

CONTENTS

Preface	xi
1 BASICS	1
1.1 Introduction	1
1.2 Why the Field Approach is Important	3
1.3 The Role of Circuit Analysis	4
1.4 Getting Started	5
1.5 Voltage and the Electric Field	6
1.6 Current	7
1.7 Capacitance	8
1.8 Mutual and Self-Capacitance	10
1.9 E Fields Inside Conductors	11
1.10 The D Field	12
1.11 Energy Storage in a Capacitor	12
1.12 The Energy Stored in an Electric Field	13
1.13 The Magnetic Field	13
1.14 Rise Time/Fall Time	15
1.15 Moving Energy into Components	15
1.16 Faraday's Law	16
1.17 Self- and Mutual Inductance	16
1.18 Poynting's Vector	17
1.19 Fields at DC	18
Glossary	19
2 TRANSMISSION LINES	22
2.1 Introduction	22
2.2 Some Common Assumptions	24
2.3 Transmission Line Types	25
2.4 Characteristic Impedance	27

2.5	Wave Velocity	29
2.6	Step Waves on a Properly Terminated Line	30
2.7	The Open Circuited Transmission Line	31
2.8	The Short Circuited Transmission Line	33
2.9	Waves that Transition between Lines with Different Characteristic Impedances	35
2.10	Nonlinear Terminations	38
2.11	Discharging a Charged Open Transmission Line	38
2.12	Ground/Power Planes	40
2.13	The Ground and Power Planes as a Tapered Transmission Line	41
2.14	Pulling Energy from a Tapered Transmission Line (TTL)	43
2.15	The Energy Flow Through Cascaded (Series) Transmission Lines	45
2.16	An Analysis of Cascaded Transmission Lines	48
2.17	Series (Source) Terminating a Transmission Line	49
2.18	Parallel (Shunt) Terminations	50
2.19	Stubs	52
2.20	Decoupling Capacitor as a Stub	54
2.21	Transmission Line Networks	54
2.22	The Network Program	55
2.23	Measuring Characteristic Impedance	56
	Glossary	57
3	RADIATION AND INTERFERENCE COUPLING	61
3.1	Introduction	61
3.2	The Nature of Fields in Logic Structures	62
3.3	Classical Radiation	62
3.4	Radiation from Step Function Waves	63
3.5	Common Mode and Normal Mode	66
3.6	The Radiation Pattern along a Transmission Line	70
3.7	Notes on Radiation	70
3.8	The Cross Coupling Process (Cross Talk)	71
3.9	Magnetic Component of Cross Coupling	72
3.10	Capacitive Component of Cross Coupling	74
3.11	Cross Coupling Continued	75
3.12	Cross Coupling between Parallel Transmission Lines of Equal Length	76
3.13	Radiation from Board Edges	78
3.14	Ground Bounce	79

3.15	Susceptibility	80
	Glossary	80

4 ENERGY MANAGEMENT 82

4.1	Introduction	82
4.2	The Power Time Constant	84
4.3	Capacitors	86
4.4	The Four-Terminal Capacitor or DTL	87
4.5	Types of DTLs	89
4.6	Circuit Board Resonances	90
4.7	Decoupling Capacitors	90
4.8	The Board Decoupling Problem	92
4.9	The IC Decoupling Problem	93
4.10	Comments on Energy Management	94
4.11	Skin Effect	95
4.12	Dielectric Losses	97
4.13	Split Ground/Power Planes	97
4.14	The Analog/digital Interface Problem	98
4.15	Power Dissipation	99
4.16	Traces through Conducting Planes	100
4.17	Trace Geometries that Reduce Termination Resistor Counts	101
4.18	The Control of Connecting Spaces	101
4.19	Another way to look at Energy Flow in Transmission Lines	103
	Glossary	104

5 SIGNAL INTEGRITY ENGINEERING 106

5.1	Introduction	106
5.2	The Envelope of Permitted Logic Levels	107
5.3	Net Lists	108
5.4	Noise Budgets	108
5.5	Logic Level Variation	109
5.6	Logic and Voltage Drops	110
5.7	Measuring the Performance of a Net	111
5.8	The Decoupling Capacitor	112
5.9	Cross Coupling Problems	114
5.10	Characteristic Impedance and the Error Budget	114
5.11	Resistor Networks	116
5.12	Ferrite Beads	117

5.13	Grounding in Facilities: A Brief Review	118
5.14	Grounding as Applied to Electronic Hardware	120
5.15	Internal Grounding of a Digital Circuit Board	123
5.16	Power Line Interference	124
5.17	Electrostatic Discharge	125
	Glossary	126
6	CIRCUIT BOARDS	130
6.1	Introduction	130
6.2	More about Characteristic Impedance	131
6.3	Microstrip	133
6.4	Centered Stripline	135
6.5	Embedded Microstrip	136
6.6	Asymmetric Stripline	137
6.7	Two-Layer Boards	140
6.8	Four-Layer Circuit Board	143
6.9	Six-Layer Boards	145
	Glossary	147
	Abbreviations and Acronyms	149
	Bibliography	157
	Index	159