
        +-------------------------------+
```

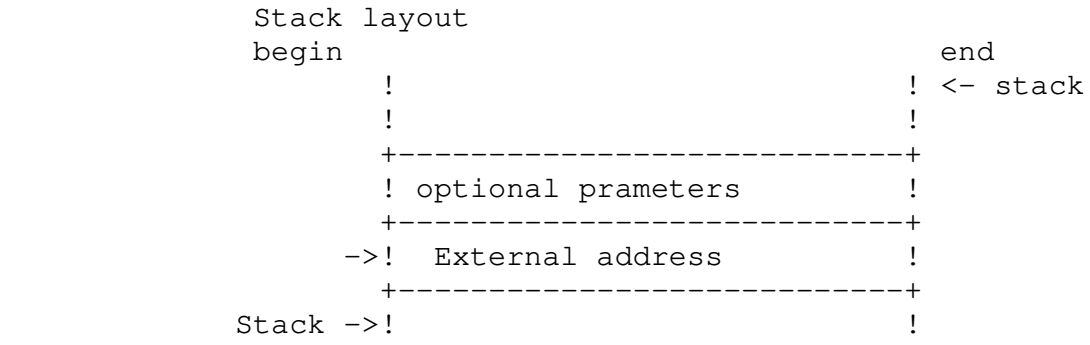
12 WRMEM write byte to physical memory

Address XX on stack on entry, byte Y to write

```
 Stack layout :
 start                                    end
        !                               !
        +-------------------------------+
stack ->!  Address XX                   !
        +-------------------------------+
        !   byte to memory              !
        +-------------------------------+<-  stack
```

CAP Call Assembly Procedure

BB X X, CAP – Call assembly procedure
The CAP instruction is used to call an assembly-language routine previously loaded into a specified address.
The actual action of this instruction may be considered to be system-dependent.
Local parameters are stored at the stack with LDCI.



A way to call any system dependent and hardware dependent routine.

Syntax

PROCEDURE <name> {< parameter list>} ; extern = <address>

Where

- name is the internal name of the procedure in the Pascal program
- address is the location of the routine in memory, to be supplied outside of the Pascal program. As Pascal-M is a 16 bit only compiler, this limits addressing space to 64K
-

At entry the routine is free to perform any action.

The optional parameter list allows to pass data and variables to the called routine. The routine is responsible for the interpreter stack handling, see the M-code instructions what to expect on the stack and how to return values.

On return the routine must remove the 2 bytes of the interpreter stack containing the called address.

Examples for V1 of the Pascal-M compiler KIM-1 interpreter.

```
        .org    $00C0   ; because the compiler knows this
        ;
proc1   lda     #$00    ; procedure ttyin ;extern = $00C0 ;
        sta     setin
        jmp     procex
        nop
```

```
proc2   lda     #$01    ; procedure sethsr ;extern = $00C8 ;
        sta     setin
        jmp     procex
             nop
proc3   lda     #$00    ; procedure  ttyout ;extern = $00D0 ;
        sta     setout
        jmp     procex
        nop
proc4   lda     #$01    ; procedure sethsp ;extern = $0058
        sta     setout
procex  jsr     pull2
        jmp     loop
```

Implementation of CAP in KIM-1 6502 interpreter

```
        ;
        ; BB CAP
        ;
cap     ldx     #$00
        lda     (pc,x)
        sta     tmp2l2 + 1
        ldx     #pc
        jsr     incr              ; pc := pc + 1
        lda     (pc,x)
        sta     tmp2l2
        ldx     #pc
        jsr     incr
        jmp     (tmp2l2)          ; jump to new address
        ;
```

Compiler error messages

2 Syntax: identifier expected
3 Syntax: Program expected
4 Syntax: ")" expected
5 Syntax: ":" exepected
6 Syntax: illegal symbol
7 Syntax: actual parameter list
8 Syntax: OF expected
9 Syntax: "(" expected
10 Syntax: type specfication expected
11 Syntax: "[" expected
12 Syntax: "]" expected
13 Syntax: END expected
14 Syntax: ";" expected
15 Syntax: integer expected
16 Syntax: "-" expected
17 Syntax: BEGIN expected
18 Syntax: error in declaration part
19 Syntax: error in field list
20 Syntax: "," expected
21 Syntax: "*" expected

50 Syntax: "error in constant
51 Syntax: ":=" expected
52 Syntax: THEN expected
53 Syntax: UNTIL expected
54 Syntax: DO expected
55 Syntax: TO/DOWNTO expected
56 Syntax: IF expected
58 Syntax: ill-formed expression
59 Syntax: error in variable

101 Identifier declared twice
102 Low bound exceeds high-bound
103 Identifier is not a type identifier
104 Identifier not declared
105 Sign not allowed
106 Number expected
107 Incompatible subrange types
110 Tag type must be an ordinal type
111 Incompatible with tag type
113 Index type must be an ordinal type
115 Base type must be scalar or subrange
116 Error in type of procedure parameter
117 Unsatisfied forward reference
118 Forward reference type identifier
119 Forward declared : repetition par. list
120 Function result: scalar,subrange,pointer' ;

122 Forward declared: repetition result type' ;
123 Missing result type in function declar.
125 Error in type of standard function par.
126 Number of parameters disagrees with decl' ;
129 Incompatible operands
130 Expression is not of SET type
131 Test on equality allowed only
132 Inclusion not allowed in set comparisons' ;
134 Illegal type of operands
135 Boolean operands required
136 Set element must be scalar or subrange
137 Set element types not compatible
138 Type must be array
139 Index type is not compatible with decl.
140 Type must be record
141 Type must be pointer
142 Illegal parameter substitution
143 Illegal type of loop control variable
144 Illegal type of expression
145 Type conflict
147 Case label and case expression not comp.' ;
148 Subrange bounds must be scalar
149 Index type must not be an integer
150 Assignment to standard function illegal
152 No such field in this record
154 Actual parameter must be a variable
155 Control variable declared interm. level
156 Value already as a label in CASE
157 Too many cases in CASE statement
160 Previous declaration was not forward
161 Again forward declared
169 SET element not in range 0 .. 63
170 String constant must not exceed one line' ;
171 Integer constant exceeds range (32767)
172 Too many nested scopes of identifiers
173 Too many nested procedures/functions
174 Index expression out of bounds
175 Internal compiler error : standard funct' ;
176 Illegal character found
177 Error in type
178 Illegal reference to variable
179 Internal error : wrong size variable
180 Maximum number of files exceeded