Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

OnLine Lecture 137: Introduction to Discontinuities

- Why this topic is important
  - ✓ Changes in the impedance a signal sees due to physical design feature is absolutely unavoidable
  - ✓ All we can hope to do is optimize the physical design to minimize their impact
  - ✓ By understanding how discontinuities created by geometry changes affect signals, we can identify what is important and equally of value, what is not, in optimizing the physical design of a system
- Level
  - ✓ intermediate
- Recommended prerequisites:
  - ✓ OLL-105 Impedance in the time and frequency domain
  - ✓ OLL-115 characteristic impedance
  - ✓ OLL-120 modeling transmission lines
  - ✓ OLL-135 reflections in the time domain

Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

Copyright © 2005 by Bogatin Enterprises, LLC

Bogatin Enterprises, LLC
26235 W. 110th Terr.
Olathe, KS 66061
v: 913-393-1305
f: 913-393-0929
e: info@BeTheSignal.com
www.BeTheSignal.com

Be The Signal — MYTHS — Bogatin Enterprises, L.L.C.

Outline

- Four important classes of discontinuities
- The reflection and transmission properties of each type of discontinuity
- How much noise is too much
- The role of signal rise time
- General behavior, simulations, rules of thumb and design guidelines

Be The Signal — MYTHS — Bogatin Enterprises, L.L.C.

Golden rule to minimize reflection noise:

Keep the instantaneous impedance the signal sees constant throughout its path.

Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

The Strategy For Designing Out Discontinuities

RULES

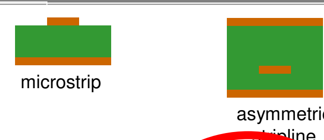
1. Follow guidelines to improve our aim when we shoot from the hip

2. System level numerical simulations!

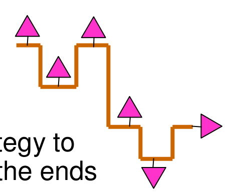
Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

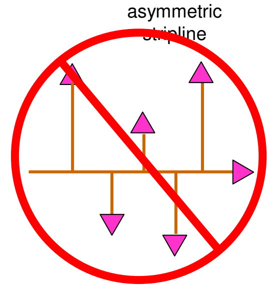
Best Design Practices (OLL-136 Terminations and Topologies)

- Use controlled impedance interconnect

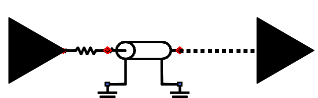


- Route with a linear topology





- Implement a termination strategy to manage the reflections from the ends



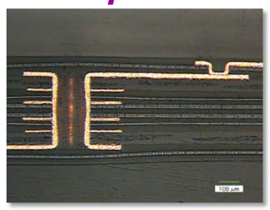
- ***Minimize discontinuities along the line***

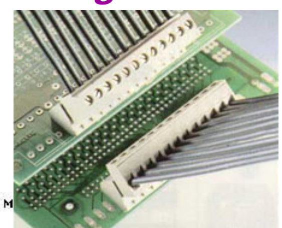
Be The Signal — Bogatin Enterprises, L.L.C.

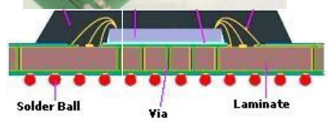
What is a Discontinuity?

A discontinuity: a change in the instantaneous impedance the signal sees

- Vias- layer transitions
- Connectors
- Package leads
- Solder balls
- Stubs
- 90 degree bends, or corners
- Test pads
- Neck downs when passing through a via field
- Engineering change wires
- Gaps in the return path- intentional and unintentional







Be The Signal — Bogatin Enterprises, L.L.C.

Why Worry

- Problems from discontinuities:
  - ✓ Reflection noise
  - ✓ Rise time degradation
  - ✓ Possible enhanced cross talk: switching noise and ground bounce (OLL-220 Switching noise and ground bounce)
- Solutions
  - ✓ Minimize geometry changes
  - ✓ Compensation
  - ✓ Simulate to evaluate if it is a problem
  - ✓ OLL-138 Via design
  - ✓ OLL-139 Optimizing the physical design of discontinuities.

