

Index

Page numbers in **bold** refer to subjects in photographs.

SYMBOLS AND NUMBERS

μ A702 integrated circuit, 208–209
 μ A741 integrated circuit, 142
¼" audio plug and jack, 146–147
10-turn potentiometer, 30–31
12AX7 vacuum tube, **174**, 182–183
15-turn trimmer potentiometer, 28–29
1N740 diode, 66
1N914 diode, 67
1N1100 diode, 67
1N4002 diode, 64–65
1N5236B diode, 67
2-layer printed circuit board. *See* two-layer printed circuit board
2N2222 transistor, 70–71
2N3904 transistor, 72–73
24LC64 integrated circuit, 80
32 kHz quartz crystal, 14–15, 260–261
3.5 mm audio connectors, 148–149, 273
3656HG isolation amplifier, 266–269
5×7 LED dot matrix display, 254–255
7-segment display. *See* seven-segment display
702 integrated circuit, 208–209
741 integrated circuit, **142**
74F651 integrated circuit, **77**
9LS capacitor, 194–195

A

AC power cable, 139
Adafruit circuit board, **82**
Adobe Lightroom, 280
AlGaAs (aluminum gallium arsenide), 88
alphanumeric LED display
 dot matrix, 254–255
 segmented, 258–259
aluminum electrolytic capacitor, 37, 43
 for context, **50**, **78**
ambient light sensor, 100–101
Amiga motherboard, **20**, **28**, **33**, **49**, **50**, **56**, **72**
amplifier
 guitar, **174–175**, 192
 isolation, 266–269
 operational (op-amp), **142**, 208–209

analog
 integrated circuit, 208–209
 panel meter, 216–217
 telephone cable, 141
 video cable, 166–167
analog panel meter, 216–217
anode
 capacitor, 40–42
 diode, **67**, 207
 LED, 88, 92
 nixie tube, 180
 vacuum fluorescent display, 184
anodizing, 37, 40
APD (avalanche photodiode), **224–225**, 264–265
Apple, 110, 126, 151
Arduino, 78
ATmega328 microcontroller, 78–79, 82, 112
audio
 capacitor, 38
 connector, 146–149
 electret microphone, 134–135
 guitar amplifier, **174–175**, 192
 magnetic buzzer, 124–125
 speaker, 126–127
 vacuum tube, 182–183
avalanche photodiode module, **224–225**, 264–265
axial inductor, 44–45
axial lead fuse, 56
axial multilayer ceramic capacitor, 197
AxiDraw, 279

B

ball grid array (BGA), **62–63**, 84–87, 100, 246
barrel plug and jack, **78**, 144–145
basic USB cable, 168–171
bearing, 122, 123
bicolor LED, 91
bimetallic strip, 118–119
BIOS chip, 210
bipolar junction transistor (BJT), 70–75, 214
BNC plug and jack, **136–37**, 156–157
bobbin, 44, 46, 52, 198, 218

bond wire
 chip-on-board, 240-241
 cleaning of, 274
 in hybrid circuits, **224-225**, 253-259, 264-269
 in image sensors, **102-103**, 130-131
 in integrated circuits, 75-77, **79**, 80-84, 209, 246-247
 in LEDs, 88-95, 250, 253-259
 in transistors, 70-71, 73, 135
bridge rectifier, 68-69
brushed DC motor, 120-121
brushless motor, 122
bubble display, LED, 256-257
button, 109, 112-115
buzzer, 124-125

C

cable

 CAT6 Ethernet, 162
 guitar, 146
 HDMI, 164-165
 IDC ribbon, 140
 modular telephone, 141
 photography of, 275-276
 SATA, 163
 television, 153-155
 twinaxial, 163
 USB, 168-169, 172-173, 275
 VGA, 166-167
 wire, 138

cable, coaxial

 with BNC connectors, 156-157
 LMR-195, 150
 RG-59 cable TV, 153-155
 RG-6, 152
 semi-rigid, 158-159

cable, power

 AC, 139
 with barrel plug, 144
 laptop, 151

cables and connectors, 137

cadmium compounds, 204

calculator, 184-185, 212-213, 256-257

camera (component)

