

Chapter One	11
Introduction	11
What You Will Learn.....	12
Who Will Benefit from This Book?	13
The General Format of This Book.....	13
Why Measure?	14
Obtain or Validate Data	14
Design, Selection and Optimization	17
Troubleshooting	18
Validation or Verification	20
Terminology.....	21
Measurement	21
High Fidelity	21
Precise.....	22
Non-Invasive	22
Indirect Measurement	23
In-Situ or In-Circuit	23
 Chapter Two	 24
Measurement Philosophy	24
Cause No Damage.....	24
Measure without Influencing the Measurement.....	25
Validate the Test Setup and Measurement Limits	27
Measure in the Most Efficient and Direct Way	28
Non-Invasive vs. Invasive Measurement	28
In-Situ Measurement	29
Indirect vs. Direct Measurement.....	29
Document Measurements Thoroughly	30
The Test Engineer and Contact Information	31
The Purpose of the Test.....	31
Simulated or Expected Results If Available	33
The Date and Physical Location of the Testing.....	34
Operational Test Environment and Conditions.....	35
The Model of Each Piece of Test Equipment (Including Probes) and Verification they are Calibrated.....	36
Setup Diagram and/or Photograph	36
Measurement Annotations and Comments	38

Any Observed Anomalies	38
Summary of the Results and any Follow-On Work	38
Chapter Three	39
Measurement Fundamentals	39
Sensitivity	39
Noise Floor	41
Dynamic Range	43
Noise Density	49
Signal Averaging	54
Scaling	57
Attenuators	59
Preamplifiers	60
Linear vs. Log display	62
Measurement Domains	64
Frequency Domain	64
Gain and Phase	65
S-Parameters	66
Impedance	67
Time Domain	68
Spectrum Domain	71
Comparing Domains	74
Tips and Tricks	76
Chapter References	77
Chapter Four	78
Test Instruments	78
Frequency Response Analyzers and Vector Network Analyzers	80
The OMICRON Lab Bode 100—Key Features	81
Agilent Technologies E5061B—Key Features	82
Oscilloscopes	83
Teledyne Lecroy Waverunner 640Zi—Key Features	84
Rohde & Schwarz RTO1044—Key Features	85
Tektronix DPO7354C—Key Features	86

Power Integrity

Tektronix DPO72004B Key Features	87
Waverunner 845Zi—Key Features	88
Tektronix MSO5204—Key Features.....	89
Teledyne Lecroy HDO6104—Key Features.....	90
Tektronix MDO4104-6—Key Features	91
OMICRON Lab ISAQ 100—Key Features	92
Spectrum Analyzers	93
Tektronix RSA5106—Key Features.....	93
Agilent Technologies N9020A—Key Features	94
Agilent Technologies E5052B—Key Features	95
Signal Generators.....	96
Agilent Technologies E8257D—Key Features	96
TDR/TDT S-Parameter Analyzers.....	97
PICOTEST G5100A—Key Features	97
TDR/TDT	98
Tektronix DSA8300—Key Features	98
Tektronix 80E10—Key Features	99
Teledyne Lecroy SPARQ 4012E—Key Features	100
Agilent Technologies E5071C Key Features	101
Chapter Five	102
Probes, Injectors and Interconnects.....	102
Voltage Probes	102
Probe Circuit Interaction	105
Flattening the Probe Response	109
Confirming Measurements	111
Selecting a Voltage Probe	113
Passive Probes.....	114
Active Probes	116
Key Features for ZS2500 (ZS4000).....	117
Differential Probes	117
Specialty Probes	118
Low Impedance Probes	118
Multiport Probes	119
Port Splitter	119

Performance Probes	121
Direct Coaxial Cables.....	122
Current Probes.....	123
Insertion Impedance.....	125
Improving Sensitivity	127
Differential or Common Mode Current	127
Near-Field Probes	128
Signal Injectors.....	129
Injection Transformers	130
Solid State Voltage Injectors	131
Solid-State Current Injectors	132
Specialty Coaxial Cables.....	132
DC Bias/Blocker.....	132
Attenuators	133
Line Injector	133
Preamplifier	133
Common Mode Transformers	134
Impedance Fixtures	134
Other Connections	135
Banana Leads	135
Chapter References	136
Chapter 6.....	137
The Distributed System	137
Noise Paths within a Voltage Regulator	138
Internal Noise	140
Power Supply Rejection Ratio (PSRR)	143
Output Impedance	145
Reverse Transfer and Crosstalk	146
Control Loop Stability	148
Impact on Output Impedance	149
Impact on Noise.....	150
Impact on PSRR	152
Impact on Reverse Transfer	152
How Poor Stability Propagates Through the System.....	154

