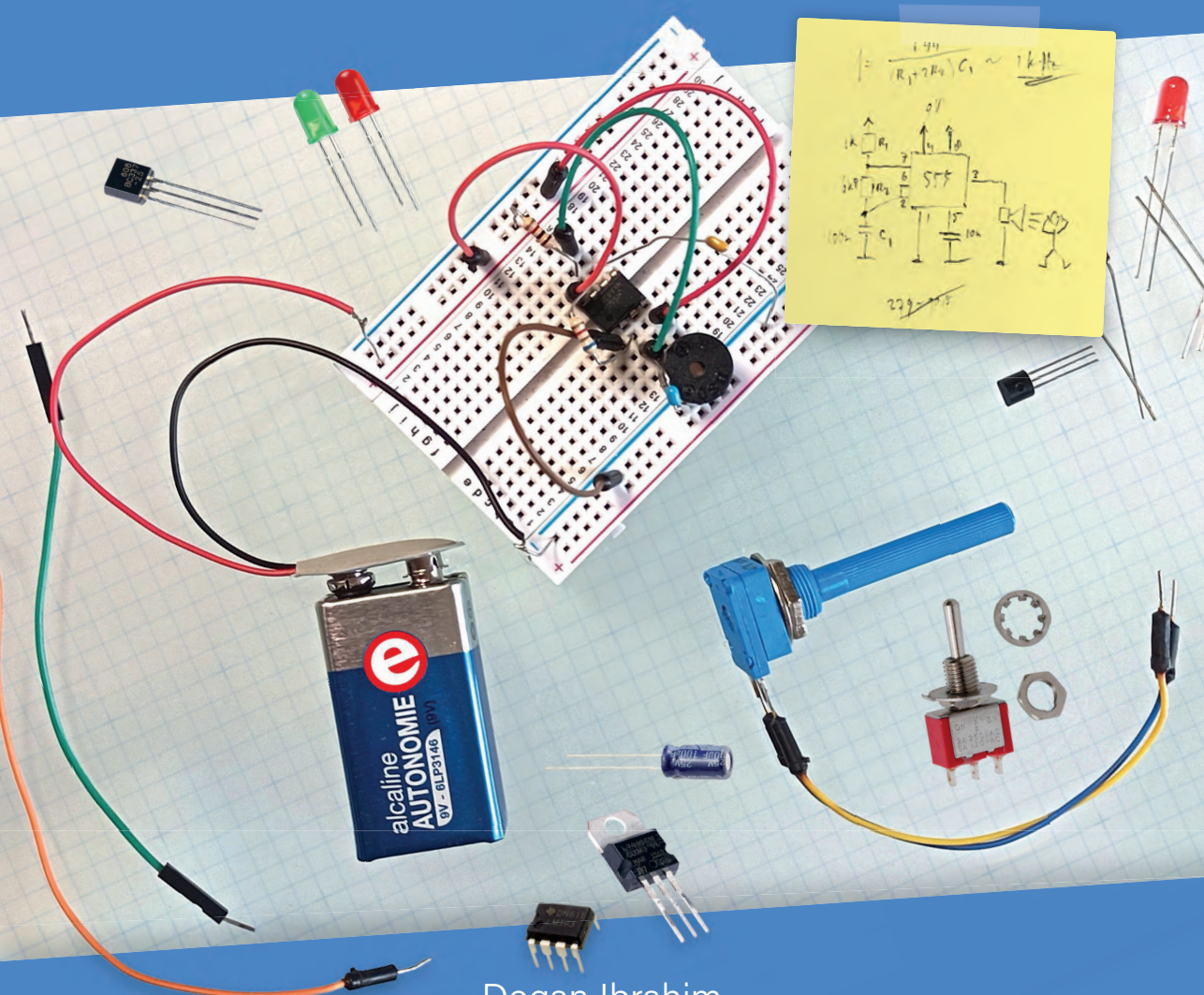
elektor books

Practical Electronics Crash Course

Learning circuit design the fun way



Dogan Ibrahim
Ahmet Ibrahim

elektor
design > share > earn

Practical Electronics Crash Course

Learning circuit design
the fun way

Dr. Dogan Ibrahim
Ahmet Ibrahim

elektor
design › share › earn

This is an Elektor Publication. Elektor is the media brand of
Elektor International Media B.V.
PO Box 11, NL-6114-ZG Susteren, The Netherlands
Phone: +31 46 4389444

All rights reserved. No part of this book may be reproduced in any material form, including photocopying, or storing in any medium by electronic means and whether or not transiently or incidentally to some other use of this publication, without the written permission of the copyright holder except in accordance with the provisions of the Copyright Designs and Patents Act 1988 or under the terms of a licence issued by the Copyright Licencing Agency Ltd., 90 Tottenham Court Road, London, England W1P 9HE. Applications for the copyright holder's permission to reproduce any part of the publication should be addressed to the publishers.

Declaration

The authors and publisher have used their best efforts in ensuring the correctness of the information contained in this book. They do not assume, or hereby disclaim, any liability to any party for any loss or damage caused by errors or omissions in this book, whether such errors or omissions result from negligence, accident or any other cause.