 ambient light sensor for, 100-101
 CMOS sensor, 102-103
 flash, smartphone LED, 100, **128**, 244, **245**
 flashbulb, 202-203
 flex circuit, 235
 smartphone, 128-131, 245
 viewfinder, 186

camera (photography of this book)

 depth of field, 281
 equipment, 278-279
 robotic control of, 282

Canon, 278

capacitance, 34, 37, 40, 134, 194, 196

capacitor

 aluminum electrolytic, 37
 axial multilayer ceramic chip, 197
 ceramic disc, 32-33
 chip, 36, 42-43, 228, 247, 264, 268
 Cornell-Dubilier, 194-195
 dipped silver mica, 196
 dipped tantalum, 40-41
 in electret microphone, 134
 film, 38-39, 228
 glass, 34-35
 mica, 194-196
 multilayer ceramic, **12-13**, 36, 197
 polymer aluminum, 43
 polymer tantalum chip, 42
 three-terminal filter, 49
 tubular ceramic, 198-199

carbon

 composition resistor, 192-193, **215**, **284**
 filament, 201
 film resistor, 16-17, 272
 paste, 42-43, 192-193
 silicone rubber with, 236-237

cartridge fuse, 54-55, **185**

Casio AL-1000 calculator, 212

cassette tape player, 218

category 6 (CAT6) ethernet cable, 162

cathode

 capacitor, 40, 42, 43
 diode, **67**, 207
 LED, 88, 92
 neon bulb, 176
 nixie tube, 180
 vacuum fluorescent display, 184
 vacuum tube, 182

cathode ray tube, 186-189

cat whisker, 206-207, 274

CdS cell, 204-205

cell phone. *See* smartphone

cement, 19

ceramic

 capacitor, **12-13**, 32-33, 36, 197-199
 circuit board, 226. *See also* thick film
 in fuse, 56, 60-61
 hard drive slider, **105**, 220-223

integrated circuit package, 76–77, 102–103, 210–211

magnetic. *See* ferrite

in Nixie tube, 180

in photoresistor, 204–205

in resistor, 16–29, 191, 192

in thermal switch, 118–119

ceramic disc capacitor, 32–33

cermet, 23, 26, 28

chip (integrated circuit). *See* integrated circuit

chip capacitor. *See* capacitor

chip on board (CoB), **236**, 240, 241, 243

chip resistor. *See* resistor

choke, 51, 248

ChronoDot, **260**

circuit board

- flexible. *See* flex and rigid-flex circuit boards
- multilayer. *See* multilayer circuit board
- single-side. *See* single-side printed circuit board
- smartphone, 233, 244–247
- two-layer. *See* two-layer printed circuit board

cleaning, 274

clock, 260–262

CMOS image sensor, 102–103

coaxial cable. *See* cable, coaxial

CoB. *See* chip on board

coil

- analog panel meter, 216–217
- cathode ray tube filament, 188
- deflection yoke, 187–189
- GMR hard drive head, 223
- inductor, 44–47, 198–199, 249
- light bulb filament, 200–201
- magnetic tape head, 218–219
- motor, **14**, 120–123, 130, 132–133, 220
- NFC card, 242–243
- relay, 116
- speaker and buzzer, 124–127
- thin-film hard drive head, 220–221
- transformer, 50–53, **235**, **248**, 266–267, **269**
- voice, 126–27, 130, 132–133, 220

color sensor, 80–81, 100–101

commutator, motor, 120

compact power fuse, 58

composite, 192. *See also* cermet

composite devices, 225

conformal coating, 268

connector

- 3.5 mm audio, 148–149
- barrel plug and jack, 144–145
- BNC, **136–37**, 156–157
- cathode ray tube (CRT), 187
- DE-9, 160–161
- elastomeric, 236–237
- F, 154–155, 276
- gold fingers, 238–239
- IDC ribbon cable, 140
- modular telephone cable (RJ25), 141
- quarter-inch audio, 146–147
- SMA, 158–159
- USB, 168–171

copper

- foil, 52–53, 218–219
- heat spreader, 86–87
- lead frame, **73**, 81–82, **143**, 261
- plating, 152, 230
- semi-rigid coax, 158–159
- terminals, **36**, **42**, 46–47
- traces, 84, 228–230, **231–236**, **239–240**, **244–249**, 250, 255
- wire, 138
- wire (other), 30–31
- wire, in cables, 139–141, **145**, 150–153, 158–159, 162–169, 172–173
- wire, magnet. *See* magnet wire
- wire leads, 44–45, **48**, 49, 56, **61**, 64–65, 69, 207