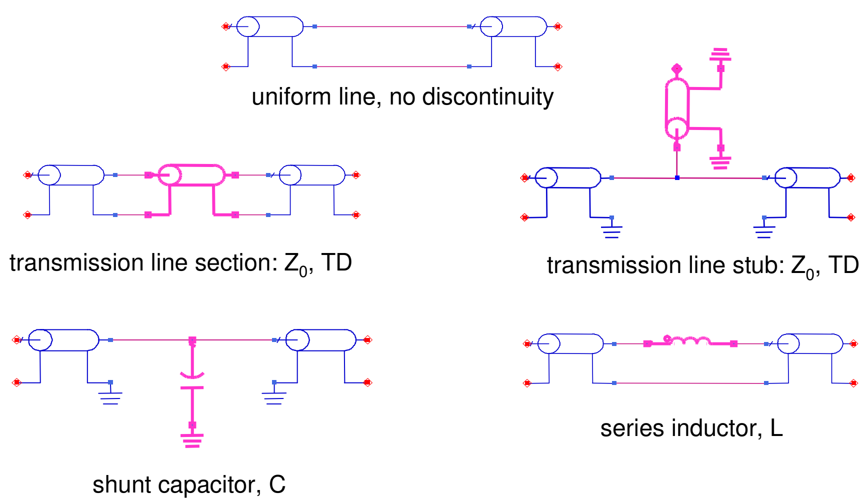
Be The Signal · MYTHS · Bogatin Enterprises, L.L.C.

What to Watch For

- Reflected noise back to the driver
- Transmitted noise into the receiver
- Delay adder
- Rise time degradation

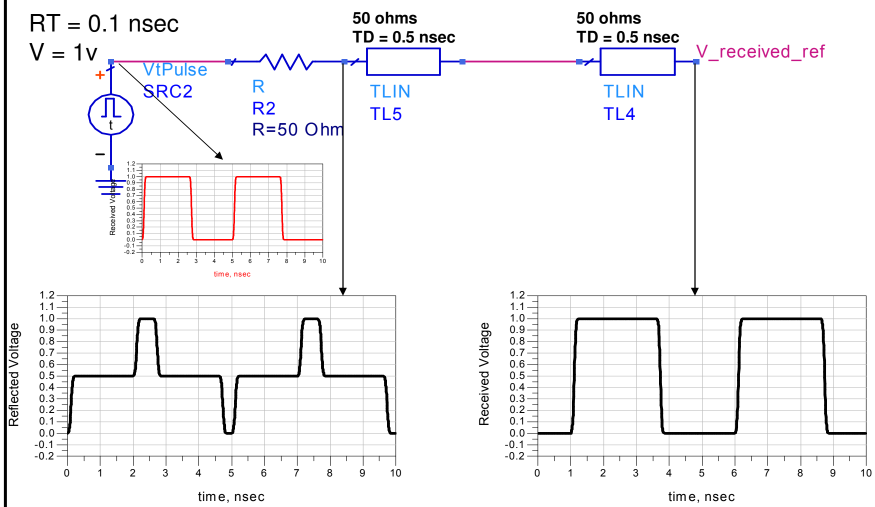
Be The Signal · MYTHS · Bogatin Enterprises, L.L.C.