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN 978-3-89576-605-3 Print
ISBN 978-3-89576-606-0 eBook

© Copyright 2024 Elektor International Media
www.elektor.com
Editor: Clemens Valens
Prepress Production: D-Vision, Julian van den Berg
Printers: Ipskamp, Enschede, The Netherlands

Elektor is the world's leading source of essential technical information and electronics products for pro engineers, electronics designers, and the companies seeking to engage them. Each day, our international team develops and delivers high-quality content - via a variety of media channels (including magazines, video, digital media, and social media) in several languages - relating to electronics design and DIY electronics. **www.elektormagazine.com**

Contents

Preface 12

Chapter 1 • Electricity 13

1.1 Overview 13

1.2 What is Electricity? 13

1.3 Electronic Circuits 14

1.4 DC and AC 14

1.5 Electric Power 16

1.6 Basic Lamp/Switch Circuits 17

1.6.1 One Switch Only 17

1.6.2 More Than One Switch 18

1.6.3 Two-Way Switch 19

Chapter 2 • Passive Components 20

2.1 Overview 20

2.2 Resistors 20

2.2.1 Types of Resistors 21

2.2.2 Resistive Materials 23

2.2.3 Resistor Specifications 24

2.2.4 Resistor Colour Code 24

2.2.5 Ohm's Law 27

2.2.6 Resistors in Series and Parallel 27

2.2.6 Resistors in Electrical Circuits - Examples 28

2.2.7 Voltage Divider Circuit 30

2.2.8 Other Types of Resistors 32

2.2.9 Project 1 – Resistor Circuit 33

2.2.10 Using a Circuit Simulation Program 35

2.3 Capacitors 37

2.3.1 Types of Capacitors 38

2.3.2 Capacitor Values 39

2.3.3 Capacitor Value Marking 39

2.3.4 Capacitors in Series and Parallel 40

2.4 Inductors 42
2.4.1 Types of Inductors 42
2.4.2 Inductor Values 43
2.4.3 Inductor Markings 43
2.4.4 Inductors in Series and Parallel 45
2.4.5 Mutual Inductance 46
2.5 A Simple RC Network 46
2.5.1 Project 2 – Resistor-Capacitor Transient Response 49
2.6 Resistor-Capacitor-Inductor Circuit Transient Response 51
2.7 Resistance Versus Impedance 53
Chapter 3 • Magnetics 55
3.1 Overview 55
3.2 Magnets in Electronics 55
3.3 Electromagnets 55
3.4 The Reed Switch 56
3.5 Loudspeakers 57
3.6 Transformers 58
3.7 Relays 61
Chapter 4 • Active Components 64
4.1 Overview 64
4.2 Semiconductor Diodes 64
4.2.1 Diode Types 65
4.2.2 Diode Circuits 71
4.2.2.1 Simple LED Circuit 71
4.2.2.2 Project 1 – LED With Push-Button 72
4.2.2.3 Project 2 – RGB LED With Push-Buttons 73
4.2.2.4 Project 3 – Zener Diode Regulator 75
4.2.2.5 Rectifier Circuits 78
4.3 Bipolar Transistors 83
4.3.1 DC Voltages and Currents in a Transistor 84
4.3.2 Common Emitter Amplifier 86

4.3.3 Transistor as a Switch 90
4.3.3.1 Project 4 – Transistor Switch With LED 92
4.3.4 MOSFET as a Switch 94
4.3.4.1 Project 5 – MOSFET Switch With LED 96
4.3.4.2 Project 6 – Steady Hand Game 98
Chapter 5 ● Simple Circuits Based on Previous Chapters 101
5.1 Overview 101
5.2 Mechanical Switches 101
5.2.1 Project 1 – Upstairs-Downstairs Two-Way Switch 105
5.2.2 Contact Bounce Problems 106
5.3 Project 2 – Relay With LED 106
5.4 Electronic Buzzers 107
5.5 Optocouplers. 108
5.5.1 Example Optocoupler Circuit 109
5.6 Transistor Oscillators and Other Circuits 109
5.6.1 Sine Wave Transistor Oscillators 109
5.6.2 The Multivibrator 114
5.6.2.1 Project 3 – Astable Multivibrator Flashing LEDs 116
5.6.2.2 Project 4 – Monostable Multivibrator Timed LED 118
5.7 The 555 Timer. 119
5.7.1 Project 5 – Blinking an LED With the 555. 120
5.7.2 Project 6 – Alternating LEDs. 123
5.7.3 Project 7 – 1 kHz Buzzer 124
5.7.4 Project 8 – Continuity Tester 126
5.7.5 Project 9 – Alarm with Three Sounds. 127
5.7.6 Project 10 – Mosquito Repeller 129
5.7.7 Project 11 – Darkness Detector 130
5.7.8 Project 12 – Metronome 132
5.7.9 Project 13 – LED Timer 134
5.7.10 Project 14 – Outside Light with Long Delay 136
5.7.11 Project 15 – Improved Metronome 137

