ISO/IEC 1539-1:2023-11 (E)

Programming languages - Fortran - Part 1: Base language

Contents

Page

Foreword . . . xii

Introduction . . . xiii

1 Scope . . . 1

2 Normative references . . . 2

3 Terms and definitions . . . 3

4 Notation, conformance, and compatibility . . . 30
4.1 Notation, symbols and abbreviated terms . . . 30
4.1.1 Syntax rules . . . 30
4.1.2 Constraints . . . 31
4.1.3 Assumed syntax rules . . . 31
4.1.4 Syntax conventions and characteristics . . . 31
4.1.5 Text conventions . . . 32
4.2 Conformance . . . 32
4.3 Compatibility . . . 33
4.3.1 Previous Fortran standards . . . 33
4.3.2 New intrinsic procedures . . . 33
4.3.3 Fortran 2018 compatibility . . . 33
4.3.4 Fortran 2008 compatibility . . . 34
4.3.5 Fortran 2003 compatibility . . . 35
4.3.6 Fortran 95 compatibility . . . 36
4.3.7 Fortran 90 compatibility . . . 36
4.3.8 FORTRAN 77 compatibility . . . 37
4.4 Deleted and obsolescent features . . . 37
4.4.1 General . . . 37
4.4.2 Nature of deleted features . . . 37
4.4.3 Nature of obsolescent features . . . 38

5 Fortran concepts . . . 39
5.1 High level syntax . . . 39
5.2 Program unit concepts . . . 42
5.2.1 Program units and scoping units . . . 42
5.2.2 Program . . . 42
5.2.3 Procedure . . . 42
5.2.4 Module . . . 43
5.2.5 Submodule . . . 43
5.3 Execution concepts . . . 43
5.3.1 Statement classification . . . 43
5.3.2 Statement order . . . 43
5.3.3 The END statement . . . 44
5.3.4 Program execution . . . 44
5.3.5 Execution sequence . . . 45

5.3.6 Image execution states . . . 45
5.3.7 Termination of execution . . . 46
5.4 Data concepts . . . 46
5.4.1 Type . . . 46
5.4.2 Data value . . . 47
5.4.3 Data entity . . . 47
5.4.4 Definition of objects and pointers . . . 48
5.4.5 Reference . . . 49
5.4.6 Array . . . 49
5.4.7 Coarray . . . 49
5.4.8 Established coarrays . . . 50
5.4.9 Pointer . . . 50
5.4.10 Allocatable variables . . . 50
5.4.11 Storage . . . 51
5.5 Fundamental concepts . . . 51
5.5.1 Names and designators . . . 51
5.5.2 Statement keyword . . . 51
5.5.3 Other keywords . . . 51
5.5.4 Association . . . 51
5.5.5 Intrinsic . . . 51
5.5.6 Operator . . . 52
5.5.7 Companion processors . . . 52

6 Lexical tokens and source form . . . 53
6.1 Processor character set . . . 53
6.1.1 Characters . . . 53
6.1.2 Letters . . . 53
6.1.3 Digits . . . 53
6.1.4 Underscore . . . 53
6.1.5 Special characters . . . 53
6.1.6 Other characters . . . 54
6.2 Low-level syntax . . . 54
6.2.1 Tokens . . . 54
6.2.2 Names . . . 54
6.2.3 Constants . . . 55
6.2.4 Operators . . . 55
6.2.5 Statement labels . . . 56
6.2.6 Delimiters . . . 56
6.3 Source form . . . 57
6.3.1 Program units, statements, and lines . . . 57
6.3.2 Free source form . . . 57
6.3.3 Fixed source form . . . 58
6.4 Including source text . . . 59

7 Types . . . 61
7.1 Characteristics of types . . . 61
7.1.1 The concept of type . . . 61
7.1.2 Type classification . . . 61
7.1.3 Set of values . . . 61
7.1.4 Constants . . . 61
7.1.5 Operations . . . 61
7.2 Type parameters . . . 62
7.3 Types, type specifiers, and values . . . 63
7.3.1 Relationship of types and values to objects . . . 63
7.3.2 Type specifiers . . . 63
7.3.3 Type compatibility . . . 65