Four Fundamental Models for Discontinuities



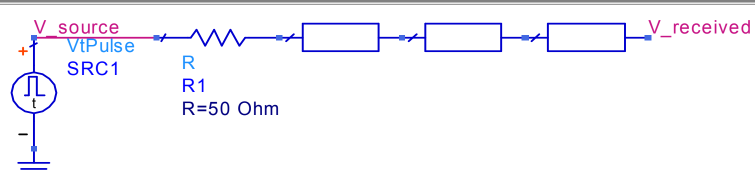
Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Series Terminated Uniform Line: Baseline



Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Series Uniform Transmission Line Segment



- Parameters:
  - ✓ Z_0
  - ✓ TD
- Examples:
  - ✓ Neck downs through via fields
  - ✓ Surface trace passing under component
  - ✓ Package trace
  - ✓ Poorly designed buried layer

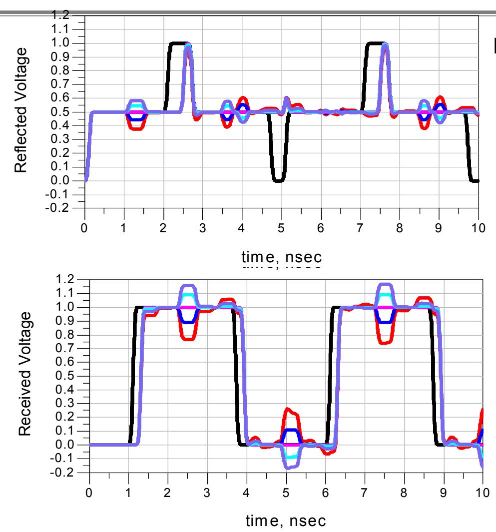
Be The Signal MYTHS Bogatin Enterprises, L.L.C.

What to Expect

- Reflected signal:
  - ✓ Positive if Z_0 > 50 ohms, negative if Z_0 < 50 ohms
  - ✓ If 2 x TD > RT, should see flat bottom
  - ✓ If 2 x TD < RT, will see a pulse
  - ✓ Rho ~ (Z_0 – 50 Ohms)/100 Ohms
  - ✓ For < 10% reflection noise, keep Z_0 within 10 ohms of 50 ohms: 40-60 ohms
  - ✓ As TD goes down, can allow larger impedance change: rho ~2 xTD/RT x rho_{long}
- Transmitted signal:
  - ✓ Same conditions should apply

Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Effect of the T Line Impedance



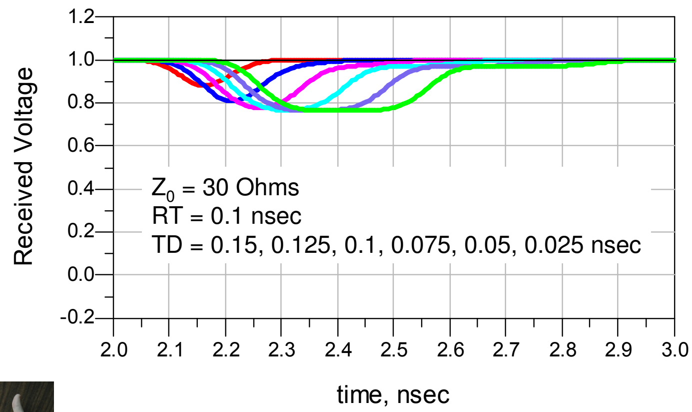
Black trace is with no discontinuity

TD = 0.2 nsec
(RT = 0.1 nsec)

