
Contents

Acknowledgments	xiii
1 Introduction	1
What You Will Learn from This Book	1
Who Will Benefit from This Book	2
The General Format of This Book	2
Why Measure	3
Obtain or Validate Data	3
Design, Selection, and Optimization	5
Troubleshooting	5
Validation or Verification	7
Terminology	7
2 Measurement Philosophy	11
Cause No Damage	11
Measure without Influencing the Measurement ...	11
Validate the Test Setup and	
Measurement Limits	12
Measure in the Most Efficient and Direct Way	14
Noninvasive versus Invasive	
Measurement	14
In situ Measurement	14
Indirect versus Direct Measurement	14
Document Measurements Thoroughly	15
The Test Engineer and Contact	
Information	15
The Purpose of the Test	16
Simulated or Expected Results if	
Available	17
The Date and Physical Location	
of the Testing	18
Operational Test Environment	
and Conditions	18
The Model of Each Piece of Test Equipment	
(Including Probes) and Verification That	
They Are Calibrated	18
Setup Diagram and/or Picture	19
Measurement Annotations and	
Comments	20
Any Observed Anomalies	20

Summary of the Results and Any Follow-Up Work	20
3 Measurement Fundamentals	21
Sensitivity	21
Noise Floor	22
Dynamic Range	22
Noise Density	27
Signal Averaging	31
Scaling	33
Attenuators	34
Preamplifiers	35
Linear versus Log Display	36
Measurement Domains	38
Frequency Domain	38
Gain and Phase	38
S-Parameters	38
Impedance	39
Time Domain	40
Spectrum Domain	42
Comparing Domains	44
Endnotes	46
4 Test Instruments	47
Frequency Response Analyzers and Vector Network Analyzers	47
OMICRON Lab Bode 100	49
Agilent Technologies E5061B	50
Oscilloscopes	50
Teledyne Lecroy Waverunner 6Zi	51
Rohde & Schwarz RTO1044	52
Tektronix DPO7000	53
Tektronix DPO72004B	54
Teledyne Lecroy Wavemaster 8Zi	55
Tektronix MSO5204	56
Teledyne Lecroy HDO6104	56
Tektronix MDO4104-6	58
OMICRON Lab ISAQ 100	59
Spectrum Analyzers	59
Tektronix RSA5106A	59
Agilent Technologies N9020A	60
Agilent Technologies E5052B	61
Signal Generators	62
Agilent Technologies E8257D	62
TDR/TDT S-Parameter Analyzers	63
Picotest G5100A	63

	Tektronix DSA8300/E8010E	63
	Teledyne Lecroy SPARQ 4012E	65
	Agilent Technologies E5071C	66
5	Probes, Injectors, and Interconnects	69
	Voltage Probes	69
	Probe Circuit Interaction	70
	Flattening the Probe Response	72
	Confirming Measurements	74
	Selecting a Voltage Probe	75
	Passive Probes	77
	Active Probes	79
	Differential Probes	79
	Specialty Probes	80
	Other Connections	91
	Endnotes	91
6	The Distributed System	93
	Noise Paths within a Voltage Regulator	93
	Internal Noise	95
	Power Supply Rejection Ratio (PSRR)	95
	Output Impedance	99
	Reverse Transfer and Crosstalk	99
	Control Loop Stability	101
	Impact on Output Impedance	101
	Impact on Noise	102
	Impact on PSRR	102
	Impact on Reverse Transfer	103
	How Poor Stability Propagates through the System	103
	Adding the PDNs	106
	Endnotes	108
7	Measuring Impedance	109
	Selecting a Measurement Method	109
	Single-Port Measurements	109
	Two-Port Measurements	123
	Current Injection Measurements	139
	Impedance Adapters	142
	Endnotes	148
8	Measuring Stability	151
	Stability and Why It Matters	151
	Control Loop Basics	151
	Gain Margin, Phase Margin, Delay Margin, and Stability Margin	153
	Bode Plots and Nyquist Charts	154

	Open-Loop Measurement	159
	Injection Devices	161
	Small Signal versus Large Signal	164
	Closed-Loop Measurement	169
	ON and OFF Measurements	170
	Forward Measurements	171
	Minor Loop Gain	171
	Noninvasive Closed-Loop Measurement ...	174
	Endnotes	179
9	Measuring PSRR	181
	Measurement Methods	182
	In-Circuit or Out-of-Circuit	182
	Direct or Indirect Measurement	182
	Modulating the Input	183
	Line Injector	184
	Current Injector	188
	DC Amplifier	189
	Choosing the Measurement Domain	189
	VNA	189
	Spectrum Analyzer	189
	Oscilloscope	190
	Probes and Sensitivity	190
	Endnotes	200
10	Reverse Transfer and Crosstalk	201
	Reverse Transfer of Various Topologies	201
	Series Linear Regulators	201
	Shunt Regulators	201
	POL Regulators	203
	Operational Amplifiers	204
	Modulating the Output Current	204
	Current Injector	205
	DC Bias Injector	205
	Measuring the Input Current	205
	Calibrating the Measurement	205
	Measuring the Input Voltage	207
	Calibrating the Measurement	209
	Indirect Measurement	209
	Endnotes	216
11	Measuring Step Load Response	217
	Generating the Transient	217
	Current Injector versus Electronic Load	217
	Slew Rate	219
	Current Modulation Waveform	221

Measuring the Response(s)	223
Large Signal versus Small Signal	223
Notes about Averaging	224
Sample Rate and Time Scale	226
Endnotes	232
12 Measuring Ripple and Noise	233
Selecting a Measurement Method	234
In or Out of System	234
Direct or Indirect	234
Time or Spectral Domain	234
Connecting the Equipment	235
Passive Scope Probes	235
Active Scope Probes	236
Direct 50- Ω Terminated Connection	236
Choosing the Equipment	237
Averaging and Filtering	252
Endnotes	252
13 Measuring Edges	253
Relating Bandwidth and Rise Time	253
Cascading Rise Times	256
Impact of Filters and Bandwidth	
Limiting	257
Sampling Rate and Interleaved Sampling	261
Interpolation	264
Coaxial Cables	265
Effects of High-Frequency Losses	265
The Criticality of the Probe Connection	267
Printed Circuit Board Issues	269
Probes	269
Endnotes	273
14 Troubleshooting with Near-Field Probes	275
The Basics of Emissions	275
The Near-Field Probes	277
Probe and Orientation	278
The Measurement Instrument	281
Spectrum Gating	281
Endnotes	295
15 High-Frequency Impedance Measurement	297
Time Domain	297
Time Domain Reflectometry	298
Calibration	299
Reference Plane	300

Setting TDR Pulse Rise Time	303
Interpreting TDR Measurements	304
Estimating Inductance and Capacitance	307
S-Parameter Measurements	314
Endnotes	316
Index	319