5.7.13 The Bistable 555 138
5.8 Project 15 – Two-Transistor Blinky 139
5.9 Fixed-Output Voltage Regulator ICs 140
5.10 Reverse Polarity Protection 141
Chapter 6 • Operational Amplifiers 143
6.1 Overview 143
6.2 Operational Amplifier Structure 143
6.3 Inverting Amplifier 144
6.4 Noninverting Amplifier 146
6.5 Voltage Follower 147
6.6 Summing Amplifier 147
6.7 Difference Amplifier 148
6.8 Integrator 149
6.9 Differentiator 150
6.10 Comparator 150
6.11 Summing Amplifier Simulation 151
6.12 Project 1 – Comparator With LED 152
Chapter 7 • Logic Gates 155
7.1 Overview 155
7.2 Commonly Used Logic Gates 155
7.2.1 AND Gate 155
7.2.2 OR Gate 155
7.2.3 NOT Gate 156
7.2.4 NAND Gate 156
7.2.5 NOR Gate 156
7.2.6 XOR gate 157
7.2.7 XNOR Gate 157
7.3 Logic Gate IC Families 157
7.3.1 Mixing Different Logic Families 159
7.4 Project 1 – AND Gate with LED and Push-buttons 162
7.5 Diode Logic 163

7.5.1 Diode OR Gate 163
7.5.2 Diode AND Gate 164
7.5.3 Mixed Diode AND & OR Gate 164
7.5.4 Diode Logic vs. Digital Logic 165
7.5.5 Single-Gate Logic Devices 165
7.6 Flip-Flops 165
7.7 Counters 167
7.8 The 74595 Shift Register 170
7.9 What is an FPGA? 172
Chapter 8 • Advanced Subjects 174
8.1 Overview 174
8.2 Alternating Current (AC) Analysis 174
8.2.1 Root Mean Square (RMS) 175
8.2.2 Resistors and AC 175
8.2.3 Inductors and AC 175
8.2.4 Capacitors and AC 176
8.2.5 RLC Circuit and Resonance 176
8.2.6 Power in AC circuits 180
8.3 Amplifiers 181
8.3.1 Amplifier Gain 181
8.3.2 The LM386 Amplifier 183
8.3.3 The TDA2030 185
8.4 Oscillators 186
8.4.1 Phase-Shift Sine Wave Oscillator 186
8.4.2 Square Wave Oscillator 187
8.5 Filters 188
8.5.1 Filter Roll-Off and Filter Order 189
8.5.2 Filter Design Program 190
8.5.3 Low-Pass Active Filters 190
8.5.4 High-Pass Active Filters 192
8.5.5 Band-Pass Active Filters 193

8.5.6 Passive Low-Pass Filter 195
8.6 Sensors 196
8.6.1 Temperature Sensors 198
8.6.2 Force Sensors. 203
8.6.3 Light Sensors 204
8.6.4 Sound Sensors 204
8.6.5 Acceleration Sensors. 205
8.6.6 Soil Moisture Sensors 205
8.6.7 Distance Sensors 206
8.7 Switched-Mode Power Supply (SMPS) 206
8.7.1 The LM2576 Buck Converter 207
8.7.2 The LM2577 Boost Converter 207
8.8 Interesting Electronic Kits. 208
Chapter 9 ● Test and Measurement 210
9.1 Overview 210
9.2 Power Supplies 210
9.2.1 Fixed or Variable Voltage 210
9.2.2 Number of Output Channels. 210
9.2.3 Current Capacity. 211
9.2.4 Current Limiting 211
9.3 Multimeter 211
9.3.1 Parts of a Multimeter. 212
9.3.2 Voltage Measurement 213
9.3.3 Current Measurement 214
9.3.4 Resistance Measurement 215
9.4 The Oscilloscope 215
9.4.1 Specifications 216
9.4.2 Using the Oscilloscope. 217
9.5 Function Generators. 218
9.6 Other Tools 218
9.6.1 Soldering Iron 219

9.6.2 Desoldering Pump 219
9.6.3 Miscellaneous Tools 219
9.6.4 Breadboard With Built-In Power Supply 220
9.6.5 Budget Tool Kits 220
Chapter 10 • Microcontroller Boards and MCU Programming 222
10.1 Overview 222
10.2 Microcontroller Boards & Modules 222
10.3 The Arduino UNO R4 223
10.3.1 Project 1 – Blink an External LED 227
10.4 The ESP32-DevKitC 231
10.4.1 Project 2 – Blinking an LED With the ESP32 234
10.5 The Raspberry Pi Pico 237
10.5.1 Pinouts of the RP2040 and the Pico 238
10.5.2 Pico Programming 239
10.5.3 Project 3 – Blinking an LED With MicroPython 243
10.6 The Raspberry Pi 246
10.6.1 Installing the Raspberry Pi Operating System 247
10.6.2 Project 4 – Blinking an LED With a Raspberry Pi 253
Chapter 11 • Other Topics of Interest 257
11.1 Overview 257
11.2 Component Selection 257
11.3 Reading a Datasheet 258
11.4 Schematic Capture and PCB Design 262
11.5 EMC and EMI 266
11.6 Norms and Regulations 267
Appendix – List of Components Used in Projects 269
Index 270