Contents

Preface *ix*

1 Fundamentals *1*

1.1 Frequency and Time *1*
1.2 Time and Distance *6*
1.3 Lumped Versus Distributed Systems *7*
1.4 A Note About 3 dB and RMS Frequencies *8*
1.5 Four Kinds of Reactance *10*
1.6 Ordinary Capacitance *11*
1.7 Ordinary Inductance *17*
1.8 A Better Method for Estimating Decay Time *22*
1.9 Mutual Capacitance *25*
1.10 Mutual Inductance *29*

2 High-Speed Properties of Logic Gates *37*

2.1 Historical Development of a Very Old Digital Technology *37*
2.2 Power *39*
2.3 Speed *59*
2.4 Packaging *66*

3 Measurement Techniques *83*

3.1 Rise Time and Bandwidth of Oscilloscope Probes *83*
3.2 Self-inductance of a Probe Ground Loop *86*
3.3 Spurious Signal Pickup from Probe Ground Loops *92*
3.4 How Probes Load Down a Circuit *95*
3.5 Special Probing Fixtures *98*
3.6 Avoiding Pickup from Probe Shield Currents *104*
3.7 Viewing a Serial Data Transmission System *108*
3.8 Slowing Down the System Clock *110*
3.9 Observing Crosstalk *111*
3.10 Measuring Operating Margins *113*
3.11 Observing Metastable States *120*

4 Transmission Lines *133*

4.1 Shortcomings of Ordinary Point-to-Point Wiring *133*
4.2 Infinite Uniform Transmission Line *140*
4.3 Effects of Source and Load Impedance *160*
4.4 Special Transmission Line Cases *167*
4.5 Line Impedance and Propagation Delay *178*

5 Ground Planes and Layer Stacking *189*

5.1 High-Speed Current Follows the Path of Least Inductance *189*
5.2 Crosstalk in Solid Ground Planes *191*
5.3 Crosstalk in Slotted Ground Planes *194*
5.4 Crosstalk in Cross-Hatched Ground Planes *197*
5.5 Crosstalk with Power and Ground Fingers *199*
5.6 Guard Traces *201*
5.7 Near-End and Far-End Crosstalk *204*
5.8 How to Stack Printed Circuit Board Layers *212*

6 Terminations *223*

6.1 End Terminators *223*
6.2 Source Terminators *231*
6.3 Middle Terminators *235*
6.4 AC Biasing for End Terminators *236*
6.5 Resistor Selection *239*
6.6 Crosstalk in Terminators *244*

7 Vias *249*

7.1 Mechanical Properties of Vias *249*
7.2 Capacitance of Vias *257*
7.3 Inductance of Vias *258*
7.4 Return Current and Its Relation to Vias *260*

8 Power Systems *263*

8.1 Providing a Stable Voltage Reference *263*
8.2 Distributing Uniform Voltage *268*
8.3 Everyday Distribution Problems *279*
8.4 Choosing a Bypass Capacitor *281*

9 Connectors *295*

9.1 Mutual Inductance—How Connectors Create Crosstalk *295*
9.2 Series Inductance—How Connectors Create EMI *300*
9.3 Parasitic Capacitance—Using Connectors on a Multidrop Bus *305*
9.4 Measuring Coupling in a Connector *309*
9.5 Continuity of Ground Underneath a Connector *312*
9.6 Fixing EMI Problems with External Connections *314*
9.7 Special Connectors for High-Speed Applications *316*
9.8 Differential Signaling Through a Connector *319*
9.9 Power Handling Features of Connectors *321*

10 Ribbon Cables *323*

10.1 Ribbon Cable Signal Propagation *324*
10.2 Ribbon Cable Crosstalk *329*
10.3 Ribbon Cable Connectors *336*
10.4 Ribbon Cable EMI *338*

11 Clock Distribution *341*

11.1 Timing Margin *341*
11.2 Clock Skew *343*
11.3 Using Low-Impedance Drivers *346*
11.4 Using Low-Impedance Clock Distribution Lines *348*
11.5 Source Termination of Multiple Clock Lines *350*
11.6 Controlling Crosstalk on Clock Lines *352*
11.7 Delay Adjustments *353*
11.8 Differential Distribution *360*
11.9 Clock Signal Duty Cycle *361*
11.10 Canceling Parasitic Capacitance of a Clock Repeater *362*
11.11 Decoupling Clock Receivers from the Clock Bus *364*

12 Clock Oscillators *367*

12.1 Using Canned Clock Oscillators *367*
12.2 Clock Jitter *376*

Collected References *385*

A Points to Remember *389*

B Calculation of Rise Time *399*

C MathCad Formulas *409*

Index *441*