
CONTENTS

Preface	xix
Chapter 1. An Introduction to Ada	1
1.1 The Text of an Ada Program	1
1.2 Notation for Ada Syntax	6
1.3 An Overview of Ada	7
1.3.1 Compilation Units	8
1.3.2 Subprograms and Main Programs	10
1.3.3 Statements	11
1.3.4 A Closer Look at Subprograms	14
1.3.5 Defining New Types	17
1.3.6 Extending the Meanings of Operators	19
1.3.7 Packages	20
1.3.8 Children of Packages	24
1.3.9 Private Types	27
1.3.10 Object-Oriented Programming	29
1.3.11 Handling Unexpected Situations	32
1.3.12 Generic Program Units	34
1.3.13 Concurrent Computations	36
1.3.14 Low-Level Interfaces	39
1.4 Differences in Ada 83	40
1.5 Summary	41
Chapter 2. Elementary Ada Programming	47
2.1 The Structure of a Simple Program	47
2.2 Object Declarations	48
2.3 Enumeration Type Declarations	51
2.3.1 Manipulation of Enumeration Types	52
2.3.2 Predefined Enumeration Types	53
2.4 Statements	54
2.4.1 The Assignment Statement	54

2.4.2	The Procedure Call Statement, Input, and Output	55
2.4.2.1	Procedure Call Statements	55
2.4.2.2	Input and Output	55
2.4.3	Conditional Statements	57
2.4.3.1	The if Statement	57
2.4.3.2	The case Statement	60
2.4.4	The null Statement	63
2.4.5	The loop Statement	64
2.4.5.1	The while Loop	64
2.4.5.2	The for Loop	65
2.4.5.3	The Basic Loop	67
2.4.6	The exit Statement	68
2.4.7	The raise Statement	74
2.4.8	The goto Statement	75
2.4.9	The return Statement	77
2.4.10	The delay Statement	78
2.4.11	Block Statements	79
2.5	Using Separately Compiled Facilities	81
2.5.1	Context Clauses	82
2.5.2	Using Generic Templates	83
2.6	Predefined Facilities	85
2.6.1	Command-Line Parameters and Return Codes	86
2.6.2	Time and Date	87
2.6.3	Mathematical Functions	89
2.6.3.1	Roots, Logarithms, and Exponents	89
2.6.3.2	Trigonometric Functions	89
2.6.3.3	Hyperbolic Functions	90
2.6.4	Random Values	91
2.7	Differences in Ada 83	93
2.8	Summary	95
Chapter 3.	Type Declarations	107
3.1	Introduction to Programmer-Defined Types	107
3.1.1	Abstract Data Types	107
3.1.2	Kinds of Data Types	109
3.1.2.1	Enumeration Types	109
3.1.2.2	Integer Types	109
3.1.2.3	Floating-Point Types	110
3.1.2.4	Fixed-Point Types	110
3.1.2.5	Array Types	111
3.1.2.6	Record Types	111
3.1.2.7	Tagged Types	112
3.1.2.8	Access Types	112
3.1.2.9	Task Types	112
3.1.2.10	Protected Types	112
3.1.2.11	Private Types	112
3.2	The Form of a Type Declaration	113

