

APPENDIX C: P-MACHINE OPCODES AND OPERATOR EXECUTION TIMES

This appendix presents tables of P-machine opcodes and operator execution times. Table C-1 presents the opcodes, and Table C-2 presents the operator execution times. Table C-3 lists the P-codes in a Pascal-like metalanguage.

C-1. P-MACHINE OPCODES

Instructions are one byte long, followed by zero-to-three parameters. *Most parameters specify one word of information and are one of five basic types.

UB Unsigned byte: high-order byte of parameter is implicitly zero.

SB Signed byte: high-order byte is sign extension of bit 7.

DB Don't care byte: can be treated as SB or UB, because the value is always in the range 0..127.

B Big: this parameter is one byte long when used to represent values in the range 0..127 and is two bytes when representing values in the range 128..32767. If the first byte is in the 0..127 range, the high byte of the parameter is implicitly zero. Otherwise, bit 7 of the first byte is cleared and is used as the high order byte of the parameter. The second byte is used as the low-order byte.

W Word: the next two bytes (low byte first) are the parameter value.

These mnemonics are intended only for further understanding of P-code. Neither the Western Digital Corporation nor the University of California at San Diego provide P-code assembler software.

Table C-1. P-Machine Opcodes.

Mnemonic	Instruction Code	Parameters	Description
<u>Constant One Word Loads</u>			
SLDC	0..31		Short Load Word Constant (Value 0-31). Pushes the opcode, with high byte zero, onto the stack.
LDCN	152		Load Constant Nil (FC00). Pushes nil onto the stack.
LDCB	128	UB	Load Constant Byte. Pushes UB, with high byte zero, onto the stack.
LDCI	129	W	Load Constant Word. Pushes W onto the stack.
LCA	130	B	Load Constant Address. Pushes the word address of the constant, with offset B in the constant word block, onto the stack.
<u>Local One Word Loads and Store</u>			
SLDL1..16	32..47		Short Load Local Word. Fetches the word with offset 1..16 in the local activation record and pushes it on the stack.
LDL	135	B	Load Local Word. Fetches the word with offset B in the local activation record and pushes it on the stack.
LLA	132	B	Load Local Address. Fetches address of the word with offset B in the local activation record and pushes it on the stack.
STL	164	B	Store Local. Stores Tos into the word with offset B in the local activation record.

Table C-1. P-Machine Opcodes. (Continued)

Mnemonic	Instruction Code	Parameters	Description
<u>Global One Word Loads and Store</u>			
SLDG1..16	48..63		Short Load Global Word. Fetches the word with offset 1..16 in the base activation record and pushes it on the stack.
LDO	133	B	Load Global Word. Fetches the word with offset B in the base activation record and pushes it on the stack.
LAO	134	B	Load Global Address. Pushes the word address of the word with offset B in the base activation record.
SRO	165	B	Store Global Word. Stores Tos into the word with offset B in the base activation record.
<u>Intermediate One-Word Loads and Store</u>			
LOD	137	DB,B	Load Intermediate Word. DB indicates the number of static links to traverse to find the activation record to use. B is the offset within the activation record.
LDA	136	DB,B	Load Intermediate Address.
STR	166	DB,B	Store Intermediate Word.
<u>Indirect One-Word Loads and Store</u>			
STO	196		Store Indirect. Tos is stored into the word pointed to by Tos-1.

C-2. PASCAL MICROENGINE OPERATOR EXECUTION TIMES

Table C-2 presents the execution time of all 3.0 P-code operators. Any P-code operator is made up of several operations. Any one of these operations would normally be considered as one machine-language operator on a non-stack machine. Therefore, P-code operator timings are not comparable to nonstack-machine-operator timings.

The operators are grouped by operation. The left-hand column contains the P-code mnemonic, followed by the 8-bit opcode for that P-code. Next, the P-code parameters zero to three are given. All execution times are in microseconds and were measured on an ME1600 running at 2.5 mhz.

