



1. TABLE OF CONTENTS

- 1. Table of contents3
- 2. History.....15
- 3. Tools.....19
 - 3.1. Parts manipulation19
- 4. Soldering23
 - 4.1. Soldering iron or station.....23
 - 4.2. Hot-air rework stations24
 - 4.3. Hot Air handguns.....25
 - 4.3.1. Heat gun stand26
 - 4.3.2. Preheaters26
 - 4.4. BGA station.....27
 - 4.5. Reflow ovens28
 - 4.6. Temperature and power31
 - 4.7. Soldering tips.....32
 - 4.7.1. Anatomy of a tip33
 - 4.7.2. Prolonging tip life34
 - 4.8. Heat gun nozzles35
 - 4.9. Solder36
 - 4.10. Specialty solders.....39
 - 4.11. Solder paste.....40
 - 4.12. Paste application41
 - 4.12.1. Paste dispensers41
 - 4.12.2. Stencils.....42
 - 4.12.3. Stencil printers.....43





- 4.12.4. Squeegees 44
- 4.12.5. Rework stencils 45
- 4.13. Solder balls..... 45
- 4.14. Flux..... 46
 - 4.14.1. Rosin flux 47
 - 4.14.2. No-clean flux 47
 - 4.14.3. Water soluble flux 47
 - 4.14.4. Flux dispensing 48
 - 4.14.5. Flux for lead-free versus leaded process 49
 - 4.14.6. Spattering 49
 - 4.14.7. Voiding 50
 - 4.14.8. Wetting problems 50
 - 4.14.9. Cold solder joints..... 50
- 4.15. Flux remover 50
 - 4.15.1. Applicators 51
- 4.16. Ultrasonic cleaner 51
- 5. Other soldering tools..... 53
 - 5.1. Fume extractor..... 53
 - 5.1.1. Centralized systems 53
 - 5.1.2. Individual systems 53
 - 5.2. Dental picks..... 55
 - 5.3. Xacto knife 55
 - 5.4. Solder wick 56
 - 5.5. Applicator bottles 57
 - 5.6. Soft brush..... 57
 - 5.7. Soldering sponge..... 58





- 6. Magnifiers59
 - 6.1. Pocket / inspection magnifier / wearable magnifiers.....59
 - 6.2. Bench magnifiers with built in light.....60
 - 6.3. Stereo inspection microscope60
 - 6.4. Computer microscope61
 - 6.5. Vision systems62
 - 6.6. Specialized inspection systems.....62
 - 6.7. XRAY systems63
- 7. Parts placement65
 - 7.1. Manual placement65
 - 7.2. Advanced manual and semi manual placement systems65
 - 7.3. Automatic placement.....66
- 8. Parts storage69
 - 8.1. Factory delivered storage.....69
 - 8.1.1. Tape and reel.....69
 - 8.1.2. Stick70
 - 8.1.3. Tray.....71
 - 8.1.4. Bulk cassette pack72
 - 8.2. Small volume storage73
 - 8.3. Benchtop storage73
 - 8.3.1. Spring loaded boxes or mousetrap boxes.73
 - 8.3.2. Sample containers74
 - 8.3.3. Photo Film containers.....75
 - 8.3.4. Tackle boxes75
 - 8.3.5. Jewelers and bead boxes.....75
 - 8.3.6. Pill boxes.....75





- 8.3.7. Parts sorters 76
- 8.3.8. Labeling parts containers 76
- 9. ESD and ESD safety 77
 - 9.1. What is 'static electricity' 77
 - 9.2. ESD protection 78
 - 9.3. The necessity of 'earth' 78
 - 9.4. ESD safe workstation setup 79
 - 9.5. ESD Safe storing of parts 81
 - 9.5.1. Antistatic packaging 81
 - 9.5.2. Dissipative packaging 81
 - 9.5.3. Conductive material 82
 - 9.6. Commercial solutions 82
 - 9.6.1. Bench mat 82
 - 9.6.2. ESD straps 83
 - 9.6.3. ESD-safe soldering iron and tools 83
 - 9.6.4. Clothing 83
 - 9.6.5. Ionizers 84
 - 9.6.6. Conductive flooring 85
 - 9.6.7. Antistatic cleaners and surface treatment 86
 - 9.6.8. Other solutions 86
 - 9.6.9. Testers 86
 - 9.7. Homegrown solutions 87
 - 9.7.1. Bench mat 87
 - 9.7.2. ESD ground plug 87
 - 9.7.3. ESD safe lab jacket or lab coat 87
 - 9.8. A couple of words of caution 88





