INDEX

1/20 wavelength, 270, 556
180° combiner, 699, 700, 784
1/f noise, 338, 364, 368, 369
1-m radiated emission measurements, 713
  antennas for, 714
  bowtop antenna for, 716
  environment for, 713
  ideal antenna for, 715
  limits for, 713, 715
360° shield termination, 84, 85, 482, 485, 555, 599, 751

Absorption loss, 245, 257, 259, 260
AC line reactor, 539
AC power distribution, 107
AC power line impedance, 492
AC resistance of conductor, 212, 214
AC resistor, 226
Active antennas, 716
Active device noise, 346
Active differential probes, 699
Active power factor correction, 538
A/D converter, 665, 669
  dynamic range, 672
  resolution, 672
  support circuitry, 676, 678
Adequate pressure, 273, 274
Addition of:
  noise powers in dB, 738
  noise voltages, 340
Administrative procedures, 14
AES48, 91
AGND and DGND pins, 665, 670, 682
Air discharge, 558
Alodine®, 276
Aluminum, 275, 284
Aluminum foil cable shields, 61, 81, 165

Amplifier:
  capacitive loads, 186
  common-mode rejection ratio, 169, 171
  decoupling, 185
  differential, 166
  instrumentation, 170
  oscillation in, 186, 188
  parametric, 329
Anechoic room (chamber), 689, 718, 726
Anodize, 274
Antenna:
  active, 716
  biconical, 714
  bowtop, 716
  capacitive loaded, 477, 752, 754
  complementary, 269
  current distribution:
    dipole, 477, 751
    monopole, 477, 751, 758
  dipole, 154, 477, 746
  dipole arrays, 761
  dumbbell, 753
  effective height, 752
  effective length, 752, 759
  for 1-m testing, 714
  ideal, 715
  ideal dipole, 477
  log periodic, 714, 762
  loop, 74, 465
  monopole, 154, 477, 748
  pattern, 466, 477,
  radiation resistance, 756
  receiving dipole, 759
  resonance, 756, 757
  rod, 240
  slot, 269
  straight wire, 240
  top hat, 477, 752, 754
INDEX

Antenna: (continued)
  TV, 762
  very high-frequency dipole, 763
  Yagi, 761
Antenna factor, 715
Antennas versus probes, 689
Anti-pad, 633, 680
Anti-resonance, 440, 444
Antistatic materials, 591
Aperture, 267
  leakage, 268, 697
  maximum linear dimension, 268, 556
  multiple, 270
  shielding effectiveness, 269, 270
Arc:
  ac versus dc, 305
  discharge, 303, 310, 312, 320
  energy, 305, 309
  metal vapor, 303, 312, 320
  secondary, 596
Arcing, 589
  contact, 302
  current, 304, 305
  voltage, 304, 305
Area:
  decoupling capacitor loop, 433
  effective decoupling capacitance, 448
  surface, 585
ARP 1481, 273, 284
ARP 1705, 277
Artificial mains network, see Line impedance stabilization network
Asymmetric stripline, current distribution, 397, 674
Attenuation:
  constant, 221
  ferrite cores, 228
  filter, 176
Audio rectification, 548
Automotive regulations, 19
Available circuit voltage, 312
Available noise power, 332
Avalanche diode, 562
Average detector, 709
Avionics regulations, 28

Band Aid approach, 5
Balance:
  cable, 165
  circuit, 78, 158
  system, 166
Balanced differential probe, 698, 783
Balancing, 158
Balun, 147
Banded end, capacitor, 198
Bandwidth:
  digital signal, 380
  noise, 334
  system, 188
Basic multilayer PCB structures, 651
Beads, ferrite, 226, 229, 231, 307, 453
Bellcore, 18
Belly-band, see Shorted turn
Beryllium copper, 284
Biconical antenna, 714
Biot-Savart law, 55, 767
Blind via, 680
Boltzmann’s constant, 328
Bonded, 111, 593
Bounce:
  contact, 308, 318, 323
  ground, 771
Bowtop antenna, 716
Braided shield, 79
Branch circuit, 109, 112
Breakdown:
  contact, 302
  voltage of air, 597
Bridge, ground plane, 487, 661
Bridge capacitor, 523
Bulk decoupling capacitor, 459
Buried Capacitance®, 450
Buried via, 680
Burst noise, 339

Cable:
  balance, 165
  coaxial, 75, 77, 166, 215
  filtering and shielding, 482, 741
  immunity protection, 555
  low-noise, 35
  ribbon, 94, 555
  shielded, 48, 56, 61, 64, 67, 72, 73, 74, 77, 79, 81, 88, 90, 166, 482
  triaxial, 78, 93
twisted pair, 75, 78

Cable shield:
  braid, 79
  foil, 81
  spiral, 81, 555
termination, 49, 58, 66, 72, 73, 84, 88, 172, 483, 485, 555, 599, 692, 741, 751