3.3 Integer Type Declarations	113
3.3.1 Signed Integer Types	114
3.3.2 Modular Integer Types	117
3.4 Discrete Types	119
3.5 Floating-Point Type Declarations	122
3.6 Fixed-Point Type Declarations	125
3.6.1 Ordinary Fixed-Point Type Declarations	125
3.6.2 Decimal Fixed-Point Type Declarations	126
3.7 Named Numbers and Universal Expressions	128
3.8 Array Type Declarations	129
3.8.1 Constrained Array Types	130
3.8.2 Unconstrained Array Types	132
3.8.3 Attributes of Arrays and Array Types	137
3.9 Record Type Declarations	139
3.10 Complex Numbers	141
3.11 More About Enumeration Type Declarations	145
3.12 Evaluation of Expressions in Declarations	147
3.13 “One-of-a-Kind” Arrays	149
3.14 Differences in Ada 83	151
3.15 Summary	153
Chapter 4. Subtypes Versus Distinct Types	165
4.1 Type Restrictions on the Use of Data	165
4.2 Subtypes	166
4.2.1 Subtype Declarations	168
4.2.2 Compatibility Between Subtype Names and Constraints	169
4.2.2.1 Range Constraints	170
4.2.2.2 Digits Constraints	171
4.2.2.3 Index Constraints	171
4.2.2.4 Accuracy Constraints	172
4.2.2.5 Summary	173
4.2.3 Subtypes of Array Indices	174
4.2.4 Subtypes of Array and Record Components	174
4.2.5 Predefined Subtypes	175
4.3 Differences Between Types and Subtypes	176
4.4 Attributes of Subtypes	179
4.5 Derived Types	179
4.6 Base Subtypes	182
4.7 Differences in Ada 83	184
4.8 Summary	185
Chapter 5. String Manipulation	189
5.1 Fixed-Length, Bounded-Length, and Unbounded-Length String Types	189
5.2 Constructing String Values	190
5.3 Dealing with Bounded-Length Strings That Are Too Long	192
5.4 Moving, Truncating, and Padding Fixed-Length Strings	193
5.5 Extracting and Replacing Individual Characters	194

5.6	Extracting, Inserting, Deleting, and Replacing Substrings	195
5.7	Producing Strings of a Particular Width	197
5.8	Sets of Characters and Character Translation	198
5.9	Translating, Searching, and Decomposing Strings	203
5.10	Comparing Strings	206
5.11	Picture-Directed Editing	207
5.11.1	Internal Representations of Pictures	207
5.11.2	Generation of Edited Output	208
5.11.3	Localization	208
5.11.4	Picture Strings	209
5.11.4.1	Digits and Fill Characters	209
5.11.4.2	Zeroes, Slashes, and Group Separators	209
5.11.4.3	Radix Marks (Decimal Points)	210
5.11.4.4	Currency Symbols	211
5.11.4.5	Distinguishing Negative Values	212
5.11.4.6	Replication Factors	213
5.11.4.7	Special Cases	214
5.11.5	Blank-When-Zero Pictures	214
5.11.6	Determining Properties of a Picture	214
5.11.7	Exceptions in Generating and Using Pictures	214
5.12	Manipulating Strings of Wide Characters	215
5.13	Differences in Ada 83	217
5.14	Summary	217
Chapter 6.	Expressions	227
6.1	Elementary Expressions	227
6.1.1	Literals	228
6.1.1.1	Numeric Literals	228
6.1.1.2	String Literals	229
6.1.1.3	Enumeration Literals	230
6.1.2	Names	230
6.1.3	Qualified Expressions	231
6.1.4	Aggregates	232
6.1.4.1	Array Aggregates	232
6.1.4.2	Record Aggregates	237
6.1.5	Type Conversions	239
6.1.6	Allocators	241
6.1.7	Function Calls	241
6.2	Compound Expressions	242
6.2.1	Exponentiation	243
6.2.2	Absolute Value	243
6.2.3	Multiplication and Division	243
6.2.4	Remainder	245
6.2.5	Plus and Minus	246
6.2.6	Concatenation	246
6.2.7	Relational Operators and Membership Tests	248
6.2.8	Logical Operators and Short-Circuit Control Forms	250

