

INTERNATIONAL
STANDARD

ISO
8485

First edition
1989-11-01

Programming languages — APL

Languages de programmation — APL



Reference number
ISO 8485 : 1989 (E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 8485 was prepared by Technical Committee ISO/TC 97, *Information processing systems*.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Annexes A and B are for information only.

© ISO 1989

All rights reserved. No part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from the publisher.

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

CONTENTS

0 Introduction	3
1 Scope and Field of Application	5
2 References	7
3 Form of the Standard	9
3.1 Form of Definitions	9
3.2 Named Arrays in Examples	10
3.3 Notes	10
3.4 Cross-References	10
3.5 General Definitions	11
4 Compliance	13
4.1 Conforming Implementations	13
4.1.1 Required Behaviour for Conforming Implementations	13
4.1.2 Required Documentation for Conforming Implementations	14
4.1.2.1 Documentation of Optional-Facilities	14
4.1.2.2 Documentation of Implementation-Defined-Facilities	14
4.1.2.3 Consistent Extensions	14
4.2 Conforming Programs	15
4.2.1 Required Behaviour for Conforming Programs	15
4.2.2 Required Documentation for Conforming Programs	15
5 Definitions	17
5.1 Characters	17
5.2 Numbers	19
5.2.1 Elementary Operations	19
5.2.2 Number Constants	20
5.2.3 Subsets of the Set of Numbers	21
5.2.4 Implementation Algorithms	23
5.2.5 Defined Operations	24
5.3 Objects	26
5.3.1 Lists	26
5.3.2 Arrays	27
5.3.3 Defined-Functions	29
5.3.4 Tokens	30
5.3.4.1 Metaclasses	32
5.3.4.2 Index-List	33
5.3.5 Symbols	33
5.3.6 Contexts	34
5.3.7 Workspaces	34
5.3.8 Sessions	35
5.3.9 Shared-Variables	36
5.3.10 Systems	37
5.4 Evaluation Sequences	39
5.4.1 Evaluation Sequence Phrases	39
5.4.2 Diagrams	41
5.5 Other Terms	42