Cable shield grounding, 88
double shielded cable, 93
high-frequency, 91
hybrid, 92, 94, 130
low-frequency, 88
triaxial cable, 93
Cabling, 44
Canada Gazette, 30
Canceling loops, 456, 474
Capacitance:
distributed, 447
embedded, 447
free-space, 585
human body, 587
transformer interwinding, 205, 498, 523
transmission line, 225
two concentric spheres, 585
Capacitive coupling, 44, 45, 74, 611
Capacitive loaded antenna, 477, 752, 754
Capacitive loads on amplifiers, 186
Capacitor:
banded end, 198
bridge, 523
bulk decoupling, 459
ceramic, 198
decoupling, 431, 631
electrolytic, 195
equivalent circuit of, 194, 201
ESL, 194, 503
ESR, 194, 506
failure modes, 200
feed-through, 200
film, 197
high-K ceramic, 198, 200
high voltage, 199
mica, 198
multilayer ceramic, 199
operating frequency, 194
paper, 197
paralleling, 202, 437, 440, 444
polarized, 195
power dissipation, 429
resonance, 200
ripple voltage, 197
stitching, 629
surface-mount, 195, 199
tubular, 198
useable frequency, 196
X-capacitor, 512
Y-capacitor, 512, 523
Capacitor contact protection network, 313, 318
Ceramic capacitor, 198
Cascaded stages:
noise factor of, 360
noise temperature of, 363
Cavity resonance, 295
CBEMA curve, 573
CE mark, 25
Cell phone, 680, 719
CENELEC, 25
Central systems with extensions, 142
Chain saw test, 669
Changing reference planes, 630, 633
Characteristic impedance, 180, 217
cox, 219
of free space, 242
of shield, 242
of transmission lines, 180, 181, 217
round conductors, 181, 219
round conductor over a plane, 181, 220
Chassis ground, 107, 131
Chassis-to-circuit ground connection, 131, 486,
625, 741, 750
Chassis wire, 527
Chatter, contact, 308, 318, 323
Chattering relay, 720
Chemical deposition, 292
Chromate conversion coating, 275
Circuit analysis, 36
Circuit orientation, 46, 54
CISPR, 26
conducted emission limits, 13, 20
radiated emission limits, 21, 715
Clamp-on current probe, 690
F-33-1, 690
F-61, 691
for ribbon cables, 692
transfer impedance, 691
Clapping hands analogy, 748
Classic ESD problem, 599
Clock jitter, 676
Clock routing, 472, 633, 740
Clocks, 624, 740
Clustered system grounding, 133, 134
CMRR, see Common-mode rejection ratio
Coaxial cable, 75, 77, 166, 215
Code of Federal Regulations, 7
Combiner, 180°, 699, 700
Common battery system, 141
Common impedance coupling, 32, 69,
124, 128
Common-mode:
choke, 145, 751
for ESD protection, 599, 601
high-frequency analysis, 152
low-frequency analysis, 147
power line filter, 512, 513, 516, 520
current, 148, 481, 500, 690
current clamp, 690
filters, 174, 511, 512, 515
Common-mode: (continued)
  rejection ratio, 161, 166, 169, 171
  voltage, 481
Common-mode cable current:
  maximum, 479
  measurement of, 690
Common-mode emissions, 477
  conducted, 498
  radiated, 477
Common mode radiation, 477
  controlling, 480
Common-mode rejection:
  network, 705
  ratio, 161, 166, 169, 171
Competent body, 24
Complementary antenna, 269
Component placement, 622
Components:
  capacitors, 194
  conductors, 208
  ferrites, 225
  inductors, 203
  passive, 194
  resistors, 206
  transformers, 204
  transmission lines, 215
Computing device, 9
Conducted emission, 492
  limits, 13, 15, 702
  measurements, 14, 700
Conducted immunity, 23, 546, 549
  limits, 546
  measurements, 720
Conduction overlap, 383
Conductive:
  gaskets, 282
  mounting of, 284
  windows, 288
  mounting of, 289
  transparent coatings, 288
  wire mesh screens, 289
Conductive coatings on plastic, 289
  chemical deposition, 292
  electroless plating, 292
  filled plastic, 293
  flame arc spray, 291
  foil linings, 292
  paint, 291
  vacuum metalizing, 291
Conductive finishes for metals, 274
  Alodine®, 276
  aluminum, 275
  chromate, 275
  gold, 274
  Iridite™, 276
  nickel, 275
  stainless steel, 275
  tin, 274
Conductive materials, 591
Conductive paint, 291
Conductive windows, 288
Conductivity:
  of copper, 241
  relative, 243
Conductor:
  ac resistance of, 212, 214
  dc resistance of, 211, 213
  inductance of rectangular, 210
  inductance of round, 209
  motion, 36
  resistance of rectangular, 213
  resistance of round, 211
Connector backshell connection, 485, 625
Connectors, ground cutout for, 634
Contact:
  breakdown, 302
  bounce, 308, 318
  chatter, 308, 318, 323
  life, 306
  materials, 306
  protection, 302
  ac circuits, 305, 318
  capacitive loads, 307
  examples, 324
  fundamentals, 310
  inductive load, 308, 311, 314, 318, 322
  lamp loads, 307
  motor loads, 307, 309
  resistive load, 323
  selection guide, 323
  protection network:
    capacitor, 313, 318
    diode, 316, 318, 322
    resistor, 307, 315
    resistor-capacitor, 316, 318, 324
    resistor-capacitor-diode, 321, 324
    varistor, 316
    zener diode, 316
Contact discharge, 558
Contact noise, 207, 338, 364
Contact rating, 306
Contention current, 384
Contractual EMC requirements, 28, 30
Control inputs, 557, 563, 592, 607
Control panels, 606
Copper fill, 634
INDEX 829

Correlation coefficient, 341
Corrosion, 34, 35, 274
Coupling channel, 30
Coupling, common impedance, 32, 69, 124, 128
Crash cart, 711
Crest factor, white noise, 333
Crisis approach, 4
Critical:
  height, 406
  signals, 623, 629, 636, 644, 645, 649, 652
Crosstalk, 44, 395
Crowbar devices, 565, 567, 571
Current, arcing, 304, 305
Current distribution:
  asymmetric stripline, 397, 674
  dipole, 477, 751, 758
  microstrip, 392, 675
  monopole, 477, 751, 758
  stripline, 395, 675
Current flow, digital logic, 412
Current probe, 690, 692
Cutoff frequency:
  shield, 60, 62, 66
  waveguide, 281
Cyclical redundancy check, 614, 616