7.4 Intrinsic types . . . 66
7.4.1 Classification and specification . . . 66
7.4.2 Intrinsic operations on intrinsic types . . . 66
7.4.3 Numeric intrinsic types . . . 66
7.4.4 Character type . . . 70
7.4.5 Logical type . . . 73
7.5 Derived types . . . 73
7.5.1 Derived type concepts . . . 73
7.5.2 Derived-type definition . . . 74
7.5.3 Derived-type parameters . . . 77
7.5.4 Components . . . 79
7.5.5 Type-bound procedures . . . 85
7.5.6 Final subroutines . . . 88
7.5.7 Type extension . . . 90
7.5.8 Derived-type values . . . 92
7.5.9 Derived-type specifier . . . 92
7.5.10 Construction of derived-type values . . . 92
7.5.11 Derived-type operations and assignment . . . 95
7.6 Other nonintrinsic types . . . 95
7.6.1 Interoperable enumerations and enum types . . . 95
7.6.2 Enumeration types . . . 97
7.7 Binary, octal, and hexadecimal literal constants . . . 99
7.8 Construction of array values . . . 100

8 Attribute declarations and specifications . . . 103
8.1 Attributes of procedures and data objects . . . 103
8.2 Type declaration statement . . . 103
8.3 Automatic data objects . . . 105
8.4 Initialization . . . 105
8.5 Attributes . . . 105
8.5.1 Attribute specification . . . 105
8.5.2 Accessibility attribute . . . 106
8.5.3 ALLOCATABLE attribute . . . 106
8.5.4 ASYNCHRONOUS attribute . . . 106
8.5.5 BIND attribute for data entities . . . 107
8.5.6 CODIMENSION attribute . . . 107
8.5.7 CONTIGUOUS attribute . . . 109
8.5.8 DIMENSION attribute . . . 110
8.5.9 EXTERNAL attribute . . . 114
8.5.10 INTENT attribute . . . 114
8.5.11 INTRINSIC attribute . . . 116
8.5.12 OPTIONAL attribute . . . 116
8.5.13 PARAMETER attribute . . . 116
8.5.14 POINTER attribute . . . 117
8.5.15 PROTECTED attribute . . . 117
8.5.16 SAVE attribute . . . 118
8.5.17 RANK clause . . . 118
8.5.18 TARGET attribute . . . 119
8.5.19 VALUE attribute . . . 119
8.5.20 VOLATILE attribute . . . 119
8.6 Attribute specification statements . . . 120
8.6.1 Accessibility statement . . . 120
8.6.2 ALLOCATABLE statement . . . 121
8.6.3 ASYNCHRONOUS statement . . . 121
8.6.4 BIND statement . . . 121
8.6.5 CODIMENSION statement . . . 122

8.6.6 CONTIGUOUS statement . . . 122
8.6.7 DATA statement . . . 122
8.6.8 DIMENSION statement . . . 124
8.6.9 INTENT statement . . . 125
8.6.10 OPTIONAL statement . . . 125
8.6.11 PARAMETER statement . . . 125
8.6.12 POINTER statement . . . 125
8.6.13 PROTECTED statement . . . 126
8.6.14 SAVE statement . . . 126
8.6.15 TARGET statement . . . 126
8.6.16 VALUE statement . . . 126
8.6.17 VOLATILE statement . . . 127
8.7 IMPLICIT statement . . . 127
8.8 IMPORT statement . . . 129
8.9 NAMELIST statement . . . 131
8.10 Storage association of data objects . . . 132
8.10.1 EQUIVALENCE statement . . . 132
8.10.2 COMMON statement . . . 134
8.10.3 Restrictions on common and equivalence . . . 135

9 Use of data objects . . . 136
9.1 Designator . . . 136
9.2 Variable . . . 136
9.3 Constants . . . 137
9.4 Scalars . . . 137
9.4.1 Substrings . . . 137
9.4.2 Structure components . . . 137
9.4.3 Coindexed named objects . . . 139
9.4.4 Complex parts . . . 139
9.4.5 Type parameter inquiry . . . 139
9.5 Arrays . . . 140
9.5.1 Order of reference . . . 140
9.5.2 Whole arrays . . . 140
9.5.3 Array elements and array sections . . . 140
9.5.4 Simply contiguous array designators . . . 144
9.6 Image selectors . . . 144
9.7 Dynamic association . . . 146
9.7.1 ALLOCATE statement . . . 146
9.7.2 NULLIFY statement . . . 150
9.7.3 DEALLOCATE statement . . . 150
9.7.4 STAT= specifier . . . 152
9.7.5 ERRMSG= specifier . . . 153