6 Syntax and Evaluation	.....	43
6.1 Introduction	.....	43
6.1.1 Evaluate-Line	.....	43
6.1.2 Character-Diagrams	.....	45
6.1.3 Evaluate-Statement	.....	52
6.1.4 Bind-Token-Class	.....	53
6.1.5 Literal-Conversion	.....	54
6.1.6 Statement-Analysis Token-Diagrams	.....	55
6.2 Reduce-Statement	.....	60
6.3 The Phrase Evaluators	.....	63
6.3.1 Diagrams	.....	64
6.3.2 Remove-Parentheses	.....	65
6.3.3 Evaluate-Niladic-Function	.....	65
6.3.4 Evaluate-Monadic-Function	.....	66
6.3.5 Evaluate-Monadic-Operator	.....	68
6.3.6 Evaluate-Dyadic-Function	.....	69
6.3.7 Evaluate-Dyadic-Operator	.....	71
6.3.8 Evaluate-Indexed-Reference	.....	72
6.3.9 Evaluate-Assignment	.....	73
6.3.10 Evaluate-Indexed-Assignment	.....	74
6.3.11 Evaluate-Variable	.....	75
6.3.12 Build-Index-List	.....	76
6.3.13 Process-End-of-Statement	.....	77
6.4 The Form Table	.....	78
7 Scalar Functions	.....	83
7.1 Monadic Scalar Functions	.....	84
7.1.1 Conjugate	..... $Z \leftarrow + B$	84
7.1.2 Negative	..... $Z \leftarrow - B$	84
7.1.3 Signum	..... $Z \leftarrow \times B$	85
7.1.4 Reciprocal	..... $Z \leftarrow \div B$	85
7.1.5 Floor	..... $Z \leftarrow \lfloor B$	86
7.1.6 Ceiling	..... $Z \leftarrow \lceil B$	86
7.1.7 Exponential	..... $Z \leftarrow * B$	87
7.1.8 Natural Logarithm	..... $Z \leftarrow \otimes B$	87
7.1.9 Magnitude	..... $Z \leftarrow | B$	88
7.1.10 Factorial	..... $Z \leftarrow ! B$	88
7.1.11 Pi times	..... $Z \leftarrow o B$	89
7.1.12 Not	..... $Z \leftarrow \sim B$	89
7.2 Dyadic Scalar Functions	.....	90
7.2.1 Plus	..... $Z \leftarrow A + B$	91
7.2.2 Minus	..... $Z \leftarrow A - B$	91
7.2.3 Times	..... $Z \leftarrow A \times B$	92
7.2.4 Divide	..... $Z \leftarrow A \div B$	92
7.2.5 Maximum	..... $Z \leftarrow A \lceil B$	93
7.2.6 Minimum	..... $Z \leftarrow A \lfloor B$	93
7.2.7 Power	..... $Z \leftarrow A * B$	94
7.2.8 Logarithm	..... $Z \leftarrow A \otimes B$	94
7.2.9 Residue	..... $Z \leftarrow A | B$	95
7.2.10 Binomial	..... $Z \leftarrow A ! B$	96
7.2.11 Circular Functions	..... $Z \leftarrow A o B$	97
7.2.12 And	..... $Z \leftarrow A \wedge B$	99
7.2.13 Or	..... $Z \leftarrow A \vee B$	99
7.2.14 Nand	..... $Z \leftarrow A \wedge\bar{B}$	100
7.2.15 Nor	..... $Z \leftarrow A \bar{\wedge} B$	100
7.2.16 Equal	..... $Z \leftarrow A = B$	101
7.2.17 Less than	..... $Z \leftarrow A < B$	103
7.2.18 Less than or equal to	..... $Z \leftarrow A \leq B$	103
7.2.19 Not equal	..... $Z \leftarrow A \neq B$	104
7.2.20 Greater than or equal to	..... $Z \leftarrow A \geq B$	104
7.2.21 Greater than	..... $Z \leftarrow A > B$	105

