

From Basics to Bytecode

**From Basics to Bytecode:
A Guide to Computers
and Programming**

**Set Lonnert
with AI Collaboration**

Adobe and PostScript are either registered trademarks or trademarks of Adobe Systems Incorporated in the United States and/or other countries.

Oracle and Java are registered trademarks of Oracle and/or its affiliates. Other names may be trademarks of their respective owners.

Raspberry Pi is a trademark of Raspberry Pi Ltd.

All other trademarks are the property of their respective owners.

All images are in the public domain unless otherwise stated.

Cover illustration in: Journal for Manufactures and Household Management, Scheutz, Stockholm, 1825, third issue, between pp. 96–97. Uppsala University Library. <https://urn.kb.se/resolve?urn=urn:nbn:se:alvin:portal:record-95006>
An illustration of the Jacquard mechanism. A device that uses punched cards to control the lifting of individual warp threads on a loom, making it possible to automate the weaving of intricate patterns with precision.

This work is marked with CC0 1.0 Universal.

To view a copy of this license, visit:

<https://creativecommons.org/publicdomain/zero/1.0/>

Authors: Set Lonnert with AI Collaboration 2025

Publisher: BoD, Books on Demand, Stockholm, Sweden

Printer: Libri Plureos GmbH, Hamburg, Germany

ISBN: 978-91-XXXX-XXX-X

Contents

Introduction	i
1 Foundations	1
1.1 Prerequisites	1
1.2 Foundations of Programming	1
1.3 Simple data types	2
1.3.1 Integers in binary	2
1.3.2 Floating-point numbers	4
1.3.3 Characters and ASCII	4
1.3.4 Strings	5
1.3.5 Representations and types	5
1.3.6 Summary	6
1.4 Variables	7
1.4.1 Assignment	7
1.4.2 Mutable and immutable variables	9
1.4.3 Summary	12
1.5 Control structures	13
1.5.1 Conventional control structures	13
1.5.2 Control structures in computers	17
1.5.3 Summary	18
1.6 Functions	19
1.6.1 Calling functions	20
1.6.2 Summary	23
1.7 Practice	24
2 Understanding VMs	29
2.1 Simple VMs	29
2.1.1 The stack	30
2.1.2 Interpreter technique	31
2.1.3 VM1 implementation	31

2.1.4	REGVM implementation	33
2.1.5	Portability	36
2.1.6	Summary	38
2.2	Stack-based VM	39
2.2.1	Comparisons	41
2.2.2	Iterations	42
2.2.3	Error handling	43
2.2.4	Summary	45
2.3	Memory and functions	46
2.3.1	Frame pointer	51
2.3.2	Local storage	53
2.3.3	Memory management	54
2.3.4	Frame stack	55
2.3.5	Summary	60
2.4	Practice	62
3	Development Environment	67
3.1	Prerequisites	67
3.2	Basic tools	67
3.3	Debugging	68
3.3.1	Process	70
3.3.2	Tools	71
3.3.3	Summary	78
3.4	Optimisation	78
3.4.1	Memory	83
3.4.2	Time	85
3.4.3	Confusion matrix	87
3.4.4	Summary	93
3.5	Tests and testing	93
3.5.1	Automated testing and continuous integration	97
3.5.2	Summary	100
3.6	Practice	101
4	Building and Experimenting	105
4.1	Prerequisites	105
4.2	The computer as hardware	105
4.2.1	Hardware	108
4.2.2	The Pico	110
4.2.3	Summary	113
4.2.4	Practice	114
4.3	Input/Output	115