Z_0 = 30, 40, 50, 60, 70 Ohms

Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

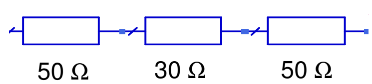
Effect of the T Line Time Delay

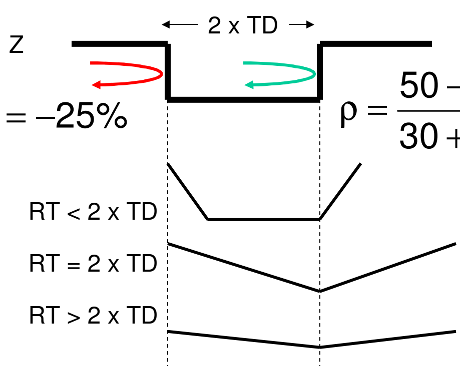


Keep TD < 50% RT

Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

Time Delay and Rise Time Interactions





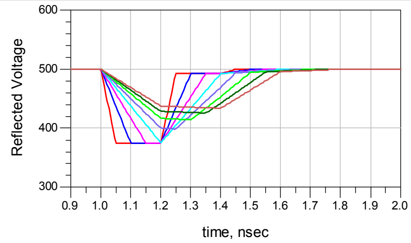
$$\rho = \frac{30-50}{30+50} = -25\%$$

$$\rho = \frac{50-30}{30+50} = +25\%$$

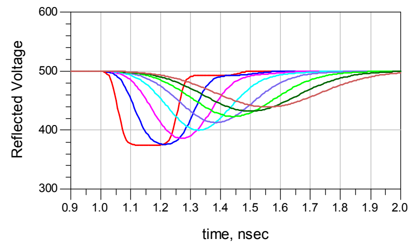
Bogatin Enterprises, L.L.C.

Effect of the Signal Rise Time

TD = 0.1 nsec
RT =
0.5 x TD
1 x TD
1.5 x TD
2 x TD
2.5 x TD
3 x TD
3.5 x TD
4 x TD



Reflected amplitude is reduced when RT > 2 x TD (teal trace)

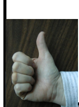


When the edge is not an ideal ramp (Gaussian), estimate is less precise (rise time is not 0-100)

Bogatin Enterprises, L.L.C.

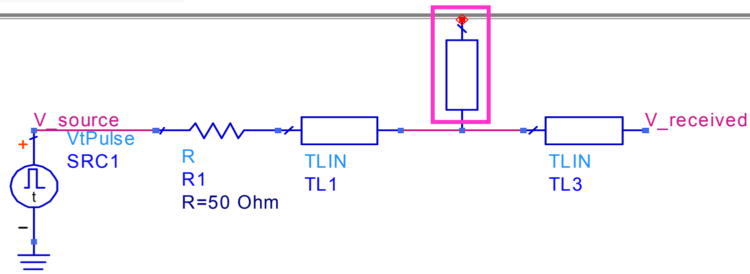
Summary of Guidelines for transmission line segment

- Reflected noise:
  - ✓ If 2 x TD > RT $$Noise\% = \frac{V_{reflection}}{V_{signal}} \sim \frac{\Delta Z}{100}$$
  - ✓ If 2 x TD < RT $$Noise\% = \frac{V_{reflection}}{V_{signal}} \sim \frac{\Delta Z}{100} x \frac{2 \text{ x } TD}{RT}$$
- Design guidelines (for < 10% noise)
  - ✓ Keep impedance within +/- 10 ohms of 50: 40< Z_0 < 60
  - ✓ If Z_0 is more than 10 Ohms off, keep TD < 0.5 x RT
  - ✓ If Z_0 is more than 20 Ohms off, keep TD < 0.2 x RT (20% RT)
  - ✓ **Len (in inches) < RT (nsec)**



Bogatin Enterprises, L.L.C.

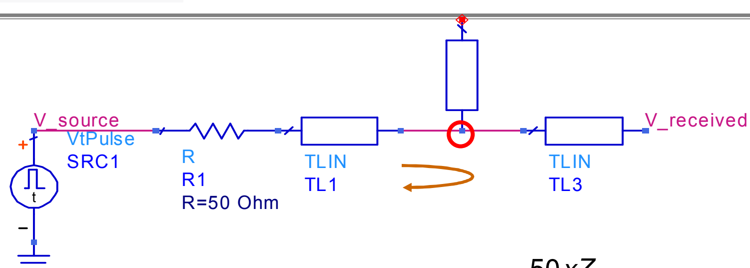
Transmission Line Stub



- Parameters:
  - ✓ Z_0
  - ✓ TD
- Examples:
  - ✓ Routing stubs
  - ✓ Plating stubs in packages
  - ✓ Through hole via stubs

Bogatin Enterprises, L.L.C.