- 10. Setting up an efficient workbench89
 - 10.1. The essentials89
 - 10.2. Other things to keep close at hand91
 - 10.3. Taming components.....91
 - 10.3.1. Dealing with tape and reel.....92
 - 10.3.2. Dealing with loose parts92
 - 10.3.3. Vacuum pens93
 - 10.3.4. Poster putty to the rescue93
 - 10.4. Taming the workpiece.....94
 - 10.4.1. Helping hands94
 - 10.4.2. The bench95
- 11. Circuit board assemblies97
 - 11.1. Premade forms.....97
 - 11.2. Etched boards.....98
 - 11.2.1. The home route98
 - 11.2.2. The professional services.....99
 - 11.3. Some board terminology.....99
 - 11.4. Different assembly types.....100
 - 11.4.1. SMD Parts on one side only100
 - 11.4.2. SMD and thru-hole parts on one side only101
 - 11.4.3. SMD parts top and bottom103
 - 11.4.4. SMD parts top and bottom + through hole104
- 12. Printed circuit boards.....107
 - 12.1. Some history.....107
 - 12.2. PCB material108
 - 12.2.1. The FR4 misnomer109





- 12.2.2. Dielectrical constant..... 109
- 12.2.3. Laminate thickness..... 110
- 12.2.4. Copper thickness 110
- 12.3. The mechanical process..... 110
- 12.4. The chemical process..... 111
 - 12.4.1. Photoplotting 114
 - 12.4.2. Drill file 115
 - 12.4.3. Process evolution 116
 - 12.4.4. Through-hole metallization 117
 - 12.4.5. Etching after metallization 119
 - 12.4.6. Multilayer boards..... 120
 - 12.4.7. Soldermask..... 122
 - 12.4.8. Silkscreen 123
 - 12.4.9. Pitfalls with soldermask and silkscreen 123
- 12.5. Surface protection 123
- 12.6. Electrical test..... 125
- 13. Making boards in the home or small lab 127
 - 13.1. Toner transfer method..... 127
 - 13.2. Photographic method 130
 - 13.2.1. Pre-coated boards 130
 - 13.2.2. Developer 131
 - 13.2.3. Light source 131
 - 13.3. Etching 132
 - 13.3.1. Ferric chloride 132
 - 13.3.2. Persulfates..... 133
 - 13.3.3. Hydrochloric acid / Hydrogen peroxide..... 134





- 13.4. Post processing.....135
- 14. Reflow soldering.....137
 - 14.1. Reflow profile137
 - 14.2. Defects138
 - 14.2.1. Mechanically induced failures139
- 15. Sockets and package adapters141
 - 15.1. Sockets141
 - 15.2. Package adapters142
- 16. SMD components.....145
 - 16.1. Resistors145
 - 16.1.1. Footprints145
 - 16.1.2. Resistor technology147
 - 16.1.3. Values149
 - 16.1.4. Value indication151
 - 16.1.5. Power rating151
 - 16.1.6. Voltage rating151
 - 16.1.7. Resistor networks152
 - 16.1.8. Practical tips for the lab resistor box154
 - 16.2. Capacitors.....154
 - 16.2.1. Footprints154
 - 16.2.2. Ceramic capacitors.....156
 - 16.3. Capacitor classification157
 - 16.3.1. Class-I.....157
 - 16.3.2. Class –II158
 - 16.3.3. Film capacitors159
 - 16.3.4. Tantalum capacitors161