See also coil

core memory, 212–213

Cornell-Dubilier 9LS capacitor, 194–195

credit card, 241

CRT (cathode ray tube), 186–189

crystal, quartz, 14–15, 210–211, 260–263

crystal diode, 206–207

crystal oscillator, 262–263

crystal radio, 206

CUI dc-dc converter, 249

cutting and polishing, 272–273

D

d'Arsonval movement, 216–217

DB-9. *See* DE-9 connector

DC-DC converter, 46, 249

DE-9 connector, 160–161

depth of field, 281

deflection yoke, 187–189

diaphragm, 124, **127**, 134

die. *See* diode; integrated circuit; transistor

dielectric, 34

- coaxial cable, 150, 153, 157–158
- metal oxide, 37, 42

dielectric (*continued*)
mica, 194, 196
plastic film, 38
differential signaling, 163, 164
diode
1N740, 66
1N914, 67
1N1100, 67
1N4002, 64–65
1N5236, 67
crystal, 206
germanium, 207
glass-encapsulated, 66–67, 207, **284**
in isolation amplifier, 269
laser, 94–95
light detecting. *See* photodiode
light emitting. *See* LED
point-contact, 206–207
rectifier bridge, 68–69
Zener, 67
diorama illusion, 281
DIP (dual in-line package)
EPROM with window, 210–211
integrated circuits, **19–20, 72, 76–79, 98, 112, 126, 142, 185**
optocoupler, 96
socket, 142–143
switch, 110–111
dipped silver mica capacitor, 196
dipped tantalum capacitor, 40–41
dot matrix LED display, 254–255
drain wire, 162–163, 165–167
DS3231 real time clock, 260–261
dual in-line package. *See* DIP

E

EEPROM, 80. *See also* EPROM
EG&G, 265
eighth-inch plug, 148, 273
elastomeric connector, 236–237
electret microphone, 134–135
electrolyte, 37, 42–43
electromagnetic interference (EMI), 48–49, 150, 162–163, 168, 172
electromagnetic relay, 116–117
electromechanics, 105
electron gun, 186, 188–189
electrons, 64, 182, 184, 186, 188
EMV credit card chip, 241
enamel, 25, 191
encoder, 98–99

epoxy
for assembly, 28, 44, 60, **107**, 124, 208, 218–219
coating, 20, 22, 38, 40–41
conductive, 40, 43, 66
encapsulation, 42, 64, 72–73, 82, 238, 246
glob-top packaging, **236**, 240–243
lens, 88–93, 99, 250–251, 256–257
for photography. *See* potting (for photography)
EPROM (erasable programmable read-only memory), 210–211
erase head, 218
Ethernet cable, 162
Ethernet transformer, 248
Excelitas, 265

F

Fairchild, 178, 208
F connector, 154–155, 276
ferrite
bead, 48–49
inductors, 44–47, 198
in magnetic yoke, 187
memory core, 212
in transformer, 50, 52, **248**
fiberglass
circuit boards, 86, 228, 230, 232, 234, 241, 250
in fuses, 54, 58–59
in power resistor, 19
See also circuit board
field, magnetic. *See* magnetic field
filament, 182, 184, 188, 200–201
LED, 226–227
film capacitor, 38–39, 228
film resistor, carbon, 16–17, 272
filter
optical, 81, 100, 102, 128–131
three-terminal capacitor, 49
flash (camera)
flashbulb, 202–3
smartphone LED, 100, **128**, 244, **245**
flash memory (microSD card), 238–239
flex and rigid-flex circuit boards, **104, 132–133, 220, 222–223**, 234–235
flip chip, 87, 214, **247**
focus stacking, 282
foil
aluminum, 34–35, 37, 43, 150, 152, 164–168, **169**
copper, 52, 218–219
magnesium, 202–203

other metals, 162-163, 172-173, 196, 218-219
frit, glass, 76, **211**
fuse
axial lead, 56
liquid power, 57
low-power cartridge, 54-55, **185**
power, 58-59
thermal, 60-61