6.2.8.1	Logical Operators Applied to Boolean Values	251
6.2.8.2	Logical Operators Applied to Vectors of Boolean Values	251
6.2.8.3	Short-Circuit Control Forms	252
6.2.8.4	Parentheses in Logical Expressions	253
6.2.8.5	Special Rules for Types Derived from Boolean	253
6.3	Static Expressions and Static Subtypes	253
6.4	Universal Expressions	258
6.5	Differences in Ada 83	260
6.6	Summary	262
Chapter 7. Subprograms		271
7.1	Procedure Bodies	271
7.2	Function Bodies	276
7.3	Subprogram Specifications and Declarations	278
7.4	Subprogram Calls	279
7.5	Recursive Subprograms	282
7.6	Overloading	287
7.6.1	Overloading Subprograms	287
7.6.2	Defining New Meanings for Operators	292
7.6.3	Additional Details	300
7.7	Nesting Subprograms	302
7.8	The Inline Pragma	305
7.9	The Process of Passing Parameters	307
7.10	Differences in Ada 83	309
7.11	Summary	310
Chapter 8. Access Types		317
8.1	Naming Objects Designated by Access Values	318
8.2	Aliased and Dynamically Allocated Objects	321
8.2.1	Aliased Objects	321
8.2.2	Dynamically Allocated Objects	324
8.3	Access-to-Object-Type Declarations	328
8.4	Access-to-Subprogram-Type Declarations	333
8.5	The Use of Access Types	336
8.5.1	Selecting the Object or Subprogram Playing a Certain Role	337
8.5.2	Shared Data	339
8.5.3	Reducing Copying of Data	340
8.5.4	Pointing to Arrays of Various Sizes	343
8.5.5	Table-Driven Subprogram Invocation	346
8.5.6	Recursive Data Types	348
8.6	Subtypes of Access Types	352
8.7	Access Values as Subprogram Parameters	353
8.8	Lifetimes of Access Types and the Entities They Point To	355
8.9	Conversions Among Access Types	360
8.10	Differences in Ada 83	362
8.11	Summary	363

Chapter 9. Types with Discriminants	371
9.1 Records with Varying Structure	371
9.2 Declaring Record Types with Discriminants	374
9.2.1 Declaring Record Types with Variants	375
9.2.2 Declaring Record Types with Variable-Length Components	379
9.2.3 Declaring Types Whose Components Have Discriminants	380
9.2.4 Allowable Uses of Discriminants	381
9.3 Subtypes of Types with Discriminants	382
9.3.1 Mutable and Immutable Records	383
9.4 Pointing to Objects with Discriminants	388
9.4.1 Allocators for Records with Discriminants	388
9.4.2 Discriminant Constraints for Access Types	390
9.5 Subprogram Parameters with Discriminants	392
9.6 Full Form of a Discriminant Constraint	394
9.7 Position of Discriminants in Record Aggregates	395
9.8 When Expressions Are Evaluated	395
9.9 Differences in Ada 83	398
9.10 Summary	398
Chapter 10. Packages	405
10.1 Package Declarations and Package Bodies	406
10.2 The Syntax of Packages	407
10.3 The Placement and Lifetime of a Package	410
10.4 Children of Packages	418
10.5 Fractions Revisited	426
10.6 use Clauses	429
10.7 Renaming Declarations	436
10.8 Packages Without Bodies	445
10.9 Differences in Ada 83	449
10.10 Summary	452
Chapter 11. Private and Limited Types	459
11.1 Abstract Data Types Versus Internal Representations	459
11.2 Declaration of Private Types	461
11.3 Children of Packages With Private Parts	467
11.4 Deferred Constants	471
11.5 Programmer-Defined Equality and Inequality	474
11.6 Limited Types	478
11.7 Returning Objects by Reference	482
11.8 Private Types With Discriminants	484
11.8.1 Example: A Private Type for Varying Character Strings	484
11.8.2 Indefinite Private Types	489
11.8.3 Access Discriminants	490
11.9 Differences in Ada 83	492
11.10 Summary	494