daisy chain ground, 123
Damping factor, 184
DC resistance of a conductor, 211, 213
DC to 1-GHz voltage probe, 700
DC to DC converters, 509
Decay time, 590
Decibel, 733
Declaration of conformity, 9, 24
Decoupling:
  amplifier, 185
  capacitor, 431, 631
    bulk, 459
  loop area, 433
  minimum value, 457
  mounting, 459, 457, 458
  placement, 457
  type, 456
  value, 456
  effect of on radiated emission, 454
  filter, 183, 185
  global, 459
  logic circuits, 431, 741
  low-frequency analog, 183
  power supply, 178, 425
Decoupling capacitance area, 448
Decoupling network, 432
  inductance, 432
  loop area, 433
  minimum number of capacitors, 457
  multiple capacitor, 437
    equal value, 437
    many different values, 444
    two different values, 440
  resonance, 433, 436
  single capacitor, 437
  target impedance, 438, 445, 457
Decoupling strategies, 436
Detecting errors:
  input/output, 614
  memory, 614
  program flow, 612
Detector functions, 709
  average, 709
  peak, 709
  quasi-peak, 709
Device level RFI protection, 549
Dielectric constant, 182, 241
Dielectric loss, 223
Differential amplifier, 166
Differential-mode emissions:
  conducted, 501
  radiated, 465, 470, 471
Differential-mode filter, 175, 512, 514, 515
Differential-mode radiation, 465
  controlling, 471
Differential-mode rejection network, 705
Differential signal, 661
Differential voltage probe:
  active, 698
  balanced, 698
  CMRR, 783
  dc to 1 GHz, 700
  passive, 698, 783
Digital circuit:
  bandwidth, 380
  ground noise, 384, 389, 408
  ground noise waveshape, 784
  grounding, 379
  power distribution, 425
  radiation, 464
    common-mode, 477
    differential-mode, 465
Digital device, 9
Digital logic current flow, 412
Microstrip, 414
Stripline, 415
Source of, 412, 414, 415, 417, 418
Summary, 418
Digital logic noise sources, 380, 381
Diode:
  - clamps to the power supply, 605
  - contact protection network, 316, 318, 322
  - noise, 338, 350, 509
  - recovery time, 509
Dipole, 154, 477, 746
  - arrays, 761
  - current distribution, 477, 751, 758
  - effective length, 752, 759
  - impedance, 752, 759
  - monopole equivalence, 757, 760
  - radiation resistance, 756
  - receiving, 759, 760
  - resonance, 756, 757
  - very high-frequency, 763
Dipoles for dummies, 746
Directives, 23
  - automotive, 19
  - EMC, 20, 24
  - medical, 20
Discharge:
  - arc, 303, 310, 312, 320
  - electrostatic, 558, 580, 589
  - glow, 302, 305, 310, 320
  - Townsend, 302
  - vacuum, 303
Discontinuities, shield, 268
Dissimilar metals, joints of, 283
Dissipation factor, 223
Dissipative filters, 185
Distributed capacitance, 447
Distributed system, 140
Dithered clock, 475, 524
DO-160, 30
Documentation, engineering, 6
DOD-HDBK-263, 582, 591
Double shield cable grounding, 93
Drain wire, 165
Dremel® motor tool, 718
Dumbbell antenna, 753
Dynamic internal current, 428
Earth grounds, 107, 108, 114
Earth resistance, 114
Effect of decoupling on radiated emission, 454
Effective:
  - height, 752
  - length, 752, 759
  - radiated power, 547
Effective decoupling capacitance area, 448
Effective decoupling strategies, 436
Eight-layer PCB stackup, 644
Electric field, 240, 253, 254
  - Electric field probe, 695
  - Electric field coupling, 44, 45, 74
  - Electrical fast transient, 558, 722
  - Electrically long cables, 96
  - Electroless plating, 292
  - Electrolytic action, 35
  - Electrolytic capacitor, 195
  - Electromagnetic compatibility, definition, 4
  - Electromagnetic environment, 17
  - Electrostatic discharge, 558, 580, 589
  - air, 558
  - contact 558
  - European Union requirements, 558
  - ground plate, 604
  - grounding, 608
  - margin, 727
  - protection, 591
    - control panels, 606
    - diode clamps to power supply, 605
    - hardening sensitive circuits, 607
    - hardware interrupts, 613
    - I/O cable treatment, 599
    - insulated enclosures, 603
    - keyboards, 606
    - metallic enclosures, 594
    - non-grounded products, 609
    - software, 612
    - three-pronged approach, 591
  - safe clearance distance, 597
  - statistical process, 616
  - testing, 558, 588, 721
  - time windows, 616
  - waveshape, 588
Electrostatic shield (transformer), 204
Electrostatic voltages, typical, 582
Embedded PCB capacitance, 447
EMC crash cart, 711
EMC directive, 20, 24
EMC measurements, see Precompliance EMC measurements
EMC regulations:
  - automotive, 19
  - avionics, 28
  - Canadian, 19
  - European Union, 20
  - FCC, 6
  - medical, 17
  - military, 27
  - telecom, 18
  - EMI gasket, 283
Emission:
  - conducted, 12, 492
  - definition, 4
radiated, 11, 464  
requirements, 20  
Emitter follower, 186  
Empirical equation, ground plane inductance, 404  
Enclosure RFI suppression techniques, 556  
End effects, 409  
Energy, arc, 305, 309  
Engineering documentation, 6  
Environment:  
electromagnetic, 17  
precompliance test, 713  
radiated test, 689  
radio frequency (rf), 547  
Equipment development time schedule, 5  
Equipment grounding, 132  
central systems with extensions, 142  
clustered system, 133  
common battery system, 141  
distributed system, 140  
isolated system, 133  
Equipotential, 120  
Equivalent circuit:  
capacitor, 194, 201  
electric coupling, 37, 54  
feed-through capacitor, 201  
ferrite, 227  
inductor, 203  
magnetic coupling, 38, 54  
resistor, 206  
Equivalent input noise voltage, 352, 353, 367, 370, 371  
ERP, see Effective radiated power  
Error correcting codes, 614  
ESD, see Electrostatic discharge  
Example:  
balanced circuit, 166  
common-mode conducted emission, 501  
contact protection, 324  
DC-to-DC converter, 509  
decoupling capacitors, number of and value, 447  
differential amplifier, 173  
differential-mode conducted emission, 505  
inductance of conductor, 211  
inductance of rectangular loop, 777  
maximum loop area, 468  
mutual inductance, 55  
noise bandwidth, 334  
noise factor of cascaded stages, 360  
power bus impedance, 182  
power gain, 735  
power line voltage interruption, 573  
power supply noise, 379  
radiated emission, 468, 470  
selective shielding, 74  
self-resonant frequency, 433  
static voltage, 582  
transmission line:  
inductance, 778  
phase shift, 221  
characteristic impedance, 221  
use of noise factor, 361  
Excess noise, 207, 338  
Exemptions, FCC, 16  
Experimental data:  
ground grid voltage, 389  
ground plane inductance, 401, 787  
ground plane voltage, 409, 628  
magnetic field cable shielding, 70  
magnetic field shielding effectiveness, 265  
transfer impedance, 278  
External inductance, 209, 765  
F-301 shielded loop probe, 694  
F-31-1 current probe, 690  
F-61 current probe, 691  
Far field, 238, 240, 252  
Faraday shield, 296  
transformer, 204, 498, 524  
Faraday's law, 52, 781  
FAT, 30  
FCC, 6  
conducted emission limits, 13  
exemptions, 16  
measurement procedure, 10, 11, 13, 14  
radiated emission limits, 12, 715  
regulations, 6  
Part 15, 7  
Part 18, 7  
Part 68, 7  
Federal Communications Commission, see FCC  
Federal Register, 30  
Feed-through capacitor, 200  
Fence, PCB, 294  
Ferrite:  
beads, 226, 229, 231, 307, 453  
cores, 226, 227, 232, 555, 751  
equivalent circuit, 227  
tiles, 689  
Ferrites, 225  
aplications of, 229  
as ac resistors, 226  
attenuation, 228  
dc bias current, 231
INDEX