What to Expect



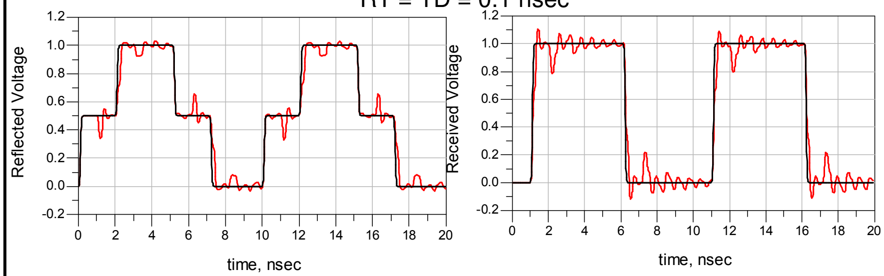
- Reflected signal will have a negative dip.
  - ✓ Lower impedance of stub, larger the dip
  - ✓ Longer TD, larger the dip
- Received signal will see the dip from second incidence reflection
- Lower impact from higher stub impedance, shorter time delay

$$\rho = \frac{\frac{50 x Z_0}{50 + Z_0} - 50}{\frac{50 x Z_0}{50 + Z_0} + 50} \sim \frac{-1}{1 + \frac{Z_0}{25}}$$

Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

General Features of Stub Effects: Z_0 = 50 Ohms, TD = RT

RT = TD = 0.1 nsec

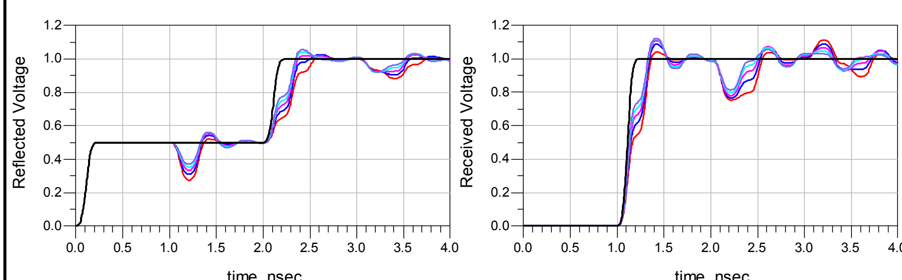


- Received signal:
  - ✓ Ringing last for a a multiple round trip times (3 x 1 nsec)
  - ✓ Undershoot at 1 nsec from reflection from the stub can cause false switching
- Reflected signal:
  - ✓ Large dip from the stub

Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

Effect of the Impedance of the Stub: Z_0 = 30Ω, 40Ω, 50Ω, 60Ω, 70Ω,

TD = RT = 0.1 nsec

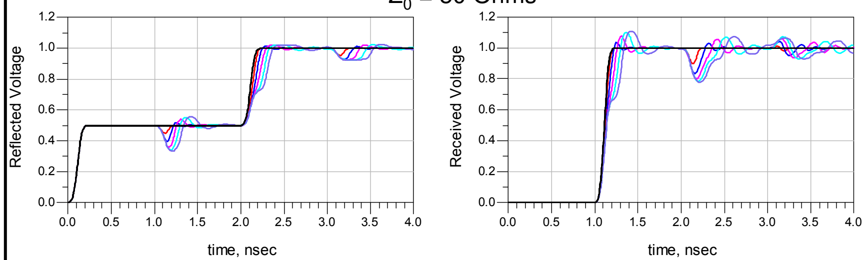


- Noise magnitude roughly High impedance for the stub is lower noise in reflection
- Decreasing impedance, not a big impact on the received noise

Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

Effect of the Time Delay of the Stub: TD = RT, 80%, 60%, 40%, 20%

Z_0 = 50 Ohms



- Shorter TD reduces received noise
  - ✓ Provided TD < 50% RT
  - ✓ Less than 10% noise if TD < 20% RT

Be The Signal
MYTHS
Bogatin Enterprises, L.L.C.