Chapter 12. Classwide Programming	499
12.1 Object-Oriented Programming Concepts	499
12.1.1 Data Abstraction	499
12.1.2 Inheritance	500
12.1.3 Polymorphism	500
12.2 Derived Types	502
12.3 Type Extension	507
12.3.1 Conversions Among Tagged Types	510
12.3.2 Extension Aggregates	511
12.3.3 Type Extensions and Information Hiding	513
12.3.4 Implementing a Private Extension with an Intermediate Type	517
12.3.5 Type Extensions and Child Packages	519
12.3.6 Limited Tagged Types	521
12.4 Classwide Types	522
12.4.1 Creating Pointers to Objects of Classwide Types	525
12.4.2 Conversions Involving Classwide Types	526
12.4.3 Classwide Subprograms	527
12.4.4 Dispatching Operations	532
12.4.4.1 Controlling Dispatching	535
12.4.4.2 Dispatching Based on Function Results	539
12.4.4.3 Operations on Values with Mixed Tags	540
12.4.4.4 Redispaching	541
12.4.4.5 When to Use Classwide Subprograms and When to Use Dispatching Subprograms	546
12.4.4.6 Explicitly Testing for Tag Values	548
12.4.4.7 Private Dispatching Subprograms	551
12.4.5 Abstract Types and Abstract Subprograms	552
12.4.5.1 Inherited Functions Returning Results of a Tagged Derived Type	556
12.4.5.2 Abstract Subprograms of Untagged Types	560
12.4.6 Types Whose Operations Make Them Mutually Dependent	562
12.5 Automatic Initialization and Finalization	564
12.5.1 The Package <code>Ada.Finalization</code>	566
12.5.2 When Operations on Controlled Types Take Place	571
12.6 Details	575
12.6.1 Derived Types with Discriminants	575
12.6.1.1 Discriminants of Untagged Derived Types	576
12.6.1.2 Discriminants of Tagged Derived Types	577
12.6.2 Creating Pointers to Tagged-Type Formal Parameters	579
12.6.3 Lifetimes of Tagged Types and Their Extensions	579
12.6.4 Equality Operations for Types with Tagged Components	580
12.7 Differences in Ada 83	582
12.8 Summary	584
Chapter 13. Separate Compilation	591
13.1 The Compilation Environment	592
13.1.1 Program Libraries	592
13.1.2 Other Realizations of Compilation Environments	593

13.2	Compilation Units and Compilations	593
13.3	Subunits	597
13.4	Semantic Dependence and Order of Compilation	604
13.4.1	Top-Down Development and Independent Development	608
13.4.2	Recompilation	609
13.5	Elaboration of Compilation Units	614
13.6	Differences in Ada 83	623
13.7	Summary	624
Chapter 14.	Exceptions	631
14.1	Handling Exceptions	632
14.1.1	Exceptions in Sequences of Statements	633
14.1.2	Exceptions Raised by Declarations	638
14.1.3	Exceptions Raised in Handlers	638
14.2	Propagation of Exceptions	639
14.2.1	Propagation from Block Statements	639
14.2.2	Propagation from Subprogram Bodies	640
14.2.3	Propagation from Packages	640
14.3	Predefined Exceptions	641
14.3.1	Constraint_Error	641
14.3.2	Program_Error	644
14.3.3	Storage_Error	644
14.3.4	Unpredictability in the Raising of Predefined Exceptions	645
14.4	Programmer-Defined Exceptions	647
14.5	Exception Occurrences	651
14.6	Exceptions and Finalization	653
14.6.1	Finalization Due to the Raising of an Exception	654
14.6.2	Exceptions Raised During Finalization	655
14.7	When Errors Are Caught	656
14.8	Suppressing Run-Time Checks	659
14.9	Differences in Ada 83	662
14.10	Summary	664
Chapter 15.	Generic Units	671
15.1	Templates and Instances	671
15.2	Generic Formal Parameters	683
15.2.1	Generic Formal Objects	683
15.2.2	Generic Formal Subprograms	685
15.2.3	Generic Formal Types	692
15.2.3.1	Generic Formal Parameters for Numeric Types	692
15.2.3.2	Generic Formal Discrete Types	695
15.2.3.3	Generic Formal Array Types	697
15.2.3.4	Generic Formal Access Types	700
15.2.3.5	Generic Formal Private Types	702
15.2.3.6	Generic Formal Tagged Types	706
15.2.3.7	Generic Formal Derived Types	710
15.2.3.8	Generic Formal Types with Discriminants	714