Many of the P-code execution times are data dependent. For this table, the best and worst times are listed with comments describing how the values relate to the operands of the instruction. For some P-codes, the execution time between the best and worst is equally probable, depending on the execution environment. However, for some of these data-dependent P-codes, the execution times near the best case values are more probable than those of the worst case. For example, all operators that require static link traversal (LOD, LDA, STR, CPI, CXI, and LSL) traverse one-to-four links. In fact, compiler enforced restrictions disallow traversals of more than eight links. Thus, the worst case execution time for any of those P-codes, while theoretically possible, can never occur.

Under the mnemonic for each P-code is a notational description of the P-machine stack both before and after the execution of the P-code. A stack status description consists of a single pair of enclosing brackets ([]). The stack status on the left side of the colon represents the status prior to execution of the P-code, while the stack status on right of the colon represents the status following the execution of the P-code. Within the brackets, the stack grows from left to right, with individual operands separated by commas. Operands within stack status descriptions are of the following types:

- activation - a block of four, 16-bit words representing the record of activation of a procedure or function (MSCW).
- addr - a 16-bit word address.
- bool - a 16-bit value representing a Pascal BOOLEAN. The low-order bit signifies the Boolean value, all other bits are 0. A value of 0 represents FALSE; a value of 1 represents TRUE.
- byte-ptr - two, 16-bit values representing the address of an 8-bit byte.

func-result - either 1 or 2 16-bit values representing the result of a function left on the stack when returning from a function. No words are left on return from a procedure.

int - a 16-bit two's complement Pascal INTEGER.

nil - a 16-bit value representing a NIL pascal pointer.

pack-ptr - a "packed field pointer": three, 16-bit values defining the address of field of a packed variable. The values, from highest to lowest stack position, are 1) the rightmost bit # of the packed field, 2) the field width in bits and 3) the address of the word containing the field.

param - a block of 16-bit words representing the values of the parameters being passed to a procedure or function.

real - two, 16-bit values representing a Pascal REAL. One value contains the sign, exponent and high-order mantissa bits, the other value contains the low-order mantissa bits.

seg#/proc# - a 16-bit word containing 2, 8-bit bytes. The high byte is the segment number; the low byte, the procedure number of a procedure or function being invoked via P-code CPF.

set - a block of 1..256, 16-bit words representing a Pascal SET. The highest word in the set defines the number of words in the block of words below.

word - a 16-bit value.

word-block - a block of 2..255, 16-bit words.

All P-code parameters are one of five basic types :

UB - "Unsigned byte" : value in the range 0..255, high-order byte is implicitly zero.

SB - "Signed byte" : value in the range -128..127, high-order byte is implicitly sign extension of bit 7.

DB - "Don't care byte" : value in the range 0..127, high-order byte is implicitly 0.

B - "Big" : one byte long when used to represent values in the range 0..127; two bytes long when used to represent values in the range 128..32767. If the first byte is in the range 0..127, the high byte is implicitly 0. Otherwise, bit 7 of the first byte is cleared, and the first byte is used as the high-order byte of the parameter. The second byte is used as the low-order byte.

W - "Word" : two-byte value in the range 0..32767. The first byte is used as the low byte of the parameter.

Table C-2. Operator Execution Times.

Mnemonic	Opcode	Parameters	Time	Remarks
<u>Constant One-Word Loads</u>				
SLDC0..31 [] : [word]	0..31		2.8	
LDCN [] : [nil]	152		6.4	
LDCB [] : [word]	128	UB	5.6	
LDCI [] : [word]	129	W	8.4	
LCA [] : [addr]	130	B	8.0	
<u>Local One-Word Loads and Stores</u>				
SLDL1..16 [] : [word]	32..47		6.4	
LDL [] : [word]	135	B	9.6	
LIA [] : [addr]	132	B	7.6	
STL [word] : []	164	B	9.6	