832  INDEX

Ferrites (continued)
   for ESD protection, 601
   impedance,
      versus frequency, 228
      versus de bias current, 232
   saturation, 231
Fiber optics, 146
Field-effect transistor:
   noise, 368
   noise factor, 368
   noise model, 368
   total input noise voltage, 370
   $V_{o-I}$ model, 370
Field emission, 303
Field induced upset, 609
Fields surrounding a microstrip line, 392
Figure of merit, power distribution system, 181
Filled plastic, 293
Filter:
   analog decoupling, 183, 185
   attenuation, 176
   common mode, 174, 511, 512, 515
   damping factor, 184
   differential mode, 175, 512, 514, 515
   dissipative, 185
   $L-C$, 183, 185, 550
   multi-element, 176
   parasitic effects, 177
   pin connector, 603
   power entry, 460
   $R-C$, 183, 185, 188, 550
   reactive, 185
   resonance, 184, 433
   single element, 176
Film capacitor, 197
Filtering, 158, 174
Flame/arc spray, 291
Flicker, 22, 725
Flicker noise, 338
Flyback converter, 496
Foil:
   cable shields, 81
   linings, 292
Four-layer PCB stackup, 638
Fourier spectrum:
   square wave, 468
   transient digital logic current, 429
   triangle wave, 429
Fourteen-layer PCB stackup, 653
Free-space:
   antenna pattern, 466, 477
   capacitance, 585
   Frequency dithering, 475, 524
Gain at resonance, 184, 383
Galvanic:
   action, 33
   corrosion, 34
   couple, 33, 283
   isolation, 204
   series, 34
Gas discharge, see Glow discharge
Gas tubes, 567, 570, 602
Gasket, conductive, 282
Gaussian distribution, 333, 338, 339
General PCB design procedure, 653
Glow discharge, 302, 305, 310, 320
Gold, 274
Gold plated contacts, 306
Ground:
   ac power, 107, 108, 114
   bounce, 771
   cable shield, 49, 58, 66, 72, 73, 84, 88, 172,
      483, 485, 555, 599, 692, 741, 751
   categories of, 107
   chassis, 107, 131
   daisy chain, 123
   definition, 120
   earth, 107, 114
   equipment, 132
   ESD, 595, 608
   fill, 634
   grid, 388, 390, 636
   hard, 590
   hierarchical, 123, 132
   hybrid, 130
   insulated, 116
   isolated, 116
   I/O, 485
   loop, 69, 142
   multipoint, 126
   noise, 384, 389, 409, 628
   noise voltage, waveshape, 784
   resistance, earth, 114
   rod, 110, 115
   safety, 107, 110
   signal, 107, 120
   single point, 124, 662
   single reference, 154
   soft, 590, 609
   star, 123, 662
Ground plane, 390
   bridge, 487, 661
   holes, 390, 627
   impedance, 400
   inductance:
      calculated, 402
measured, 400, 402, 787
measurement of, 780, 786
resistance, 403
slots, 627, 740
split, 628, 660, 668, 741
voltage, 408, 628
measurement, 628, 781, 782
test instrumentation, 786
waveshape, 784
Ground plane current distribution:
asymmetric stripline, 397, 674
microstrip line, 392, 662
stripline, 395
Ground resistance, 114
Ground rod, 110, 115
Ground-to-ground via, 632, 645
Ground strap:
inductance, 136
resonance, 138
Grounded conductor, 110
Grounding, 106, 379
branch circuit, 109, 112
clustered system, 133, 134
digital circuit, 379
equipment, 132
ESD, 608
hierarchical, 123, 132
myths, 114, 119
of shields, 296
system, 132
Grounding conductor, 110
Grounding electrode, 110, 115
Grounding objectives, 120
Hard:
errors, 593
ground, 590
Hardening sensitive circuits, 607
Hardware interrupts, 613
Harmonic analyzer, 724
Harmonic content:
square wave, 469
triangle wave, 430
Harmonic current limits, 724
Harmonic emission, 22
Harmonic suppression, 536
active power factor correction, 536, 538
inductive input filters, 538
Hershey kiss, 475
Heuristic argument, 407
Hierarchical grounding, 123, 132
High-K ceramic capacitor, 198, 200
High-frequency digital decoupling, 425
High-frequency power supply noise, 520
High-resolution A/D converters, 671
High-speed signal lines, 564
High-voltage transients, characteristics of, 558
Holes in shield, 267
Homemade:
balanced differential probe, 698
magnetic field probe, 695
Honeycomb ventilation panel, 282
Human body:
capacitance, 587
ESD model, 587
resistance, 587
Hybrid:
cable shield grounding, 92, 94, 130
ground, 130
protection network, 570
Ideal:
antenna for 1-m testing, 715
shield, 287
Image plane, 553, 636
Images, theory of, 759
Immunity, 545
conducted, 23, 546, 549
definition, 545
ESD, 558, 591
measurements, 717
performance criteria, 545, 593
power line, 566, 572
radiated, 546, 549
requirements, 23, 180, 181, 217, 219, 220, 242
transient, 557
Immunity testing, 717
Impedance:
characteristic, 241
coupling, 32, 69, 124, 128
power line, 492
shield, 242
transfer, 75, 80, 83, 273, 277, 279
wave, 239, 241, 277
Inductance, 209, 385, 765
decoupling network, 432
external, 209, 765
ground plane, 400, 402, 785
empirical equation for, 404
small trace heights, 403
ground strap, 136
internal, 209, 765
leakage, 513
loop, 209, 767, 768, 776
flat conductor, 210, 385
round conductor, 209, 385
Inductance (continued)
- minimizing, 385, 766, 778
- mutual, 37, 52, 54, 386, 391, 768, 773
- near via, 409
- notation, 785
- partial, 387, 765, 770
- mutual, 390, 773
- net, 387, 776
- self, 771
- rectangular loop, 768, 776
- self, 52, 767
- transmission line, 224, 778
- unequal parallel conductors, 777
- Induction motor, 528
  - slip, 529
  - synchronous speed, 528
- Inductive charging, 583
- Inductive coupling, 44, 52, 54, 58, 610
- Inductive input filter, 538
- Inductive kick, 308
- Inductor, equivalent circuit, 203
- Industrial process control equipment, 684
- Industrial, scientific and medical equipment, 7, 20
- Industry Canada, 19, 548
- Information technology equipment, 20, 27
- Inrush current:
  - limit, 725
  - measurement, 725
- Instability:
  - amplifier, 186, 188
  - power supply, 524
- Instrumentation amplifier, 170
- Insulated ground, 116
- Insulators, 242, 591
- Integrated noise factor, 348
- Interference: definition, 4
- Internal inductance, 209, 765
- Internal shields, 293, 597
- International Harmonization, 26
- Interrupts, 557, 563, 592, 607
- Intrinsic noise sources, 328
- I/O:
  - cable treatment, 599
  - ground, 485
  - ground plane, 485, 604
  - ionizer, 589
  - Iridite™, 276
- ISM equipment, 7, 20
- Isolated:
  - ground, 116
  - ground planes, 675
  - ground receptacle, 116
  - system grounding, 133
- Isolation, power supply, 183, 452
- Isolation transformer, 118, 144, 204, 569
- Isosceles triangle wave, 428, 429
- ITE Equipment, 20, 27
- Jitter, clock, 676
- Johnson noise, 328
- Joints:
  - in shields, 273, 280
  - of dissimilar metal, 33, 283
- Keep out zones, 622
- Keyboards, 606
- Layout of:
  - transient voltage suppression diodes, 562
  - 566
- L-C:
  - network resonance, 184, 433, 436
  - filter, 183, 185, 550
- Leakage:
  - aperture, 268, 697
  - charge, 589
  - inductance, 513
  - requirements, 511
- Legal EMC requirements, 8, 18, 23
- Lightning surge, see Surge
- Limits for 1-m radiated emission testing, 713, 715
- Line impedance stabilization network, 13, 494, 700
- Line reactor, 539
- LISN, see Line impedance stabilization network
- Log periodic antenna, 714, 762
- Logarithms, properties of, 733
- Loop antenna, 74, 465
- Loop area, 390, 468
- decoupling capacitor, 433
- Loop inductance, 209, 767, 768, 776
- rectangular conductor, 210, 385
- round conductor, 209, 385
- Loop probe, 74, 694
- Loss tangent, 223
- Low-frequency analog decoupling, 183
- Low-noise cable, 35
- Low power transmitters, 719
- Magnesium, 276
- Magnetic field, 240, 253, 255
  - coupling, 44, 52, 56, 61, 64, 67, 70, 520
  - emission, 525
  - field probe, 74, 694
INDEX 835

