SIGNAL Integrity Issues and Printed Circuit Board Design

2×10

Induced current loop

VCC

Id

Prentice Hall Modern Semiconductor Design Series

Douglas Brooks

VCC

TABLE OF CONTENTS

PRE	FACE	xvii
Part	1 BASIC CONCEPTS	1
1 E	lectronic Concepts	3
	Current	
	Charge	5
	Voltage	6
	Direct and Alternating Voltage and Current	8
	Harmonics	11
	Measurement of AC Voltage or Current	
	Frequency, Rise/Fall Times, and Period	
	Frequency Measurement	
	Complex Waveforms (Fourier Analyses)	
	Chapter Endnotes	23
	Direction of Current Flow	23
	Some Standard Symbols Used in Electronics	24
	Some Fundamental Definitions	25
	Impportant Names in Electronics	
2 P	ropagation Times	27
	Propagation Speed	27
	Propagation Times	
	Trace Configurations and Signal Propagation	
	Circuit Timing Issues	
	Wavelength	

3	Electrical Components	
	The Three Basics	
	Resistance	
	Ohm's Law	
	Capacitance	
	Charge Storage	
	Formula for Capacitance	
	Capacitance Functions and Effects	
	Inductance	
	Formulas for Inductance	
	Charge and Discharge Currents.	
	Resonance	60
4	Voltage and Current Changes and Time Constants	63
	Voltage and Current Changes Through Resistors	
	Voltage and Current Changes Through Capacitors	
	Voltage and Current Changes Through Inductors	
	Some Interesting Inductive Circuit Dynamics	
	Time Constants	71
	A Note on Charge and Discharge Equations	76
5	Resistance	77
	Kirchhoff's Laws	
	Series Resistors	79
	Parallel Resistors	
	Voltage Dividers	
	Amplifier Feedback and Gain	
	Power	
	Equivalent Circuits	
	Power Curve	
	Power Sources	
	Conductance	94
6	Reactance	97
	Capacitive Reactance	
	Inductive Reactance	
	Ohm's Law for Reactance	
	Series LC Combinations	
	Parallel LC Circuits	
	Resonance	
	Poles and Zeros	

х

Tab	le	of	Co	nte	nts

	Susceptance	
7 In	npedance and Phase Shift	
	Impedance	
	Effect of Frequency	
	Another RC Example	
	Classic RC Filter	
	Combining Impedances	
	Resonance and Q	
	Series RLC Circuits	
	Series RLC at Resonance	
	Admittance	
	Chapter Endnotes	
	Detailed Calculations for Figure 7-8	
	RLC Simulation	
	Imaginary Numbers	
	ng Trace Layon 2	
Part	2 SIGNAL INTEGRITY ISSUES	
8 Si	gnal Integrity Overview	
8 Si 9 El	gnal Integrity Overview	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background	
8 Si ₁ 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations Some Basic Truths	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations Some Basic Truths Signal Coupling	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations Some Basic Truths Signal Coupling Loop Area	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations Some Basic Truths Signal Coupling Loop Area Slots in Planes 1	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations Some Basic Truths Signal Coupling Loop Area Slots in Planes 1 Return Pathways	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations Some Basic Truths Signal Coupling Loop Area Slots in Planes 1 Return Pathways Power Plane Returns	
8 Si 9 El	Integrity Overview	
8 Si 9 El	Integrity Overview	
8 Si 9 El	Integrity Overview	149 155 155 155 156 158 159 161 162 163 164 165 166 167
8 Si 9 El	Integrity Overview	
8 Si 9 El	Integrity Overview	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations Some Basic Truths Signal Coupling Loop Area Slots in Planes 1 Return Pathways Power Plane Returns Changing Trace Layers Unrelated Planes Stubs Common Mode	
8 Si 9 El	gnal Integrity Overview lectromagnetic Interference (EMI) Background Fields and Cancellations Some Basic Truths Signal Coupling Loop Area Slots in Planes 1 Return Pathways Power Plane Returns Changing Trace Layers Unrelated Planes Stubs Common Mode The 20-H Rule	149 155 155 155 156 158 159 161 162 163 164 165 166 167 168 169 173