8 Structural Primitive Functions	.....	107
8.1 Introduction	.....	107
8.2 Monadic Structural Primitive Functions	.....	107
8.2.1 Ravel	..... $Z \leftarrow , B$	107
8.2.2 Shape	..... $Z \leftarrow p B$	108
8.2.3 Index Generator	..... $Z \leftarrow i B$	109
8.3 Dyadic Structural Primitive Functions	.....	110
8.3.1 Reshape	..... $Z \leftarrow A p B$	110
8.3.2 Join	..... $Z \leftarrow A , B$	111
9 Operators	.....	113
9.1 Introduction	.....	113
9.2 Monadic Operators	.....	114
9.2.1 Reduction	..... $Z \leftarrow f/ B$	114
9.2.1 Reduction	..... $Z \leftarrow f/[K] B$	114
9.2.1 Reduction	..... $Z \leftarrow f\# B$	114
9.2.1 Reduction	..... $Z \leftarrow f\#[K] B$	114
9.2.2 Scan	..... $Z \leftarrow f\backslash B$	116
9.2.2 Scan	..... $Z \leftarrow f\backslash[K] B$	116
9.2.2 Scan	..... $Z \leftarrow f\# B$	116
9.2.2 Scan	..... $Z \leftarrow f\#[K] B$	116
9.3 Dyadic Operators	.....	117
9.3.1 Outer Product	..... $Z \leftarrow A \circ . f B$	117
9.3.2 Inner Product	..... $Z \leftarrow A f . g B$	118
10 Mixed Functions	.....	119
10.1 Monadic Mixed Functions	.....	119
10.1.1 Roll	..... $Z \leftarrow ? B$	119
10.1.2 Grade Up	..... $Z \leftarrow \Delta B$	121
10.1.3 Grade Down	..... $Z \leftarrow \nabla B$	122
10.1.4 Reverse	..... $Z \leftarrow \phi B$	123
10.1.4 Reverse	..... $Z \leftarrow \theta B$	123
10.1.4 Reverse	..... $Z \leftarrow \phi[K] B$	123
10.1.4 Reverse	..... $Z \leftarrow \theta[K] B$	123
10.1.5 Monadic Transpose	..... $Z \leftarrow \& B$	124
10.1.6 Matrix Inverse	..... $Z \leftarrow \boxdot B$	125
10.1.7 Execute	..... $Z \leftarrow \Phi B$	126
10.2 Dyadic Mixed Functions	.....	127
10.2.1 Join Along an Axis	..... $Z \leftarrow A ,[K] B$	127
10.2.2 Index of	..... $Z \leftarrow A i B$	130
10.2.3 Member of	..... $Z \leftarrow A \in B$	131
10.2.4 Deal	..... $Z \leftarrow A ? B$	132
10.2.5 Compress	..... $Z \leftarrow A / B$	133
10.2.5 Compress	..... $Z \leftarrow A \# B$	133
10.2.5 Compress	..... $Z \leftarrow A /[K] B$	133
10.2.5 Compress	..... $Z \leftarrow A \#\![K] B$	133
10.2.6 Expand	..... $Z \leftarrow A \backslash B$	135
10.2.6 Expand	..... $Z \leftarrow A \times B$	135
10.2.6 Expand	..... $Z \leftarrow A \backslash[K] B$	135
10.2.6 Expand	..... $Z \leftarrow A \times[K] B$	135
10.2.7 Rotate	..... $Z \leftarrow A \phi B$	137
10.2.7 Rotate	..... $Z \leftarrow A \theta B$	137
10.2.7 Rotate	..... $Z \leftarrow A \phi[K] B$	137
10.2.7 Rotate	..... $Z \leftarrow A \theta[K] B$	137
10.2.8 Base Value	..... $Z \leftarrow A \perp B$	139
10.2.9 Representation	..... $Z \leftarrow A \top B$	140
10.2.10 Dyadic Transpose	..... $Z \leftarrow A \& B$	142
10.2.11 Take	..... $Z \leftarrow A \uparrow B$	144
10.2.12 Drop	..... $Z \leftarrow A \downarrow B$	145
10.2.13 Matrix Divide	..... $Z \leftarrow A \boxdot B$	146
10.2.14 Indexed Reference	..... $Z \leftarrow A[I]$	147
10.2.15 Indexed Assignment	..... $Z \leftarrow V[I] \leftarrow B$	148