Table C-2. Operator Execution Times. (Continued)

Mnemonic	Opcode	Parameters	Time	Remarks
<u>Global One-Word Loads and Stores</u>				
SLD01..16 [] : [word]	48..63		7.2	
LDO [] : [word]	133	B	10.0	
LAO [] : [addr]	134	B	8.0	
SRO [word] : []	165	B	13.2	
<u>Intermediate One-Word Loads and Stores</u>				
LOD [] : [word]	137	DB, B	17.2 to 423.6	17.2 + 3.2(DB).
LDA [] : [addr]	136	DB, B	15.2 to 421.6	15.2 + 3.2(DB).
STR [word] : []	166	DB, B	16.8 to 423.2	16.8 + 3.2(DB).
<u>Indirect One-Word Loads and Stores</u>				
STO [addr, word] : []	196		8.0	

Table C-2. Operator Execution Times. (Continued)

Mnemonic	Opcode	Parameters	Time	Remarks
<u>Extended One-Word Loads and Stores</u>				
LDE	154	UB, B	26.8	
		[] : [word]		
LAE	155	UB, B	24.8	
		[] : [addr]		
STE	217	UB, B	26.0	
		[word] : []		
<u>Multiple-Word Loads and Stores (Sets and Reals)</u>				
LDC	131	B, UB	18.0 to 1038.0	18.0 + 4.0(UB)
		[] : [word-block]		
LDM	208	UB	10.4 to 1540.4	10.4 + 6.0(UB)
		[addr] : [word-block]		
STM	142	UB	12.4 to 1532.4	12.4 + 6.0(UB)
		[word-block,addr] : []		
<u>Byte Arrays</u>				
LDB	167		12.0	
		[byte-ptr] : [word]		
STB	200		13.6	
		[byte-ptr,word] : []		

Table C-2. Operator Execution Times. (Continued)

Mnemonic	Opcode	Parameters	Time	Remarks
Record and Array Indexing and Assignment				
MOV	197	B	13.2 to 196615.2	13.2 + 6.0(B).
[addr,addr] : []				
SIND0..7	120..127		8.4	
[addr] : [word]				
IND	230	B	12.4	
[addr] : [word]				
INC	231	B	9.6	
[addr] : [addr]				
IXA	215	B	9.6 to 56.8	9.6 is best case time (index (TOS) is 0), time increases when index exceeds B. Worst case time (56.8) arrives with array element size (B) of 16384.
[addr,word] : [addr]				
IXP	216	UB1, UB2		
[addr,word] : [pack-ptr]				
	Elements per word	Best time	Worst time	Times indicated are for indices (TOS) in the 1st word of the array. Values in parenthesis indicate index range for which the corresponding time is obtained. ALL times are 73.6 larger if index is not in 1st word.
	3	27.6(0)	37.2(2)	
	4	27.6(0)	38.8(3)	
	5	27.6(0)	39.6(4)	
	8	27.6(0)	38.0(3..7)	
	16	27.6(0)	35.6(2..15)	
LDP	201		18.4 to 50.4	18.4 + 2.0(fieldwidth) + 2.0(right bit #).
[pack-ptr] : [word]				
STP	202		20.4 to 64.4	20.4 + 2.0(fieldwidth) + 2.8(right bit #).
[pack-ptr,word] : []				

Table C-2. Operator Execution Times. (Continued)

Mnemonic	Opcode	Parameters	Time	Remarks
<u>Logicals</u>				
LAND	161	[word,word] : [word]	8.0	
LOR	160	[word,word] : [word]	8.0	
LNOT	229	[word] : [word]	5.2	
BNOT	159	[bool.] : [bool.]	6.0	
LEUSW	180	[word,word] : [bool]	9.6 10.4	TRUE FALSE
GEUSW	181	[word,word] : [bool]	9.6 10.4	TRUE FALSE