Guidelines for Stub Design

- Higher impedance stubs will reflect less noise
- Reflected noise back to the driver is $\rho \sim \dfrac{-1}{1+\dfrac{Z_0}{25}}$
- Reflection noise at the receiver is ~ 20%
- If TD < 0.5 x RT, received signal will decrease

Bogatin Enterprises, L.L.C.

Very Useful Rule of Thumb

- Keep TD < 20% RT
- Len of discontinuity = TD x v = TD x 6 inch/nsec
- Len < 20% x v x RT= 1.2 x RT ~ RT

Len (in inches) < RT (nsec)

Examples:
RT = 1 nsec, Len < 1 inch
RT = 0.25 nsec, Len < 0.25 inches
RT = 0.1 nsec, Len < 0.1 inches

Bogatin Enterprises, L.L.C.

This concludes session A. Please return to www.BeTheSignal.com and start session B

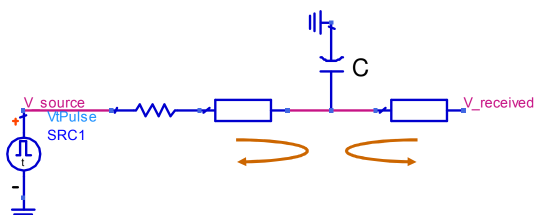
Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Welcome back to session B of OnLine Lecture OLL137 Introduction to Discontinuities

Be The Signal MYTHS Bogatin Enterprises, L.L.C.

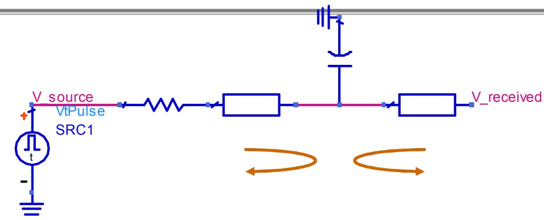
Shunt C Discontinuities

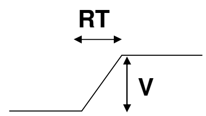
- Examples
  - ✓ Via capture pads
  - ✓ Test points
  - ✓ Component leads
  - ✓ Empty connectors
  - ✓ 90 degree bends



© Eric Bogatin 2005
www.BeTheSignal.com

Impact from Shunt C Discontinuities





$$Z_{cap} = \frac{V}{C\frac{dV}{dt}} = \frac{V}{C\frac{V}{RT}} = \frac{RT}{C}$$

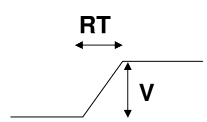
Shunt impedance

Examples:

RT = 1 nsec, C = 1 pF, Z_{cap} ~ 1000 Ohms

RT = 0.1 nsec, C = 1 pF, Z_{cap} ~ 100 Ohms

Estimating Reflected Noise



$$Z_{cap} = \frac{V}{C\frac{dV}{dt}} = \frac{V}{C\frac{V}{RT}} = \frac{RT}{C}$$

$$\rho \sim \frac{-1}{1+\frac{Z_{Cap}}{25}} \qquad \rho \sim \frac{-1}{1+\frac{RT}{25xC}} \sim -\frac{25xC}{RT}$$

Examples:

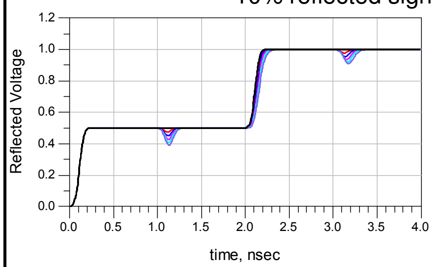
RT = 1 nsec, C = 1 pF, rho ~-0.025/1 ~ -2.5%