10 Expressions and assignment . . . 154
10.1 Expressions . . . 154
10.1.1 Expression semantics . . . 154
10.1.2 Form of an expression . . . 154
10.1.3 Precedence of operators . . . 158
10.1.4 Evaluation of operations . . . 160
10.1.5 Intrinsic operations . . . 161
10.1.6 Defined operations . . . 167
10.1.7 Evaluation of operands . . . 168
10.1.8 Integrity of parentheses . . . 169
10.1.9 Type, type parameters, and shape of an expression . . . 169
10.1.10 Conformability rules for elemental operations . . . 171
10.1.11 Specification expression . . . 171

10.1.12 Constant expression . . . 173
10.2 Assignment . . . 174
10.2.1 Assignment statement . . . 174
10.2.2 Pointer assignment . . . 179
10.2.3 Masked array assignment – WHERE . . . 183
10.2.4 FORALL . . . 186

11 Execution control . . . 189
11.1 Executable constructs containing blocks . . . 189
11.1.1 Blocks . . . 189
11.1.2 Rules governing blocks . . . 189
11.1.3 ASSOCIATE construct . . . 190
11.1.4 BLOCK construct . . . 191
11.1.5 CHANGE TEAM construct . . . 193
11.1.6 CRITICAL construct . . . 195
11.1.7 DO construct . . . 196
11.1.8 IF construct and statement . . . 204
11.1.9 SELECT CASE construct . . . 205
11.1.10 SELECT RANK construct . . . 208
11.1.11 SELECT TYPE construct . . . 210
11.1.12 EXIT statement . . . 213
11.2 Branching . . . 213
11.2.1 Branch concepts . . . 213
11.2.2 GO TO statement . . . 213
11.2.3 Computed GO TO statement . . . 214
11.3 CONTINUE statement . . . 214
11.4 STOP and ERROR STOP statements . . . 214
11.5 FAIL IMAGE statement . . . 215
11.6 NOTIFY WAIT statement . . . 215
11.7 Image execution control . . . 216
11.7.1 Image control statements . . . 216
11.7.2 Segments . . . 217
11.7.3 SYNC ALL statement . . . 218
11.7.4 SYNC IMAGES statement . . . 219
11.7.5 SYNC MEMORY statement . . . 220
11.7.6 SYNC TEAM statement . . . 221
11.7.7 EVENT POST statement . . . 222
11.7.8 EVENT WAIT statement . . . 222
11.7.9 FORM TEAM statement . . . 222
11.7.10 LOCK and UNLOCK statements . . . 223
11.7.11 STAT= and ERRMSG= specifiers in image control statements . . . 225

12 Input/output statements . . . 228
12.1 Input/output concepts . . . 228
12.2 Records . . . 228
12.2.1 Definition of a record . . . 228
12.2.2 Formatted record . . . 228
12.2.3 Unformatted record . . . 228
12.2.4 Endfile record . . . 229
12.3 External files . . . 229
12.3.1 External file concepts . . . 229
12.3.2 File existence . . . 229
12.3.3 File access . . . 230
12.3.4 File position . . . 232
12.3.5 File storage units . . . 233
12.4 Internal files . . . 234

12.5 File connection . . . 234
12.5.1 Referring to a file . . . 234
12.5.2 Connection modes . . . 235
12.5.3 Unit existence . . . 236
12.5.4 Connection of a file to a unit . . . 236
12.5.5 Preconnection . . . 237
12.5.6 OPEN statement . . . 237
12.5.7 CLOSE statement . . . 241
12.6 Data transfer statements . . . 243
12.6.1 Form of input and output statements . . . 243
12.6.2 Control information list . . . 243
12.6.3 Data transfer input/output list . . . 248
12.6.4 Execution of a data transfer input/output statement . . . 250
12.6.5 Termination of data transfer statements . . . 261
12.7 Waiting on pending data transfer . . . 261
12.7.1 Wait operation . . . 261
12.7.2 WAIT statement . . . 261
12.8 File positioning statements . . . 262
12.8.1 Syntax . . . 262
12.8.2 BACKSPACE statement . . . 263
12.8.3 ENDFILE statement . . . 263
12.8.4 REWIND statement . . . 263
12.9 FLUSH statement . . . 264
12.10 File inquiry statement . . . 264
12.10.1 Forms of the INQUIRE statement . . . 264
12.10.2 Inquiry specifiers . . . 265
12.10.3 Inquire by output list . . . 271
12.11 Error, end-of-record, and end-of-file conditions . . . 271
12.11.1 Occurrence of input/output conditions . . . 271
12.11.2 Error conditions and the ERR= specifier . . . 272
12.11.3 End-of-file condition and the END= specifier . . . 272
12.11.4 End-of-record condition and the EOR= specifier . . . 273
12.11.5 IOSTAT= specifier . . . 273
12.11.6 IOMSG= specifier . . . 274
12.12 Restrictions on input/output statements . . . 274