15.2.4	Generic Formal Packages	716
15.3	Generic Child Units and Children of Generic Units	721
15.4	Defaults for Generic Parameters	723
15.4.1	Defaults for Generic Formal Constants	723
15.4.2	Defaults for Generic Formal Subprograms	724
15.5	Differences in Ada 83	726
15.6	Summary	729
Chapter 16.	Predefined Input and Output	741
16.1	Basic Concepts	741
16.1.1	External and Internal Files	741
16.1.2	Textual and Internal-Form Input/Output	742
16.1.3	File Modes	742
16.2	An Overview of the Input/Output Packages	743
16.3	Manipulating External Files	745
16.3.1	Opening Files	745
16.3.2	Closing Files	746
16.3.3	Resetting Files	747
16.3.4	Determining the Status of Files	747
16.3.5	Exceptions	747
16.4	Textual Input and Output	748
16.4.1	Columns, Lines, and Pages	748
16.4.1.1	Columns, Lines, and Pages in Output Files	750
16.4.1.2	Columns, Lines, and Pages in Input Files	751
16.4.1.3	Control Characters in Textual Files	752
16.4.2	Versions of Get and Put	753
16.4.2.1	Get and Put for Signed Integer Types	756
16.4.2.2	Get and Put for Modular Integer Types	760
16.4.2.3	Get and Put for Floating-Point Types	760
16.4.2.4	Get and Put for Complex Types	764
16.4.2.5	Get and Put for Ordinary Fixed-Point Types	765
16.4.2.6	Get and Put for Decimal Fixed-Point Types	765
16.4.2.7	Get and Put for Enumeration Types	766
16.4.3	Interactive Input/Output and Buffering	769
16.4.4	Standard and Default Files	771
16.4.5	Output to and Input from Strings	775
16.4.6	Exceptions	777
16.5	Sequential Internal-Form Input/Output	780
16.6	Direct Internal-Form Input/Output	781
16.7	Streams	786
16.7.1	Sending Values of Particular Types to and from Streams	788
16.7.2	Internal-Form Files as Streams	792
16.7.3	Textual Files as Streams	794
16.7.4	External Tags	795
16.8	Differences in Ada 83	795
16.9	Summary	796

Chapter 17. Introduction to Tasks	807
17.1 Concurrency	807
17.2 Task Objects and Task Types	809
17.3 Activation and Termination of Tasks	816
17.4 Elementary Protected Objects	818
17.4.1 Race Conditions and Mutual Exclusion	818
17.4.2 Protected Objects and Protected Types	821
17.4.3 Protected Operations	826
17.4.4 Examples of Protected Types	831
17.5 Elementary Rendezvous	836
17.5.1 The accept Statement	837
17.5.1.1 Parameters of an accept Statement	837
17.5.1.2 The Usual Form of an accept Statement	838
17.5.1.3 accept Statements Without "Bodies"	840
17.5.1.4 Restriction on the Placement of accept Statements	841
17.5.2 Example of Tasks Communicating by Rendezvous	841
17.6 Matching Identifiers	846
17.7 Differences in Ada 83	846
17.8 Summary	847
Chapter 18. Controlling Task Interaction	857
18.1 Advanced Forms of Rendezvous	858
18.1.1 Selective Acceptance of Entry Calls	858
18.1.1.1 Basic Selective Acceptance	858
18.1.1.2 Guards	860
18.1.1.3 The terminate Alternative	861
18.1.1.4 The delay Alternative	863
18.1.1.5 Selective Accepts with else Parts	866
18.1.2 Advanced Forms of Entry Calls	867
18.1.2.1 Timed Entry Calls	868
18.1.2.2 Conditional Entry Calls	869
18.2 Aborting the Actions of a Task	870
18.3 Requeuing	875
18.3.1 Requeuing from an Entry Body	876
18.3.2 Requeuing from an accept Statement	880
18.3.3 Requeuing and Cancellation of Entry Calls	884
18.4 Entry Families	885
18.5 Task Identification	893
18.6 Controlling Real-Time Behavior	894
18.6.1 Priorities	894
18.6.1.1 Priorities and Processor Allocation	895
18.6.1.2 Queuing Order and Selecting Among Entry Calls	895
18.6.1.3 Determining Priorities	896
18.6.1.4 Avoiding Priority Inversion	897
18.6.1.5 Task-Dispatching Policy	900
18.6.2 Accurate Time Measurement	901
18.6.3 Using a Restricted Set of Tasking Features	903