G

galena, 206
galvanic isolation. *See* isolation (electrical)
galvanometer (d'Arsonval movement), 216-217
General Electric, 177
germanium, 207
giant magnetoresistance, 222
glass bulb, 176-177, **200-201**, 202-203, 226
glass frit, 76, **211**
glass-to-metal seal, 18, 74-75, 118, 209
glass package
capacitor, 34-35, 197
diode, 66-67, 207, **284**
filter, 130-131
fuse, 54-55, **57**
mercury switch, 190
resistor, 18
vacuum tube, **174-175**, 178-189
glass window
on hybrid modules, **224-225**, 252-253, 258-259, 264-265
on integrated circuits, 102-103, 210-211, **273**
on laser diode, 94
glob-top packaging, **236**, 240-243
GMR hard drive head, 222
green red bicolor LED, 91
green surface-mount LED, 90

H

hard drive, **104-105**, 132, 163, 220-223, 235
HDMI cable, 164-165
head, magnetic, 218-223
header, **33, 72, 78, 82, 86, 112**, 140
headphone plug, 148-189
heat spreader, 86-87
Helicon Focus, 282
Helicon Remote, 278
hermetic seal, 18, 74, 76, 258. *See also* glass-to-metal seal
Hewlett Packard (HP), **252-255**, 256-257
high-stability film resistor, 18
holes and electrons, 64

hotel room NFC card key, 242-243
hybrid circuit
alphanumeric LED display, **254-255**, 258-259
avalanche photodiode, **224-225**, 264-265
crystal oscillator, **262-263**
DC-DC converter, **249**
IBM SLT modules, 214-215
isolation amplifier, 266-269
temperature compensated clock, 260-261
thick-film LED display, 252-253

I

IBM SLT modules, 214-215, **284**
IC. *See* integrated circuit
IDC. *See* insulation displacement connector
IF (intermediate frequency) transformer, 198-199
image sensor
CMOS, 102-103
optical mouse, 82-83
smartphone camera, 128-131
impedance, 52, 156
incandescent light bulb, 200-201
indicator
analog panel meter, 216-217
neon lamp, 176-177
See also LED; numeric display
inductor
axial, 44-45
in DC-DC converter, 249
ferrite bead, 48
IF transformer, 198-199
sintered ferrite, 47
solenoid, 116
surface mount, 46
transformers, 50-53, **235**, 248, 266-269
infrared
ambient light sensor, 100
computer mouse sensor, 98-99
filter, 100, 128, 130-131
laser diode, 94
tilt sensor, 97
insulation displacement connector
ribbon cable, 140
in RJ25 plug, 141
in USB plug 168-171
insulator, 32, 34, 37, 149, 151, 194, 196
integrated circuit
ball grid array, **62-63**, 84-87, 100-101, 246, **247**
DIP packaged, **19-20, 72, 76-79, 98, 112, 126, 142, 185**
EPROM with window, 210-211

integrated circuit (*continued*)
glob-top packaged, **236**, 240–243
image sensor, 82–83, 102–103, 128–131
SOIC packaged, 80–81, 260–261
transparent packaged, 76–77, 80–83, 100–101
in thick-film hybrid, 252–253, 262–263,
266–269
TO-3 packaged, 74–75
TO-99 packaged, 208–209
TQFP packaged, 82–83
See also individual part numbers
intermediate frequency (IF) transformer, 198–199
internet, 155, 162
iron, 44, 116, 122, 124, 218–219
isolation (electrical)
about, 50
amplifier, 266–269
optocoupler for, 96
transformer, 50, 248, 266–269

J

jack. *See* connector
JFET transistor, 134
JM38510 integrated circuit, **76**
JVC camcorder, 186