Magnetic fields in thin shields, 743
Magnetic material as a shield, 260
Margin, 726
electrostatic discharge, 727
radiated emission, 726
Maximizing emissions, 740
Maximum linear dimension, 268
Maxwell's equations, 36, 37
Measurement of:
ground noise voltage, 781
ground plane inductance, 400, 780
noise factor, 349
random noise, 341
$V_{p}$-$I_{p}$, 355
white noise, 341
Measurement procedure, FCC, 10
conducted emission, 13, 14
radiated emission, 11
Measurements, see Precompliance EMC measurements
Measurement uncertainty, 726
Measuring:
inductance, 400, 780
voltage drop across a conductor, 782
ground plane noise voltage, 781, 782
Medical equipment, 17
Metal foil linings, 292
Metal oxide varistor, 316, 567, 570, 602
contact protection network, 316
multilayer, 567
Metal reference plate, 755
Metal vapor arc, 303, 312, 320
Meter:
average responding, 341
oscilloscope, 342, 697, 725, 783
peak reading, 342
power quality, 573, 724
spectrum analyzer, 707
ture rms, 341
Mica capacitor, 198
Microprocessor:
control inputs, 557, 563, 592, 607
interrupts, 557, 563, 592, 607
resets, 557, 563, 592, 607
Microstrip, 215
fields surrounding a, 392
current distribution, 392, 662
MIL-HDBK-1250, 275
MIL-STD-461, 27
MIL-STD-462, 27
MIL-STD-C-5541E, 276
Military standards, 27
Minimizing inductance, 385, 766, 778
Minimum noise factor, 357, 366
MiniZap®, 721
Mitigation parts list, 712
Mixed-signal:
ICs, 665, 669
$AGND$ and $DGND$ pins, 665, 670, 684
decoupling, 682
PCB layout, 660
isolated ground plane, 675
partitioning, 622, 663, 669
routing discipline, 669
single ground plane, 663, 666, 674
split ground plane, 660, 668
multi-board systems, 671
power distribution, 681
sampling clock jitter, 676
support circuitry, 676, 678
Modes of propagation, 217, 295
Modulation systems, 190
Monopole, 477, 748
current distribution, 751, 758
effective height, 752
impedance, 756
reference plane, 748, 755, 761
resonance, 757
Motor:
dc, 31, 231
induction, 528
slip, 529
synchronous speed, 528
Mounting of:
conductive gaskets, 284
conductive windows, 289
MOV, see Metal oxide varistor
Multi-element filter, 176
Multilayer:
ceramic capacitor, 199
PCB, 552, 608, 637
objectives, 637
shields, 265
Multiple:
apertures, 270
dc voltages, 629, 647, 651
decoupling capacitors, 437
reflections in shields, 256, 743
Multipoint ground, 126
Mumetal, 243, 247, 263, 266
Mutual inductance, 37, 52, 54, 386, 391, 768, 773
polarity of the, 776
Mutual recognition agreement, 20
Myths, grounding, 114, 119
Narrowband transmitters, 719
National Electrical Code, 107, 109, 110, 111, 114, 116
Near field, 238, 240, 253, 259
Near field measurements, 694
NEBS, 18
NEC, see National Electrical Code
Net partial-inductance, 387, 776
Network theory, use of, 36
Neutral conductor, 108, 110
Nickel, 275, 283
Noise:
$1/f$, 338, 364, 368, 369
active device, 346
addition of, 340, 738
bandwidth, 334
burst, 339
contact, 207, 338, 364
control, 111
definition, 3
diode, 338, 350
excess, 207, 338
flicker, 338
Gaussian, 333, 338, 339
ground, 384, 389, 409, 628, 784
in rectifier diodes, 509
in resistors, 207
intrinsic, 4, 328
Johnson, 328
low-frequency, 338
man-made, 4
measuring random, 341
natural disturbances, 4
Nyquist, 328
pink, 339
popcorn, 339
shot, 337, 350, 364
temperature, 362, 363
thermal, 207, 328, 332, 340, 346, 357, 364, 365, 368
white, 332, 338, 350
Noise coupling, 31
common impedance, 32, 69, 124, 128
conductive, 31
electromagnetic, 33
Noise factor:
average, 348
calculating, 356
cascaded stages, 360
definition, 346
field-effect transistor, 368
integrated, 348
measurement of, 349
minimum, 356, 357, 366
op-amp, 375
spot, 348
transistor, 365
Noise figure, 348
Noise models:
field-effect transistor, 368
measurement of $V_n$-$I_n$, 355
op-amp, 372, 374
resistor, 329
transistor, 366
Noise path, typical, 30
Noise power, addition of, 738
Noise voltage:
addition of, 340
and current model ($V_n$-$I_n$), 353, 355, 367, 370, 371
equivalent input, 352, 353, 367, 370, 371
measurements, 697
Non-grounded products, 609
Null experiment, 693
Nyquist noise, 328
OATS, see Open area test site
Official Journal of the European Union, 30
Ohmic loss, 222
Op-amp:
noise, 370
noise factor, 375
total input noise voltage, 371
$V_n$-$I_n$ noise model, 371
Open area test site, 11, 688, 726
Optical coupling, 146
Optimum:
noise performance, 359
source resistance, 357, 366
Orientation, circuit, 46, 54
Oscillation:
in amplifiers, 186
in power supplies, 524
in switching contacts, 313
Oscilloscope, 342, 697, 725, 783
Oxidize, 274
Paint can, 288
Palladium contacts, 306
Parallel resonance, 440, 444
Paralleling capacitors, 202, 437, 440, 444
Parametric amplifier, 329
Parasitic effects in filters, 177
Parity bit, 614, 616
Partial inductance, 387, 765, 770
applications, 776
parallel conductors, 777
rectangular loop, 776
transmission line, 778
mutual, 390, 773
net, 387, 776
self, 771
Partitioning, 622, 663, 669
Parts list, mitigation, 712
Passive components, 194
capacitors, 194
conductors, 208
ferrites, 225
inductors, 203
resistors, 206
transformers, 204
transmission lines, 215
Passive differential probe, 699
Path of least:
inductance, 122
resistance, 122
PCB:
component placement, 622, 664
circuit, 294
keep out zones, 622
layer stackup, 622, 635, 654
layout, 471, 622
level shield, 293
mixed-signal, 660
multilayer, 563, 637
basic structure, 651
design objectives, 637
general design procedure, 653
partitioning, 622, 669
symmetrical construction, 638
to chassis connection, 131, 486, 625, 741, 750
PCB stackup, 622, 635
eight-layer, 644
differential-mode inductors, 635
four-layer, 638
differential-mode filtering, 512, 515
greater than twelve layers, 651
differential-mode inductors, 514
single-layer, 636
leakage inductance, 513
six-layer, 642
leakage requirements, 511
ten-layer, 648
transient suppression, 566
twelve-layer, 651
voltage:
two-layer, 636
Power rail collapse, 771
Peak detector, 709
Perforated sheet stock, 286
Performance criteria, immunity, 545
Periodic signals, 472
Permeability, 241, 243, 261
Phase constant, 221
Piezoelectric effect, 580, 721
Pigtails, 84, 484, 556, 741
Pin 1 problem, 91
Pink noise, 339
Pink polyethylene, 591
Plane-to-plane via, 632, 645
Plane wave, 240, 252, 257
Propagation constant, 220
Popcorn noise, 339
Power:

ingrid, 454
puddle, 454
Power density, 547
Power dissipation capacitance, 429
Power distribution:

analog, 178
digital circuit, 425
figure of merit, 181
mixed-signal, 681
Power entry filter, 460
Power factor correction, 536
ac line reactors, 539
active, 536, 538
passive, 536
inductive input filter, 538
Power line:
disturbance, 572
immunity, 572, 573
immunity curve, 573
impedance, 492
transient suppression, 566
voltage:
dips, 572
interruptions, 572
sags, 572
Power-line filter, 511, 566, 742
common-mode choke, 512, 513, 516, 520
current-mode filtering, 512, 515
differential-mode filtering, 512, 515
differential-mode inductors, 514
leakage inductance, 513
leakage requirements, 511
magnetic coupling to, 520, 525
mounting, 516, 742
X-capacitor, 512
Y-capacitor, 512, 523
Power meter, 573, 724
Power plane, split, 628, 647, 651, 681
Power quality tests, 573, 723
Power rail collapse, 771
Power supply:
decoupling, 178, 425
instability, 524
isolation, 452
Precompliance EMC measurements, 688
l-m radiated emission, 713
common-mode cable currents, 690
conducted:
  emission, 700
  immunity, 720
electrical fast transient, 722
electrostatic discharge, 721
flicker, 725
harmonics, 724
immunity, 717
inrush current, 725
leakage at seams, 697
magnetic fields, 694
near-field measurements, 694
noise voltage, 697
power quality, 723
radiated:
  emission, 689, 713
  immunity, 717
transient immunity, 721
Preventing ESD entry, 594
insulated enclosure, 603
metallic enclosure, 594
Printed circuit board: see PCB
Printed wiring board, see PCB
Probability density function, 333
Probes, 689
balanced differential voltage, 698
common-mode current, 690
electric field, 695
magnetic field, 74, 694
Propagation constant, 220
Propagation delay, 215, 449
Properties of logarithms, 733
Pyramidal cones, carbon loaded, 689
Q, 176, 383
Quasi-peak detector, 709
Quiet ground, 114
Radiated emission:
effect of decoupling on, 454
envelope:
  common-mode, 479
differential-mode, 470
margin, 726
measurement, 11, 713
requirements, 12, 21, 713
test environment, 689, 713
uncertainty, 726
Radiated immunity, 546
  limits, 547
  measurements, 717
Radiation:
  common-mode, 477
  controlling, 480
differential-mode, 465
  controlling, 471
Radiation resistance, 756
Radio-frequency device, 7
Radio-frequency environment, 547
Radio-frequency immunity, 546
cable suppressions techniques, 555
device level, 549
enclosure techniques, 556
\(R-C\):
  contact protection network, 316, 318, 324
  filter, 183, 185, 188, 550
\(R-C-D\) contact protection network, 321, 324
Receiving dipole, 759, 760
Receptacle, isolated ground, 116
Reciprocity, 746
Rectifier diode noise, 509
Reference plane current distribution:
  asymmetric stripline, 397
  microstrip line, 392
  stripline, 395
Reference plane, monopole, 748, 755, 761
Reference planes, changing, 630, 633
Referencing the top and bottom of the same plane, 633
Reflection loss, 245, 249, 260
electric field, 251, 254, 258
generalized equation, 256
magnetic field, 251, 255
plane wave, 252, 257
Regulations:
avtomotive, 19
  SAE J551, 19
  SAE J1113, 19
avionics, 28
  DOE-160, 30
Canadian, 19
European Union 20
FCC, 6
  Part 15, 7
  Part 18, 7
Part 68, 7
medical, 17
military, 27
  MIL-STD-461, 27
  MIL-STD-462, 27
telecom, 18
GR-1089, 18
NEBS, 18
United States, see FCC
Regulatory process, 30
Relay:
coil, 315
general purpose, 306
release time, 316
Requirements:
contractual, 28, 30
EMC, 6, 19, 20, 27, 28
legal, 8, 18, 23
Resets, 557, 563, 592, 607
Resistance:
ac, 212, 214
dc, 211, 213
human body, 587
ground plane, 403
optimum source, 357
Resistivity, 180, 590
Resistor:
equivalent circuit, 206
noise in, 207, 328
power rating, 207
variable, 208
voltage variable, 565
Resistor-capacitor contact protection network, 316, 318, 324