18.7	Potentially Blocking Operations	907
18.8	Shared Variables	908
18.8.1	Synchronized Use of Shared Variables	909
18.8.2	Unsynchronized Use of Shared Variables	911
18.8.3	Shared Variables in Package Bodies	914
18.9	Tasks and Exceptions	919
18.9.1	Exceptions in Task Bodies	920
18.9.2	Exceptions During Task Interaction	921
18.10	Tasks and Finalization	924
18.11	Determining the State of a Task	925
18.12	Differences in Ada 83	926
18.12.1	Using Passive Tasks in Place of Protected Objects	928
18.12.2	Using Successive Entry Calls in Place of Requeuing	928
18.12.3	Simulating Protected Actions with Passive Tasks	929
18.13	Summary	930
Chapter 19.	Low-Level and Multilingual Programming	941
19.1	The Package System	943
19.1.1	Alternative Run-Time Configurations	943
19.1.2	Numeric Capabilities	945
19.2	Manipulating Raw Storage and Addresses	946
19.3	Interpreting Bits as Representing More Than One Type	949
19.4	Ascertaining and Controlling How Types are Represented	954
19.4.1	The Representation of an Enumeration Type	954
19.4.2	Floating-Point Arithmetic	957
19.4.2.1	Fixed-Point Arithmetic	959
19.4.3	The Size of Objects	960
19.4.4	The Positions of Record Components	963
19.4.5	Multiple Representations for the Same Data	966
19.4.6	Freezing the Representation of a Type	968
19.5	Storage Management	969
19.5.1	Programmer-Defined Allocation and Deallocation	969
19.5.2	Controlling the Storage Allotted to Tasks	972
19.6	Interrupt Handling	972
19.6.1	Interrupt-Handling Protected Procedures	973
19.6.2	Other Kinds of Interrupt Handlers	978
19.7	Using Ada Together With Another Language	979
19.7.1	Conventions, Importing, and Exporting	979
19.7.2	Package Interfaces	983
19.7.2.1	Interfaces with C	984
19.7.2.2	Interfaces with C++	990
19.7.2.3	Interfaces with COBOL	990
19.7.2.4	Interfaces with Fortran	993
19.7.3	Generating Specific Machine Instructions	994
19.8	Differences in Ada 83	995
19.9	Summary	998

Chapter 20. Distributed Programs	1009
20.1 Models of a Distributed System	1010
20.2 Interfaces Among Partitions	1012
20.2.1 Passive Partitions	1013
20.2.2 Remote Subprogram Calls and Their Interfaces	1017
20.2.2.1 Remote-Types and Remote-Call-Interface Library Units	1017
20.2.2.2 Remote Subprogram Calls	1018
20.2.2.3 Example of a Client-Server System	1019
20.2.2.4 Dynamically Bound Remote Subprogram Calls	1024
20.3 Elaboration of Active Partitions	1028
20.4 Differences in Ada 83	1029
20.5 Summary	1030
Appendix A. Scope and Visibility	1035
A.1 Scope Rules	1035
A.2 Visibility Rules	1039
A.2.1 Nesting, Hiding, and Overriding	1039
A.2.2 Direct Visibility and Contextual Visibility	1041
A.2.3 The Effect of use Clauses	1043
A.3 The Package Standard	1044
Appendix B. Accuracy of Fixed-Point and Floating-Point Arithmetic	1045
B.1 Floating-Point Accuracy Rules in Strict Mode	1046
B.2 Fixed-Point Accuracy Rules in Strict Mode	1047
B.3 Precision of Static and Universal Expressions	1048
Appendix C. The Specialized-Needs Annexes	1049
C.1 The Systems Programming Annex	1049
C.2 The Real-Time Systems Annex	1050
C.3 The Distributed Systems Annex	1052
C.4 The Information Systems Annex	1052
C.5 The Numerics Annex	1053
C.6 The Safety and Security Annex	1054
Appendix D. Predefined Library Units and the Pragmas Applied to Them	1055
Appendix E. The Latin-1 Character Set	1059
Index	1069