K

Kapton, 234
Kevlar, 151, 173

L

laptop power cable, 151
laser
diode, 94–95
drilled microvias, 86
in optical drive, 133
printer, 94
trimming, 15, 20–23, 264–265, 268–269
LCD (liquid crystal display), 236–237
LDR (light dependent resistor), 204–205
lead (wire). *See under* copper
lead frame, 76–77, 81–83, 261
lead sulfide (galena), 206
LED (light-emitting diode)
5×7 dot matrix display, 254–255
alphanumeric display, 258–259
bubble display, vintage 256–257
camera flash, 100, **128**, 244, **245**
filament light bulb, 226–227
infrared, 97–99
in optical mouse 98–99

in optical tilt sensor, 97
in optocoupler, 96
red green bicolor, 91
seven-segment display, 250–251, 256–257
surface-mount green, 90
thick-film numeric display, 252–253
through-hole red, 88–89
white, 92–93, 226–227
lens (component)
bubble LED display, 256–257
optical drive, 133
seven-segment LED display, 250–251, 256–257
smartphone camera, 128–130
surface-mount LED, 90
through-hole LED, 88–89
lens (photography of this book)
depth of field, 281
equipment, 278–279
light bulb
incandescent, 200–201
LED filament, 226–227
neon, 176–177
light-dependent resistor, 204–205
light-emitting diode. *See* LED
light filter, 100, 102, 128–131
Lightroom, Adobe, 280
light sensor. *See* optical sensor
limit switch, 114
liquid crystal display, 236–237
liquid power fuse, 57
LM309K voltage regulator, 74–75
LMR-195 coaxial cable, 150
low-power cartridge fuse, 54–55, **185**

M

MacBook Pro cable, 151
Macetech ChronoDot, **260**
macro photography, 281
magnesium, 202
magnet (permanent), 120–127, 130, 132–133, 216–217
magnetic buzzer, 124–125
magnetic field
in core memory, 212–213
in magnetic tape and storage, 218, 222
in NFC card, 242
in relay, 116
in speaker and buzzer, 124, 126
See also inductor; motor; transformer
magnetic pole pieces, **116–117**, 122–123, **124–127**,
217–219
magnetic tape head, 218–219

magnetic yoke, 124, 187–188
magneto-resistance, giant, 222
magnet wire, 46

- in analog panel meter, **217**
- in deflection yoke, 187–189
- in hard drive head, 221
- in inductor, 44–47, 198–199, **249**
- in magnetic tape head, 218–219
- in motor, **14**, 120–123, 130, 132–133, 220
- in NFC card, **243**
- in relay, 116
- in speaker and buzzer, 124–127
- in transformer, 50–53, **248**
- in voice coil motor, 126–127, 130, 132–133

MDL2416 LED display, 258–259
memory

- core, 212–213
- EEPROM, 80
- EMV credit card chip, 241
- EPROM, 210–211
- flash (microSD card), 238–239
- hard drive, **104–105**, 220–223
- RAM module (six-layer board), **232**

mercury tilt switch, 190
meter, 178, 216–217
mica

- capacitor, 194–196
- card resistor, 191
- in vacuum tubes, **180–181**, 182–183

microcontroller, ATmega328, 78–79, **82**, **112**
microphone, 134–135, 244
microprocessor SoC (system on a chip), 86–87
microSD card, 238–239
Microsoft, 83
microswitch, 114–115
microvia, 86–87, 233, **247**
MLCC. *See* multilayer ceramic chip capacitor
mobile phone. *See* smartphone
modular telephone cable, 141
monitor (cathode ray tube), 186–189
monitor cable, 164–167
MOnSter 6502, **90**
motor

- brushed DC, 120–121
- rotary voice coil, 132, 220
- stepper, 122–23
- voice coil, 126, 128, 130, 133

Motorola, 76
mounting (for photography), 276
mouse, computer, 82–83, 98, 114
multilayer ceramic chip capacitor, 36, 197, 247

on circuit boards, **12–13**, **86**, 228–229, **232**,
235, 249

- with pen for scale, **246**
- in thick-film hybrids, 262–263, 264–265, **267**,
268–269

multilayer circuit board, **130**, 232–233, **240**,
244–247
multimeter, 58
multiplexing, 256