Power Integrity

Adding the PDNs	157
Chapter References	160
Chapter 7	161
Measuring Impedance.....	161
Selecting a Measurement Method	161
Single Port Measurements	162
Introduction.....	162
Pros	163
Cons	164
Tips and Tricks	164
Device Setup	165
Calibrating the Single Port Measurement.....	167
DC Coupled vs AC Coupled	169
Examples.....	169
Two Port Measurements	183
Introduction.....	183
Pros	190
Cons	190
Tips and Tricks	191
Device Setup	192
Calibrating the Two Port Measurement	193
AC-Coupled, Two-Port Shunt-Thru Measurement.....	193
Connecting to the DUT	194
Examples.....	196
Current Injection Measurements	209
Pros	211
Cons	211
Solid State	211
Transformer Coupled	211
Tips and Tricks	212
Device Setup	212
Examples.....	213
Impedance Adapters	215
Pro	215

Cons	216
Tips and Tricks	216
Device setup.....	216
Calibrating the Impedance Adapters	217
Examples.....	219
Chapter References	223
Chapter 8.....	225
Measuring Stability	225
Stability and Why it Matters	225
Control Loop Basics.....	226
Gain Margin, Phase Margin, Delay margin and Stability Margin	229
Bode Plots and Nyquist Charts	230
Open Loop Measurement	237
Selecting an Injection Point.....	239
Measuring High Voltage Loops	241
Injection Devices	242
Transformers.....	242
Injection Resistor	242
Solid State Injectors	244
Probes	245
Calibrating the Setup	245
Small Signal vs. Large Signal	246
Example.....	247
Tips and Tricks	252
Closed Loop Measurement	253
On and Off Measurements	253
Forward Measurements	255
Minor Loop Gain	256
Non-Invasive Closed Loop Measurement	261
Examples.....	262
Tips and Tricks	268
Chapter References	269

Chapter 9	270
Measuring PSRR	270
Measurement Methods	271
In-Circuit or Out-of-Circuit	272
Direct or Indirect Measurement.....	272
Modulating the Input	273
Line Injector	275
Current Injector	280
DC Amplifier.....	282
Choosing the Measurement Domain	282
VNA	283
Spectrum Analyzer	283
Oscilloscope	284
Probes and Sensitivity.....	284
Tips and Tricks.....	289
Examples	290
Chapter References	300
 Chapter 10	 301
Reverse Transfer and Crosstalk	301
Reverse Transfer of Various Topologies	303
Series Linear Regulators	303
Shunt Regulators	304
POL Regulators	305
Operational Amplifiers.....	305
Modulating the Output Current.....	306
Current Injector	306
DC Bias Injector	307
Measuring the Input Current.....	307
Calibrating the Measurement	308
VRTS01 Input Current Port	308
Current Probe.....	310
Measuring the Input Voltage	312
Calibrating the Measurement	313
Indirect Measurement	315

Tips and Tricks	315
Examples.....	315
Chapter References	323
Chapter 11	324
Measuring Step Load Response	324
Generating the Transient	325
Current Injector vs. Electronic Load	325
Slew Rate	327
Current Modulation Waveform	330
Measuring the Response(s).....	333
Large Signal vs. Small Signal	333
Notes about Averaging	334
Sample Rate and Time Scale	337
Additional Examples	338
Tips and Tricks	345
Chapter References	347
Chapter 12	348
Measuring Ripple and Noise	348
Selecting a Measurement Method	349
In or Out of System.....	349
Direct or Indirect.....	350
Time or Spectral Domain	350
Connecting the Equipment	351
Passive Scope Probes	351
Pros	351
Cons	352
Tips and Tricks	352
Active Scope Probes.....	352
Pros	352
Cons	353
Tips and Tricks	353
Direct 50 Ω Terminated Connection	353
Pros	353

Power Integrity

Cons	353
Tips and Tricks	354
Choosing the Equipment	354
Examples	356
Spectral Domain Examples	356
Time Domain Examples	364
Indirect Measurement Examples	369
In-Circuit Examples	374
Averaging and Filtering	376
Chapter References	377
Chapter 13	378
Measuring Edges	378
Relating Bandwidth and Rise Time	379
Cascading Rise Times	384
Impact of Filters and Bandwidth Limiting	388
Sampling Rate and Interleaved Sampling	392
Interpolation	394
Coaxial Cables	395
Effects of High Frequency Losses	396
Velocity Factor and Timing Delay	397
The Criticality of the Probe Connection	398
Printed Circuit Board Issues	403
Probes	403
Example 1: Measuring an Edge with Active and Passive Probes	404
Example 2: Rise Time of a High-Voltage Probe	406
Tips and Tricks	408
Chapter References	409
Chapter 14	410
Troubleshooting with Near Field Probes	410
The Basics of Emissions	411
Near Field Probes	414
Probe and Orientation	415

The Measurement Instrument	419
Spectrum Gating	420
Examples	422
Tips and Tricks	439
Chapter References	440
Chapter 15	441
Higher Frequency Impedance Measurements	441
Time Domain	442
TDR	443
Calibration	444
Reference Plane	445
Setting TDR Pulse Rise Time	451
Interpreting TDR Measurements	452
Estimating Inductance and Capacitance	458
Tips and Tricks	466
S-parameter Measurements	466
Chapter References	470
Afterword by Robert Bolanos—Power Integrity in a Changing Landscape	471