10	Reflections and Transmission Lines	
	Communications Model	175
	Transmission Lines	
	Critical Length	
	Reflection Coefficients	
	Visualizing Reflections	
	Determining Trace Impedance	185
	Termination Techniques	
	Parallel	
	Thevenin	192
	AC Termination	
	Series	194
	Diode	195
	Some Design Issues	196
	Changing Trace Lavers 1	196
	Power Planes	197
	Changing Trace Layers 2	197
	Slots in Planes 2	199
	Stubs	200
	Absolute vs. Relative Value of Zo	200
	Chapter Endnote	203
	On Formulas	
11	Some Transmission Line Simulations	207
	Basic Simulation	
	Series Termination	
	Placement Issues	
	Branches, or Ys	
12	Crosstalk	
	Longe S. W. S. G. W. S. and a summarised sense in a second s	
	Forward versus Backward Crosstalk	
	Backward Crosstalk	
	Forward Crosstalk	
	In Summary	
	Estimating Crosstalk	
	Calculations	
	Coupling	
	Distance	
	Terminations	
	UltraCAD Calculator	
	HyperLynx Simulation Tool	
	Design Considerations	232

xii

	Slots in Planes 3	
	Guard Bands	
13	Crosstalk Simulations	
	ilai Gapachon	0.00
	Basic Model	
	Add an Uncoupled Region	
	Effect of Length	
	Stripline	
	Stripline With Terminations	
	Summary	
14	Differential Traces and Impedance	240
14	Differential fraces and impedance	······································
	Background	
	Advantages	
	Key Assumptions	
	Design Rules	
	Design Rule 1 (Equal Length)	
	Common Mode Implications	
	Differential Signals and Loop Areas	
	Design Rule 2 (Close Together)	
	Rule 2 Consequence	
	Design Rule 3 (Differential Impedance)	
	Differential Mode Impedance	
	Common Mode Impedance	
	Design Rule 4 (Constant Separation)	
	Differential Simulations	
	Calculating Differential Impedance	
	Edge Coupled	
	Broadside Coupled	
15	Bypass Caps and Decoupling Systems	
	Traditional Approach	
	Size and Quantity	
	Placement	
	Connection	
	Power System Impedance Approach	
	Ideal Response	
	Capacitor Response	
	Inductance Effects	
	Multiple Capacitors	
	Additional Capacitor Value	

	Planar Capacitance	
	Equivalent Series Resistance (ESR)	
	Self Resonant Frequencies	
	Effects of Multiple Capacitors	
	Parallel Capacitors	
	Resonance	
	Impedance at Self-Resonant Frequency	
	Impedance at Anti-Resonance	
	General Case Analysis	
	Consequences	
	Summary	
16 Pov	wer Systems	
	Power Supply Voltages	
	Need For Power Planes	
	Strategies For Designing With Plane	
	Some Design Rules	
	Connecting Reference Planes Together	
	Overlapping Planes	
	Decoupling to Wrong Plane	
	Signals Crossing Separations	
	Stack-Ups	
	Conclusion	
17 Los	ssy Lines and Eye Diagrams	
	Lossy Lines	
	Skin Effect	
	Dielectric Absorption	
	Lossy Line Model	
	Eye Diagrams	
	Equalization	
	Passive Equalization	
	Active Equalization	
	Summary	
Part 3	Appendices, Glossary, and Index	
Appen	dices	
	A UltraCAD's Square Wave Simulator	
	B Why Inductors Induct	
	C Logarithms	

xiv

D	Phase Shift Simulation	
Е	Complex Algebra	
F	Transmission Line Simulation	
G	Echo Illustration	
Н	UltraCAD Freeware Calculators	
Ι	TDRs and VNAs	
J	Right Angle Corners	
Glossary.		
Index		307
Inuc	AK, JETA RITED	
About the	e Author	

xv