13 Input/output editing . . . 275
13.1 Format specifications . . . 275
13.2 Explicit format specification methods . . . 275
13.2.1 FORMAT statement . . . 275
13.2.2 Character format specification . . . 275
13.3 Form of a format item list . . . 276
13.3.1 Syntax . . . 276
13.3.2 Edit descriptors . . . 276
13.3.3 Fields . . . 278
13.4 Interaction between input/output list and format . . . 278
13.5 Positioning by format control . . . 280
13.6 Decimal symbol . . . 280
13.7 Data edit descriptors . . . 280
13.7.1 Purpose of data edit descriptors . . . 280
13.7.2 Numeric editing . . . 281
13.7.3 Logical editing . . . 288
13.7.4 Character editing . . . 288
13.7.5 Generalized editing . . . 289
13.7.6 User-defined derived-type editing . . . 290
13.8 Control edit descriptors . . . 290

13.8.1 Position edit descriptors . . . 290
13.8.2 Slash editing . . . 291
13.8.3 Colon editing . . . 292
13.8.4 SS, SP, and S editing . . . 292
13.8.5 LZS, LZP and LZ editing . . . 292
13.8.6 P editing . . . 292
13.8.7 BN and BZ editing . . . 293
13.8.8 RU, RD, RZ, RN, RC, and RP editing . . . 293
13.8.9 DC and DP editing . . . 293
13.9 Character string edit descriptors . . . 293
13.10 List-directed formatting . . . 294
13.10.1 Purpose of list-directed formatting . . . 294
13.10.2 Values and value separators . . . 294
13.10.3 List-directed input . . . 294
13.10.4 List-directed output . . . 296
13.11 Namelist formatting . . . 298
13.11.1 Purpose of namelist formatting . . . 298
13.11.2 Name-value subsequences . . . 298
13.11.3 Namelist input . . . 298
13.11.4 Namelist output . . . 301

14 Program units . . . 303
14.1 Main program . . . 303
14.2 Modules . . . 303
14.2.1 Module syntax and semantics . . . 303
14.2.2 The USE statement and use association . . . 304
14.2.3 Submodules . . . 307
14.3 Block data program units . . . 307

15 Procedures . . . 309
15.1 Concepts . . . 309
15.2 Procedure classifications . . . 309
15.2.1 Procedure classification by reference . . . 309
15.2.2 Procedure classification by means of definition . . . 309
15.3 Characteristics . . . 310
15.3.1 Characteristics of procedures . . . 310
15.3.2 Characteristics of dummy arguments . . . 310
15.3.3 Characteristics of function results . . . 310
15.4 Procedure interface . . . 311
15.4.1 Interface and abstract interface . . . 311
15.4.2 Implicit and explicit interfaces . . . 311
15.4.3 Specification of the procedure interface . . . 312
15.5 Procedure reference . . . 321
15.5.1 Syntax of a procedure reference . . . 321
15.5.2 Actual arguments, dummy arguments, and argument association . . . 323
15.5.3 Function reference . . . 335
15.5.4 Subroutine reference . . . 335
15.5.5 Resolving named procedure references . . . 336
15.5.6 Resolving type-bound procedure references . . . 338
15.6 Procedure definition . . . 338
15.6.1 Intrinsic procedure definition . . . 338
15.6.2 Procedures defined by subprograms . . . 338
15.6.3 Definition and invocation of procedures by means other than Fortran . . . 344
15.6.4 Statement function . . . 344
15.7 Pure procedures . . . 345
15.8 Simple procedures . . . 347

15.9 Elemental procedures . . . 348
15.9.1 Elemental procedure declaration and interface . . . 348
15.9.2 Elemental function actual arguments and results . . . 348
15.9.3 Elemental subroutine actual arguments . . . 349