11 System Functions	.....	151
11.1 Introduction	.....	151
11.2 Definition	.....	151
11.3 Diagram	.....	151
11.4 Niladic System Functions	.....	152
11.4.1 Time Stamp	.....	Z ← $\square T S$ 152
11.4.2 Atomic Vector	.....	Z ← $\square A V$ 153
11.4.3 Line Counter	.....	Z ← $\square L C$ 153
11.5 Monadic System Functions	.....	154
11.5.1 Delay	.....	Z ← $\square D L B$ 154
11.5.2 Name Class	.....	Z ← $\square N C B$ 155
11.5.3 Expunge	.....	Z ← $\square E X B$ 156
11.5.4 Name List	.....	Z ← $\square N L B$ 156
11.5.5 Query Stop	.....	Z ← $\square S T O P B$ 157
11.5.6 Query Trace	.....	Z ← $\square T R A C E B$ 157
11.6 Dyadic System Functions	.....	158
11.6.1 Name List	.....	Z ← A $\square N L B$ 158
11.6.2 Set Stop	.....	Z ← A $\square S T O P B$ 158
11.6.3 Set Trace	.....	Z ← A $\square T R A C E B$ 159
12 System Variables	.....	161
12.1 Definitions	.....	161
12.2 Evaluation Sequences	.....	162
12.2.1 Comparison Tolerance	.....	Z ← $\square C T \leftarrow B$ 162
12.2.1 Comparison Tolerance	.....	Z ← $\square C T$ 162
12.2.2 Random Link	.....	Z ← $\square R L \leftarrow B$ 163
12.2.2 Random Link	.....	Z ← $\square R L$ 163
12.2.3 Print Precision	.....	Z ← $\square P P \leftarrow B$ 164
12.2.3 Print Precision	.....	Z ← $\square P P$ 164
12.2.4 Index Origin	.....	Z ← $\square I O \leftarrow B$ 165
12.2.4 Index Origin	.....	Z ← $\square I O$ 165
12.2.5 Latent Expression	.....	Z ← $\square L X \leftarrow B$ 166
12.2.5 Latent Expression	.....	Z ← $\square L X$ 166
12.2.5 Latent Expression	.....	Z ← $\square L X[I] \leftarrow B$ 166
13 Defined Functions	.....	167
13.1 Introduction	.....	167
13.2 Definitions	.....	168
13.3 Diagrams	.....	171
13.4 Operations	.....	174
13.4.1 Call-Defined-Function	.....	Z ← $\square D F N$ 174
13.4.1 Call-Defined-Function	.....	Z ← $\square D F N B$ 174
13.4.1 Call-Defined-Function	.....	Z ← A $\square D F N B$ 174
13.4.2 Defined-Function-Control	.....	..... 175
13.4.3 Function Fix	.....	Z ← $\square F X B$ 176
13.4.4 Character Representation	.....	Z ← $\square C R B$ 177
13.5 Function Editing	.....	178
13.5.1 Evaluate-Function-Definition-Request	.....	178
13.5.2 Evaluate-Editing-Request	.....	180
13.5.3 Diagrams	.....	181
14 Shared Variables	.....	183
14.1 Informal Introduction	.....	183
14.2 Definitions	.....	186
14.3 Diagrams	.....	186
14.4 Operations	.....	186
14.4.1 Primary-Name	.....	186
14.4.2 Surrogate-Name	.....	186
14.4.3 Degree-of-Coupling	.....	186
14.4.4 Access-Control-Vector	.....	186
14.4.5 Offer	.....	187
14.4.6 Retract	.....	188
14.4.7 Shared-Variable-Reset	.....	188

14.5 Shared Variable Forms	189
14.5.1 Shared Variable Reference	Z \leftarrow SHV 189
14.5.2 Shared Variable Assignment	Z \leftarrow SHV \leftarrow B 189
14.5.3 Shared Variable Indexed Assignment	Z \leftarrow SHV[I] \leftarrow B 190
14.6 Shared Variable System Functions	191
14.6.1 Shared Variable Access Control Inquiry	Z \leftarrow OSVC B 191
14.6.2 Shared Variable Query	Z \leftarrow OSVQ B 192
14.6.3 Shared Variable Degree of Coupling	Z \leftarrow OSVO B 193
14.6.4 Shared Variable Offer	Z \leftarrow A OSVO B 194
14.6.5 Shared Variable Retraction	Z \leftarrow OSVR B 195
14.6.6 Shared Variable Access Control Set	Z \leftarrow A OSVC B 196
15 Formatting and Numeric Conversion	197
15.1 Introduction	197
15.2 Numeric Conversion	197
15.2.1 Numeric-Input-Conversion	198
15.2.2 Numeric-Output-Conversion	199
15.3 Diagrams	199
15.4 Operations	203
15.4.1 Monadic Format	Z \leftarrow Φ B 203
15.4.2 Dyadic Format	Z \leftarrow A Φ B 206
16 Input and Output	209
16.1 Introduction	209
16.2 Definitions	209
16.2.1 User Facilities	209
16.2.2 Implementation Algorithms	210
16.2.3 Prompts	211
16.3 Diagrams	211
16.4 Operations	212
16.4.1 Immediate-Execution	212
16.4.2 Quad Input	Z \leftarrow \square 213
16.4.3 Quote Quad Input	Z \leftarrow q 214
16.4.4 Quad Output	Z \leftarrow $\square \leftarrow$ B 214
16.4.5 Quote Quad Output	Z \leftarrow $\text{q} \leftarrow$ B 215
17 System Commands	217
17.1 Introduction	217
17.2 Definitions	217
17.3 Diagrams	218
17.4 Operations	219
17.4.1 Evaluate-System-Command	219
17.5 Diagrams and Evaluation Sequences	220
Annex A. The APL Character Set for Workspace Interchange	225
Annex B: The Workspace Interchange Convention	233
B.1 Introduction	233
B.1.1 Purpose of the Convention	233
B.1.2 Organisation of the Convention	233
B.2 Level 1 Description	234
B.2.1 Canonical Representation Vectors	234
B.2.2 Representation of Variables	235
B.2.3 Representation of Functions	236
B.2.4 Representation of Executable Expressions	237
B.3 Level 2 Description	238
B.3.1 Multiple Canonical Representation Vectors	238
B.3.2 Workspace Environment	238
B.3.3 Pseudovariables	239
B.3.4 Interchange Convention Identifier	239
B.3.5 Escape	239
B.3.6 Bits	239
B.3.7 Translate	239
B.3.8 Note	240
B.3.9 Workspace Identifier	240
B.3.10 End of the Stream	240