- 16.3.5. Technology 162
- 16.4. Electrolytic capacitors 163
 - 16.4.1. Construction 163
 - 16.4.2. Electrical behavior 165
- 16.5. Other capacitors 166
- 16.6. ESR: equivalent series resistance 166
- 16.7. ESL: equivalent series inductance 168
- 16.8. inductors 168
 - 16.8.1. Technology 169
 - 16.8.2. Derating..... 170
 - 16.8.3. PCB inductors 171
- 17. Active components 173
 - 17.1. Diodes 173
 - 17.1.1. Diode packages 174
 - 17.2. Transistors..... 180
 - 17.2.1. Transistor packages..... 180
 - 17.3. Integrated circuits..... 184
 - 17.3.1. Small outline packages: SO..... 184
 - 17.3.2. Power packages..... 185
 - 17.3.3. SOJ..... 186
 - 17.3.4. PLCC..... 186
 - 17.3.5. TSOP / TSSOP..... 188
 - 17.3.6. QFP / TQFP 188
 - 17.3.7. QFN 189
 - 17.3.8. BGA..... 189
 - 17.3.9. Flip Chip..... 190





- 17.3.10. Naked Die191
- 18. Identifying parts193
- 19. Test tools.....197
 - 19.1. Test leads.....197
 - 19.2. Tweezer probes197
 - 19.3. Scope probes198
 - 19.3.1. Probe holders199
 - 19.4. Smart tweezers.....200
 - 19.5. Grabbers.....200
 - 19.6. Testclips.....201
 - 19.7. SO, PLCC and TQFP contactors201
 - 19.8. Footprint adapters202
 - 19.9. Test and ZIF sockets203
- 20. Soldering techniques.....205
 - 20.1. Techniques using a standard soldering iron205
 - 20.1.1. For passive parts, 2 pin and 3 pin parts or parts with few pins205
 - 20.1.2. For coarse pitch multi-row parts205
 - 20.1.3. For TQFP or quad style packages206
 - 20.1.4. For MLF / QFN.....207
 - 20.2. Techniques involving a hot air sTATION208
 - 20.2.1. Passive parts208
 - 20.2.2. Multi-row parts like SO, TSSOP, QFP209
 - 20.2.3. MLF style.....209
 - 20.3. Solder paste and stencil techniques210
 - 20.3.1. Using a micro stencil.....211
 - 20.3.2. Full boards212





- 20.4. Practice makes perfect..... 213
- 21. Project 1: Earth bonding plug 217
- 22. Project 2: LED Tester..... 219
 - 22.1. Schematic..... 219
 - 22.2. Workbench setup..... 221
 - 22.3. Preparing the PCB 223
 - 22.3.1. Preparing the component positions..... 223
 - 22.4. Placing the first parts 225
 - 22.5. Placing the passive components 229
 - 22.6. Diodes and LEDs..... 229
 - 22.7. Finishing touches 232
 - 22.7.1. Applying flux..... 232
 - 22.8. Post processing clean-up. 233
 - 22.8.1. Ultrasonic cleaning..... 234
- 23. Project 3: PWM controller for lightbulb 237
 - 23.1. Schematic..... 237
 - 23.2. Workbench setup..... 239
- 24. Project 4: Ring light..... 245
 - 24.1. Assembly..... 246
 - 24.2. Positioning the stencil..... 246
 - 24.3. Paste application..... 248
 - 24.4. Inspecting the solder paste deposition 251
 - 24.5. Parts placement 251
 - 24.6. Soldering 252
 - 24.7. Thru-hole parts 253
- 25. Project 5: UV Exposure timer..... 255





- 25.1. The controller256
- 25.2. Assembly259
 - 25.2.1. Workbench setup259
 - 25.2.2. Board preparation259
- 25.3. Controller assembly.....263
- 25.4. Placing parts267
- 25.5. Installing the through-hole parts.....268
- 25.6. Programming the cpu.....268
- 25.7. Final assembly and wrap-up.....269
- 26. Project 6: Making your own reflow oven from a pizza toaster271
 - 26.1. Schematic271
 - 26.2. Control loop.....273
 - 26.3. Assembly274
 - 26.4. Firmware275
 - 26.5. Operation275
 - 26.6. Downloadable Material.....276
- 27. Appendix277
- 28. Project kits.....277
- 29. Index.....278