N

neon, 176–178
neon lamp, 176–177
Nexus. *See* smartphone
NFC card key, 242–243
night-light, 204–205
Nixie tube, 178–181
numeric display

- alphanumeric, 254–255, 258–259
- LED dot matrix display, 254–255
- Nixie tube, 178–181
- seven-segment LED, 250–251, 256–257
- thick-film LED display, 252–253
- vacuum fluorescent display, 184–185

O

op-amp (operational amplifier), 208–209
optical drive focusing motors, 133
optical filter, 100, 102, 128–131
optical lens assembly, 130
optical mouse, 82–83
optical sensor

- ambient light 100–101
- color, 80–81
- encoder, 98–99
- photodiode, **77**, 94, 264–265
- photoresistor, 204–205
- phototransistor, 96–99
- tilt, 97
- ULN-2232A motion detector, 77
- See also* image sensor

optocoupler, 96
O-ring, 26–27
oscillator, 260–263
oscilloscope, **30**
OSH Park circuit board, **230**
oxygen, 202

P

pager motor, 120–121
Panasonic tape recorder, 218

panel meter, 216–217
parylene, 268
passive components, 13
PCB (printed circuit board). *See* circuit board
phenolic, 192, 196
phone. *See* smartphone
phone plug, 141, 146–149
phosphor, 92, 184–186, 188–189, 226–227
photocell, 204–205
photodiode, 94, 264–265
photographic equipment, 278–279
photoresistor, 204–205
phototransistor, 96–99
piezoelectricity, 14. *See also* quartz
pigment, 204
plated through holes, 230
plug. *See* connector
point contact diode, 206–207
pole (magnetic), 122, 217–219
pole (switch), 106, 116
polyester film, 38
polyethylene foam, 150
polyimide, 234
polymer, conductive, 42–43
polymer aluminum chip capacitor, 43
polymer tantalum chip capacitor, 42
polypropylene film, 38
pot. *See* potentiometer
potentiometer
 10-turn, 30–31
 15-turn trimmer, 28–29
 trimmer 26–27
 vintage wirewound resistor as, 191
 wirewound, 24–25
potting (for photography), 275
 potted samples, 31, **61**, **121**, 125, 127, 135, **172**
 See also epoxy: encapsulation
power cable, 139, 144, 151
power fuse, 57–59
power resistor 19, 60, 191
power supply
 aluminum electrolytic capacitor in, 37
 circuit board 228–229
 dc-dc converter, 249
 optocoupler in, 96
 transformer, 52–53
 voltage regulator, 74
printed circuit board. *See* circuit board
printer, laser, 94
Processing (software), 278
pulldown resistor, 20

pushbutton switch, 109
PVC plastic, 138, 164, 166, 168
Pyrallux, 234

Q

QuadHands vise, 276
quarter-inch audio plug and jack, 146–147
quartz, 14–15, 210–211, 260–263

R

radio, crystal, 206
radio, transistor, 198
radio frequency (RF), 150, 156
RAM. *See* memory
Raspberry Pi, **84**, **86**
RDL (redistribution layer), **62–63**, 84–87, **247**
read-only memory, 210–211
real time clock, 260–261
rectifier. *See* diode
rectifier bridge, 68–69
red green bicolor LED, 91
redistribution layer, **62–63**, 84–87, **247**
reflector, 88, 92
regulator, voltage, 74–75, 249
relay, electromagnetic, 116–117
Residence Inn, 242
resin. *See* epoxy; phenolic; potting (for photography)
resistor
 carbon composition, 192–193, **215**, **284**
 carbon film, 16–17, 272
 chip (surface mount), 22, 228
 high-stability film, 18
 pulldown, 20
 termination, 20
 thick-film array, 20–21
 thin-film array, 23
 variable. *See* potentiometer
 wirewound power, 19, 60, 191
retouching (photography), 280
retro tech, 175
RF (radio frequency), 150, 156
RG-59 (cable television) cable, 153
RG-6 coaxial cable, 152
rheostat. *See* potentiometer
ribbon cable, 140
rigid-flex, 234–235
RJ25 connector, 141
ROM (read-only memory), 210–211
rotary voice coil motor, 132, 220
rotor, 26–27, 120, 122–123