B.3.11 Inclusion of Nonstandard Material	240
B.3.12 Use of Other Types	241
B.4 Level 3 Description	242
B.4.1 Atoms	242
B.4.2 Registered character sets	242
B.4.3 Escape sequences	242
B.4.4 Registered characters	242
B.4.5 ISO-APL characters	242
B.4.6 Characters	243
B.4.7 The Translate Table	243
B.4.8 Example	244
B.4.9 Escape	244
B.4.10 Bits	244
B.4.11 Translate	244
B.4.12 Example	245
B.4.13 Mapping of Characters to Bits	245
B.4.14 Stage 1 Translation	245
B.4.15 Stage 2 Translation	245
B.4.16 Example	246
B.4.17 Summary	246
B.5 Level 4 Description	247
B.5.1 Physical Media	247
B.5.2 Nine-track Magnetic Tape	247
B.6 Extended Example	248
Bibliography	253
INDEX	255

Programming languages — APL

This page intentionally left blank

0 INTRODUCTION

APL stands for **A Programming Language**. It is a notation invented by K. E. Iverson in the late 1950s for the description of algorithms, and expanded on and made into the programming system *APL\360* by Iverson and his colleagues Adin Falkoff, Larry Breed, Dick Lathwell, and Roger Moore in the mid-1960s.

Throughout this document

- the term “this standard” is understood to mean “this International Standard”;
- the words “chapter”, “section” and “subsection” are understood to mean “clause”, “subclause” and “sub-subclause”, respectively.

This page intentionally left blank

1 SCOPE AND FIELD OF APPLICATION

This standard defines the programming language APL and the environment in which APL programs are executed. Its purpose is to facilitate interchange and promote portability of APL programs and programming skills.

This standard specifies the syntax and semantics of APL programs and the characteristics of the environment in which APL programs are executed.

It also specifies requirements for conformance to this standard, including the publication of values and characteristics of implementation properties so that conforming implementations can be meaningfully compared.

This standard does not specify:

implementation properties that are likely to vary with the particular equipment or operating system used;

required values for implementation limits such as APL workspace size or numeric precision;

the data structures used to represent APL objects;

the facilities available through shared variables.

This page intentionally left blank

2 REFERENCES

ISO 2375 : 1985, *Data processing — Procedure for registration of escape sequences*.

ISO 2382-15 : 1985, *Data processing — Vocabulary — Part 15: Programming languages*.