16 Intrinsic procedures and modules . . . 350
16.1 Classes of intrinsic procedures . . . 350
16.2 Arguments to intrinsic procedures . . . 350
16.2.1 General rules . . . 350
16.2.2 The shape of array arguments . . . 351
16.2.3 Mask arguments . . . 351
16.2.4 DIM arguments and reduction functions . . . 351
16.3 Bit model . . . 351
16.3.1 General . . . 351
16.3.2 Bit sequence comparisons . . . 352
16.3.3 Bit sequences as arguments to INT and REAL . . . 352
16.4 Numeric models . . . 352
16.5 Atomic subroutines . . . 353
16.6 Collective subroutines . . . 354
16.7 Standard generic intrinsic procedures . . . 355
16.8 Specific names for standard intrinsic functions . . . 360
16.9 Specifications of the standard intrinsic procedures . . . 362
16.9.1 General . . . 362
16.10 Standard intrinsic modules . . . 457
16.10.1 General . . . 457
16.10.2 The ISO_FORTRAN_ENV intrinsic module . . . 458

17 Exceptions and IEEE arithmetic . . . 465
17.1 Overview of IEEE arithmetic support . . . 465
17.2 Derived types, constants, and operators defined in the modules . . . 466
17.3 The exceptions . . . 466
17.4 The rounding modes . . . 469
17.5 Underflow mode . . . 469
17.6 Halting . . . 470
17.7 The floating-point modes and status . . . 470
17.8 Exceptional values . . . 470
17.9 IEEE arithmetic . . . 470
17.10 Summary of the procedures . . . 471
17.11 Specifications of the procedures . . . 473
17.11.1 General . . . 473
17.12 Examples . . . 499

18 Interoperability with C . . . 502
18.1 General . . . 502
18.2 The ISO_C_BINDING intrinsic module . . . 502
18.2.1 Summary of contents . . . 502
18.2.2 Named constants and derived types in the module . . . 502
18.2.3 Procedures in the module . . . 503
18.3 Interoperability between Fortran and C entities . . . 511
18.3.1 Interoperability of intrinsic types . . . 511
18.3.2 Interoperability with C pointer types . . . 512
18.3.3 Interoperability of enum types . . . 512
18.3.4 Interoperability of derived types and C structure types . . . 512
18.3.5 Interoperability of scalar variables . . . 513
18.3.6 Interoperability of array variables . . . 514
18.3.7 Interoperability of procedures and procedure interfaces . . . 514

18.4 C descriptors . . . 517
18.5 The source file ISO_Fortran_binding.h . . . 517
18.5.1 Summary of contents . . . 517
18.5.2 The CFI_dim_t structure type . . . 517
18.5.3 The CFI_cdesc_t structure type . . . 518
18.5.4 Macros and typedefs in ISO_Fortran_binding.h . . . 519
18.5.5 Functions declared in ISO_Fortran_binding.h . . . 521
18.6 Restrictions on C descriptors . . . 529
18.7 Restrictions on formal parameters . . . 529
18.8 Restrictions on lifetimes . . . 529
18.9 Interoperation with C global variables . . . 530
18.9.1 General . . . 530
18.9.2 Binding labels for common blocks and variables . . . 531
18.10 Interoperation with C functions . . . 531
18.10.1 Definition and reference of interoperable procedures . . . 531
18.10.2 Binding labels for procedures . . . 532
18.10.3 Exceptions and IEEE arithmetic procedures . . . 532
18.10.4 Asynchronous communication . . . 533

19 Scope, association, and definition . . . 534
19.1 Scopes, identifiers, and entities . . . 534
19.2 Global identifiers . . . 534
19.3 Local identifiers . . . 535
19.3.1 Classes of local identifiers . . . 535
19.3.2 Local identifiers that are the same as common block names . . . 536
19.3.3 Function results . . . 536
19.3.4 Components, type parameters, and bindings . . . 536
19.3.5 Argument keywords . . . 536
19.4 Statement and construct entities . . . 537
19.5 Association . . . 538
19.5.1 Name association . . . 538
19.5.2 Pointer association . . . 542
19.5.3 Storage association . . . 545
19.5.4 Inheritance association . . . 547
19.5.5 Establishing associations . . . 547
19.6 Definition and undefinition of variables . . . 548
19.6.1 Definition of objects and subobjects . . . 548
19.6.2 Variables that are always defined . . . 548
19.6.3 Variables that are initially defined . . . 548
19.6.4 Variables that are initially undefined . . . 549
19.6.5 Events that cause variables to become defined . . . 549
19.6.6 Events that cause variables to become undefined . . . 551
19.6.7 Variable definition context . . . 553
19.6.8 Pointer association context . . . 554

Annex A (informative) Processor dependencies . . . 555

Annex B (informative) Deleted and obsolescent features . . . 562

Annex C (informative) Extended notes . . . 566

Index . . . 643