Resistor-capacitor-diode contact protection network, 321, 324
Resistor contact protection network, 315
Resonance:
cavity, 295
circuit, 194, 200, 313, 320, 382, 433, 434, 440, 441, 444
frequency:
capacitor, 200, 436
filter, 184
ground strap, 138
series L-C network, 433, 436
Restricted radiation device, 8
Return path discontinuity, 626
changing reference planes, 630, 633
ground plane cutouts around connectors, 634
ground plane slots, 627
ground plane splits, 628
RF environment, 547
RF immunity, 545, 546
RFI filter, 550
RFI mitigation techniques, 549
cable, 555
device level, 549
enclosure, 556
Ribbon cable, 94, 555
Ribbon cable current probe, 692
RMS meter, true, 341
Rod antenna, 240
Roleson probe, 694
Routing discipline, 669
SAE:
ARP 1481, 273, 284
ARP, 1705, 277
J1113, 19
J551, 19
Safe clearance distance, 597
Safety grounds, 107, 110
Sampling clock jitter, 676
Sanity timer, 613
Saturation, magnetic material, 264
SCIN, see Shield current induced noise
Screening, 286
Seam:
adequate pressure, 273, 274
conductive finish, 273, 274
in shields, 273, 280, 697, 742
Secondary arc, 596
Selection guide, contact protection, 323
Selective shielding (cable), 74
Self-inductance, 52, 767
Self-resonance, capacitor, 194, 200
Semianechoic chamber, 11, 689
Separate I/O ground, 485
Separating C-M from D-M conducted emissions, 704
Separately derived system, 118
Series resonance, 194, 200, 382, 433, 434, 436, 439, 441, 444
Service entrance, 108
Shield:
apertures, 267
cutoff frequency, 60, 62, 66
Faraday, 204, 296
ground of, 296
multiple reflections in, 256, 743
PCB level, 293
termination, 49, 58, 66, 72, 73, 84, 88, 172, 483, 485, 555, 599, 692, 741, 751
transfer impedance, 75, 80, 83
Shield current induced noise, 70
Shielded cable, 48, 56, 61, 64, 67, 72, 73, 74, 77, 79, 81, 88, 90, 166, 482
Shielded loop probe, 74, 694
Shielded room (chamber), 689, 718
Shielding, 238
Shielding effectiveness, 243, 258, 260, 265, 269, 270, 272
aperture, 269, 270, 272
summary, 298
Shoot-through current, 384
Shorted turn, 63, 526
Shot noise, 337, 350
Signal:
cable RFI protection, 555
grounds, 107, 120
grounding objectives, 120
integrity, 626, 645, 652
speed, 624
Signal-to-noise:
  improvement factor, 359
  ratio, 347, 351, 357
Silicon avalanche diode, 562
Silver, 284
Silver contacts, 306
Single element filter, 176
Single ground reference, 154
Single-layer PCBs, 636
Single point ground, 124, 662
Signal speed, 624
Site attenuation, 727
Six-layer PCB stackup, 642
Skin:
depth, 245
effect, 245, 626, 633
Slip (induction motor), 529
Slot antenna, 240
Spectral content of a signal, 624
Spectrum analyzer, 707
detector functions, 709
specifications, 710
Speed of light, 216
Spiral shield, 81, 555
Split ground plane, 628, 660, 668, 741
Split power plane, 628, 647, 651, 681
Spot noise factor, 348
Spread spectrum clock, 475, 524
Square wave, 468
Stackup, PCB:
basic objective, 637
eight-layer boards, 644
four-layer boards, 638
fourteen-layer boards, 653
one-layer boards, 636
six-layer boards, 642
ten-layer boards, 648	
twelve-layer boards, 651
two-layer boards, 636
Stainless steel, 275, 283
Standards, 23
Star grounds, 123, 662
Static:
discharge, 580, 589
dissipative materials, 591
generation, 580
Stitching capacitors, 629
Stokes’ theorem, 772, 775
Straight wire antenna, 240
Stripline, 215
current distribution, 395, 673
Summing:
negative power, 738
noise voltage, 340
Surface area equations, 585
Surface resistivity, 590
Surge, 559, 566
Surge protection:
  ac power lines, 566
  common-mode, 568
dc power lines, 570
differential-mode, 568
Susceptibility:
  conducted, 546
definition, 4, 545
  of inductors, 203
  radiated, 546
  regulations, 17
Switchable-mode rejection network, 706
Switched-mode power supply, 495
common-mode emission, 498
INDEX