4.3.1	The Pico pins	116
4.3.2	Light switching circuit	117
4.3.3	Programmable I/O	118
4.3.4	State machines	121
4.3.5	Circuit for traffic lights	124
4.3.6	Pedestrian crossing	126
4.3.7	Temperature measurements	128
4.3.8	Temperature indicator	129
4.3.9	Summary	132
4.3.10	Practice	134
4.4	Secondary memory	138
4.4.1	Save and load temperatures	140
4.4.2	Summary	140
4.4.3	Practice	140
4.5	External communication	140
4.5.1	UART	140
4.5.2	Connect Two Picos	142
4.5.3	Client-Server	145
4.5.4	Wireless	148
4.6	Security	149
4.6.1	Encryption/Decryption	149
4.6.2	Example	150
4.6.3	Program 1: Encrypting Program	152
4.6.4	Program 2: Decrypting Program	153
4.6.5	Secure communication	155
4.6.6	Data integrity	156
4.6.7	Hashing for Security	157
4.6.8	Symmetric/Asymmetric Encryption	159
4.6.9	Summary	161
4.6.10	Practice	162
4.7	Direct memory access	163
4.7.1	Pico and DMA	164
4.7.2	Pico and PicoDisplay	165
4.7.3	Text	168
4.7.4	Pixel graphics	168
4.7.5	Vector graphics	168
4.7.6	Summary	169
4.7.7	Practice	169
4.8	Combining I/O	169
4.8.1	Simplified web server	169
4.8.2	Summary	169

4.8.3	Practice	169
4.9	Handling errors	169
4.9.1	Types	170
4.9.2	Approaches	170
4.9.3	Summary	173
4.10	Timing and timers	174
4.10.1	Timing and Timers in the Pico	175
4.10.2	Interrupt handling	177
4.10.3	Summary	177
4.10.4	Practice	177
4.11	Concurrency and multithreading	178
4.12	Power management	183
4.13	Practice	188
5	The Compiler Pipeline	189
5.1	Prerequisites	189
5.2	Compilers, Interpreters, Assembler, and VMs	189
5.3	Syntax	192
5.3.1	Tokenisation or Lexical Analysis	193
5.3.2	Parsing	194
5.3.3	Production Rules and Grammars	196
5.3.4	Bottom-up	198
5.3.5	Top-down	204
5.3.6	Building Abstract Syntax Trees (ASTs)	208
5.3.7	Summary	210
5.4	Semantic Analysis	211
5.4.1	Symbol Table	214
5.4.2	Type System	214
5.4.3	Use of Abstract Syntax Trees (ASTs)	214
5.4.4	Rules and Constraints	214
5.4.5	Semantic Analysis Techniques	215
5.5	Intermediate Representations (IR)	215
5.5.1	Three-Address Code (TAC)	220
5.5.2	Role of IR in Optimisation	221
5.5.3	Summary	224
5.6	Code Generation Techniques	224
5.7	Loader and Linker	225
5.8	Practice	230
6	Philosophy and Methodology	237
6.1	Philosophy and style	237

6.1.1	Programming as craft	238
6.1.2	Building process	239
6.1.3	Blending philosophies	242
6.1.4	Methodologies	245
6.1.5	References	247
6.1.6	A personal note	249
6.1.7	Risks	251
6.1.8	Summary	252
6.2	Problems and methods	253
6.2.1	Example: Low customer satisfaction	253
6.2.2	Example: Thermostat	254
6.2.3	Generalisations	255
6.2.4	Methodology in the craft philosophy	259
6.3	Reflections on the history and future	261
6.3.1	AI example: LLMs	263
6.3.2	Summary	266
6.4	Method examples	266
6.4.1	Mock-ups and prototypes	267
6.4.2	Code review	271
6.4.3	Null hypothesis in programming	279
6.4.4	Summary	283
6.5	Practice	284
7	Case Studies	285
7.1	JVM	287
7.2	PostScript	287
7.3	Language and Virtual Machine Projects	292
7.4	Systems Programming Projects	292
7.5	Tools and Frameworks	292
7.6	Simulators and Emulators	293
7.7	Data Science and AI Projects	293
7.8	Creative and Visual Projects	293
8	Advanced Topics	295
8.1	Abstract data structures	295
8.2	Object-orientation	295
8.3	Functional languages	295
8.3.1	Design patterns	295
8.4	Design patterns	305
8.4.1	Factory	307
8.4.2	Observer	309

CONTENTS

8.4.3	Command	311
8.4.4	Strategy	314
8.4.5	Adapter	316
8.4.6	Composite	319
8.4.7	Decorator	320
8.5	Security	322
8.6	Garbage collection	322
8.7	Memory management	323
8.8	Graphics	323
8.9	Different VMs	323
	Register	326