RS-232, 160
RTC (real time clock), 260-261

S

sand, silica 58-59, 72, 78
sanding, 272
Sandisk microSD card, 238-239
sandpaper 272
SATA cable, 163
screw
 adjustment for trimmer, 28-29
 ferrite, 198
 terminal, 195
semiconductors, 63
 galena, 206
 germanium 207
 tailored for LED, 88
 See also diode; integrated circuit; LED;
 silicon; transistor
semi-rigid coax, 158-159
sensor
 hard drive head, 220-223
 magnetic tape head, 218-219
 microswitch, 114-115
 optical. *See* optical sensor
 sound (microphone), 134-135
 temperature, 260
 thermal switch 118-119
 tilt, 97, 190
seven-segment display,
 LED, 250-251, 256-257
 vacuum fluorescent, 184-185
Sharp calculator, 184-185
shield
 cable, 147, 150, 152-154, 158, 162-168, **169**,
 172, **173**
 copper foil, 52-53
 ferrite, 46
 metal, 198, 244, **245**
SIL (single inline) resistor array, 20-21, **262**
silica, 58-59, 72, 78
silicon chip. *See* integrated circuit
silicon diode. *See* diode
silicone rubber, 64-65, 96, 226, 236
silicon transistor. *See* transistor
silkscreening, 20, 28
silver epoxy, 40, 43
silver mica capacitor, 196
single in-line resistor array, 20-21, **262**
single-side printed circuit board, **37, 52, 96, 98-**
99, 125, 185, 228-229, 250-251

sintered ferrite inductor, 47
sintering, 40, 47
slider (hard drive), **105**, 220-223
slide switch, 108
SLT modules, 214-215
SMA connectors, 158-159
small outline integrated circuit (SOIC), 80-81
smartphone
 ambient light sensor, 100-101
 camera, 128-131
 logic board, 233, 244-247
SoC (system on a chip), 86-87
socket
 DIP dual in-line package, 142-143
 See also connector
SOIC (small outline integrated circuit), 80-81
solder
 on cables, **147, 149**, 158-159
 on fuse, 54-56, 58-59
 terminals, 20-21, 32, 44, 46, 49, 52, 64, 134,
 207, 221
 wave process, 229
solder ball, 23, **62-63**, 84-87
solder bump, 66-67, 86-87, 214, 246-247
solder mask, 228, 230, 244
solenoid
 in relay 116
 speaker coil, 124
 See also inductor; transformer
solid wire, 138
speaker, 124-127
spring
 clip, 158, 218
 contact in connector, 142-149, 154-155, 160-
 161, 170-171
 in diodes, 66-67, 206-207
 finger, 28-31, 120-121, 140, 142-143, 146-147,
 170-171
 in fuse, 54-55, 57, 60-61
 suspension, 126, 133, 262-263
 in switch and relay, 106-117
 torsion, 216-217
 wiper in potentiometer, 24-31
sputtering, 23, 32
static electricity, 32
stator, 120, 122-123
stepper motor, 122-123
stiffener, flex, 234-235
ST Microelectronics, 83, 100
stranded wire, 138
strength member, 151, 173

SuperSpeed USB cable, 172–173, 275

surface mount, 22

- ambient light sensor, 100–101
- capacitor, 36, 42–43
- on flexible circuit boards, 234–235
- green LED, 90
- in hybrid modules, **249**, 262–265, 267–269
- image sensor, 102–103
- inductor, 46–47
- integrated circuits, 80–87, **260**
- resistor, 22–23, 228–229
- on single-side circuit board, 228–229
- on smartphone, **128**, 244–247

See also multilayer ceramic chip capacitor

switch

- in connectors, 144–149
- DIP, 110–111
- electromagnetic relay, 116–117
- mercury, 190
- microswitch, 114–115
- optical tilt sensor, 97
- power, **176**
- pushbutton, 109
- slide, 108
- tactile, 112–113
- thermal, 118–119
- toggle, 106–107, **136–137**