**differential-mode emission**, 501
noise sources, 497
primary-to-secondary coupling, 523
rectifier diode noise, 509
ripple filter capacitor, 501
ESL, 503
ESR, 506
snubber network, 510
topologies, 496
Switching contacts, 302
Switching power supply, *see* Switched-mode power supply
Synchronous speed (induction motor), 528
System:
  balance, 166andwidth, 188
grounding, 132
approach, 4
Table:
  1/20 wavelength, 557
A/D converter resolution, 672
apertures, shielding effectiveness, 272
arcing current, 305
arcing voltage, 305
asymmetric stripline current, 399
bandwidth, noise, 337
Canadian EMC test standards, 20
capacitor failure modes, 200
capacitor impedance, 551
capacitor self-resonant frequency, 200
chromate coatings, 276
CISPR radiated emission limits, 21
CISPR conducted emission limits, 13
clearance distance, 597
CMRR, instrumentation amplifier, 172
common-mode current, maximum, 479
composite radiated emission limits, 22
conductive finishes for metal, 274
conductivity, 241, 243
crest factor, 334
dB units, 737
dielectric constant, 182, 241
digital logic current flow, 418
dissipation factor, 223
electrical fast transient testing, applicability matrix, 560
electrostatic voltages, 582
ESD, effect of shield termination on, 600
European Union’s EMC test standards, 25
FCC radiated emission limits, 12
FCC/CISPR conducted emission limits, 13
galvanic series, 34
ground noise voltage, 389
ground plane current:
  microstrip, 663
  stripline, 674
harmonic current limits, 724
harmonic current, isosceles-triangle, 430
impedance of PCB trace, 385
inductance of conductors, 210
inrush current, maximum, 725
instrumentation amplifier:
  CMRR, 172
gain, 172
isosceles-triangle harmonic current, 430
logic current flow, summary, 418
*L-C* network resonant frequency, 436
low-power transmitters, 719
maximum:
  common-mode current, 479
  inrush current, 725
slot length, 271
microstrip ground plane current, 663
MIL-STD-461E:
  applicability matrix, 29
  requirements, 29
noise bandwidth, 337
noise meters, 342
noise voltage, ground grid, 389
permeability, 241, 243, 264
PCB:
  stackup options, 654
  trace impedance, 385
qualitative summary of shielding, 298
radiated emission limits, comparison of, 12
reflection loss constants, 256
resistance of conductors, 210
resistor impedance versus frequency, 207
resolution, A/D converter, 672
resonant frequency of *L-C* network, 436
safe clearance distance, 597
shield cutoff frequency, 62
shield termination effect, 600
shielding effectiveness, summary, 298
skin depth, 247
slotted ground plane voltage, 628
spectrum analyzer specifications, 710
stripline ground plane current, 674
sum of powers in decibels, 739
surface resistivity, 591
surge testing, applicability matrix, 560
tan(θ), 223
thermal noise crest factor, 334
thin shield correction factor, 745
Table (continued)
transient suppression devices, 571
transients, characteristics of, 558
triboelectric series, 581
upper frequency limit, FCC radiated
emission, 13
voltage due to slotted ground plane, 628
voltage sags and interruptions, 572
white noise crest factor, 334
worst case radiated emission limits, 22
Tan(δ), 223
Target impedance, 438, 445, 457
Technical construction file, 24
Telcorida, 18
Telecom regulations, 18
TEM mode of propagation, 217
Temperature, noise, 362
Ten-layer PCB stackup, 648
Test environment, radiated emission, 689, 713
THD, see Total harmonic distortion
Theory of images, 759
Theory of partial inductance, 387, 765, 770
Thermal noise, 207, 328, 332, 340, 346, 357,
364, 365, 368
Thin shield correction factor, 256, 743, 745
Time windows, 616
Tin, 274, 283
whisker growth, 275
Top hat antenna, 477, 752, 754
Total harmonic distortion, 536, 538
Totem-pole output circuit, 383
Townsend discharge, 302
Transfer impedance:
cable shield, 75, 80, 83
measured, 278
measuring, 277
probe, 691
seam, 273, 277, 279
Transformer:
coupled input, 172
isolation, 118, 144, 204, 569
primary-to-secondary coupling, 523
Transient:
ground current, 384
hardened software, 612
immunity, 545, 557, 721
limiter, 703
load current, 427
protection:
high-speed signal lines, 564
networks, 560, 570
power supply current, 426
upset, 593
voltage suppression diodes, 561, 567, 570,
602
layout of, 562, 566
Transient hardened software, 612
Transient suppression:
devices:
characteristics of, 571
gas tubes, 567, 570, 602
MOVs, 567, 570, 602
TVS diodes, 561, 567, 570, 602
high-speed signal line, 564
networks, 560
hybrid, 570
single stage, 561
two-stage, 570
power line, 566
signal line, 561
Transistor:
noise, 364
noise factor, 365
noise model, 366
switch, 322
total input noise voltage, 367
\(V_{n-I_n}\) noise model, 367
Transmission line, 215
asymmetric stripline, 397, 674
attenuation constant, 221
balanced line, 216
capacitance, 225
characteristic impedance, 180, 181, 217
coaxial lines, 219
round conductor over a plane, 220
two round conductors, 219
coaxial, 215
dielectric loss, 223
dissipation factor, 223
distributed parameter model, 215, 217, 219
high-frequency loss, 221
inductance, 224, 778
lossless, 218
low-loss, 221
microstrip, 215, 392, 662, 675
model, 215, 217, 219
ohmic loss, 222
phase constant, 221
propagation:
constant, 220
delay, 215, 449
reflections, 225
rise time degradation, 224
stripline, 215, 395, 673, 675
velocity of propagation, 216, 448
waveguide, 215
Transparent conductive coatings, 288
Transverse electromagnetic mode of propagation, 217
Triangle wave, 428, 429
Triaxial cable, 78, 93
Triboelectric:
  charging, 580
  effect, 35
  series, 581
True rms meter, 341
TV antenna, 760
TVS diodes, see Transient voltage suppression diodes
Twelve-layer PCB stackup, 651
Twisted pair, 75, 77, 78

Universal absorption loss curve, 248
Vacuum discharge, 303
Vacuum metalizing, 291
Variable frequency motor drive, see Variable speed motor drive
Variable speed motor drive, 528
  controlling noise:
    input side, 532
    output side, 532
  harmonic suppression, 539
Varistor, see Metal oxide varistor
Vector magnetic potential, 772, 775
Velocity of propagation, 216, 448
Verification, 10
Vertical isolation, 679
Very high-frequency dipole, 763
Vias:
  blind, 680
  buried, 680
  plane-to-plane, 632, 645
Vibration sensitivity (cable), 36

$V_c - L_c$ noise model, 353, 355, 367, 370, 371
Voltage:
  arcing, 304
  dips, 572
  ground plane, 408, 628
  interruptions, 572
  sags, 572
  Voltage probe, dc to 1-GHz, 700
  Voltage variable resistor, 565

Watchdog timer, 613
Wave impedance, 239, 241, 277
Waveguide, 77, 215
Waveguide below cutoff, 280
Waveshape:
  ground noise voltage, 784
  switched-mode power supply, input, 496
  with inductive input filter, 538
Whisker growth, 275
White noise, 332, 338, 350
Windows, conductive, 288
Wire mesh screens, 289
Workbench EMC measurements, 688

X-capacitor, 512

Yagi antenna, 761
Y-capacitor, 512, 523

Z-axis coupling, 680
ZBC-2000®, 450
Zener diode contact protection network, 316
Zero signal reference plane, 114, 118, 135
Zerostat, 721
Zinc, 274
ZSRP, see Zero signal reference plane