Sylvania flashbulbs, 202–203

system in package (SiP), 246–247

system on a chip (SoC), 86–87, **244**, **246**, **247**

T

tactile switch, 112–113

tantalum capacitor, 40–42

tape recorder, 218

TCXO, 260–261

telephone cable and connector, 141

television (cathode ray tube), 186–189

television cable

- coaxial cable and connectors, 153–155
- monitor cable, 164–167

temperature compensated clock, 260–261

termination resistor, 20

thermal fuse, 60–61

thermal switch, 118

thick film

- alphanumeric LED display, 258–259
- avalanche photodiode module, **224–225**, 264–265
- chip resistors, 22
- crystal oscillator, 262–263
- IBM SLT modules, 214–215
- isolation amplifier, 266–269
- LED numeric display, 252–253
- resistor array, 20–21

thin film, 23, 220–223

thin-quad flat pack (TQFP), 82–83

three-terminal filter capacitor, 49

through-hole red LED, 88–89

tilt sensor, 97, 190

TO-3 package, 74

TO-18 package, 70

TO-56 package, 94

TO-92 package, 72

TO-99 package, 208

toggle switch, 106–107, **136–137**

toroidal transformer, 50–51, 248, 266–267, 269

TQFP (thin-quad flat pack), 82–83

trace. *See under* copper

transformer

- in digital camera, **235**
- Ethernet, 248
- IF (intermediate frequency), 198–199
- isolation, 266–269
- power supply, 52–53
- toroidal, 50–51, 248, 266–267, 269

transistor

- 2N2222, 70–71
- 2N3904, 72–73
- bipolar junction (BJT), 70–75, 214
- in circuits, 228, 264–265, 269
- JFET, 134–135
- radio, 198
- on voltage regulator IC, 74–75

transparent integrated circuits, 76–77, 80–83, 100–101

trimmer potentiometer, 26–29

Trimpot, 26–29

triode, 182–184

Triplett analog panel meter, 216–217

tube, vacuum. *See* vacuum tube

tubular ceramic capacitor, 198–199

tungsten, 180, 200–201

twinaxial cable, 163

two-layer printed circuit board, 230–231

- in a module, 249, 257
- redistribution layer, 84
- other examples, **36**, **170–171**, **208**, **236**, **239**, **260**

U

ULN-2232A integrated circuit, 77
USB, 160, 168-169, 172-173, 275

V

vacuum deposition, 23, 38
vacuum fluorescent display, 184-185
vacuum tube
 12AX7, 182-183
 cathode ray tube, 186-189
 guitar amplifier, **174-175**, 192
 vacuum fluorescent display, 184-185
variable resistor. *See* potentiometer
varnish, 44, 47, 138
VD6281 ambient light sensor, 100-101
VFD (vacuum fluorescent display), 184-185
VGA cable, 166-167
via, **80**, 84, 86, **102**, 230, 232-233, **240**, **257**
vibrating motor, 120-121
video
 cable, 164-167
 monitor (cathode ray tube), 186-189
viewfinder, 186-189
vintage LED bubble display, 256-257
vintage wirewound resistors, 191
vitreous enamel, 24-25, 191
VLSI Vision, 102
voice coil, 126-128, 130, 132-133, 220
voltage regulator, 74-75, 249
VV5353 optical mouse sensor, 83

W

watch, 14, 236
wax, 60-61
whisker, 206-207, 274
white LED, 92-93, 226-227
Widlar, Bob, 208
windings. *See* coil
windowed EPROM, 210-211
wiper, 24-31, 60
wire
 bond. *See* bond wire
 copper. *See under* copper
 fusible, 54-56, 58-59
 leads, copper. *See under* copper
 magnet. *See* magnet wire
 resistive, 19, 24, 30-31, **60**, 191
 solid and stranded, 138
 tungsten, 180, 200-201
 See also cable; cat whisker; coil; filament
wirewound
 potentiometer, 24-25
 power resistor, 19, 60, 191
wristwatch, 14, 236

Y

yoke, magnetic, 124-125, 187-189

Z

Zebra strip (elastomeric connector), 236-237
Zener diode, 67