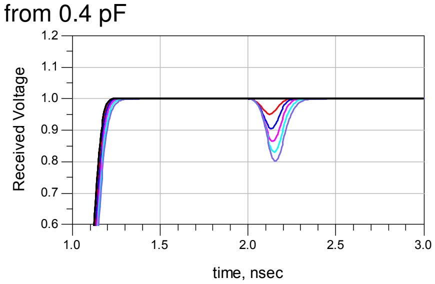
RT = 0.1 nsec, C = 1 pF, rho ~-0.025/0.1 ~ -25%

Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Simulation of Capacitive Discontinuity

RT = 0.1 nsec
C = 0.2 pF, 0.4 pF, 0.6 pF, 0.8 pF, 1 pF
Estimate:
~ 25% reflected signal from 1 pF cap.
~ 10% reflected signal from 0.4 pF

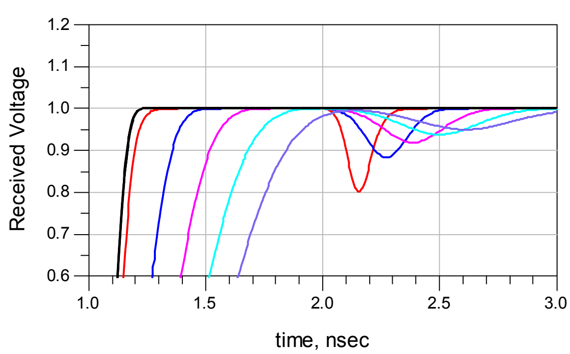




Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Effect of the Signal Rise Time

C = 1 pF
RT = 0.1 nsec, 0.2, 0.3, 0.4, 0.5



Be The Signal MYTHS Bogatin Enterprises, L.L.C.

A Rule of Thumb

$$\rho \sim \frac{-1}{1+\frac{RT}{25xC}} \sim -\frac{25xC}{RT}$$

For rho < -10%,
C < 0.1 x RT/25
C < 0.004 x RT

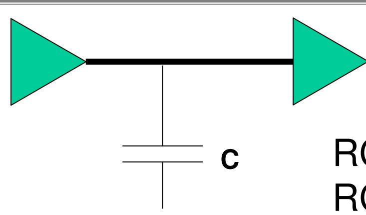
Keep C < 4 x RT

C in pF, RT in nsec

Examples
if RT = 1 nsec, C < 4 pF
If RT = 0.1 nsec, C < 0.4 pF

Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Delay Adder from Capacitive Loads



RC: R = ½ Z_0,
RC = ½ Z_0 x C

0-50% RT ~ 1.2 x ½ x Z_0 x C ~ 0.03 x C (C in pF, RT in nsec)

Example: 5 pF load: RT ~ 0.03 x 5 pF = 0.150 nsec

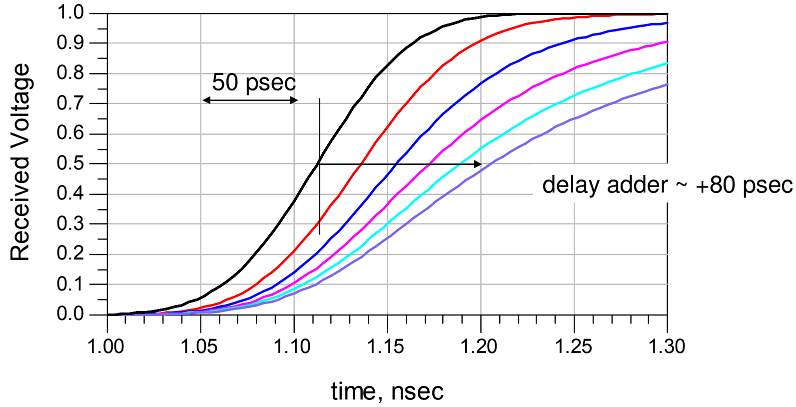
$$RT_{output} = \sqrt{RT_{incident}^2 + RT_{cap}^2}$$

$$RT_{output} = \sqrt{0.1^2 + 0.15^2} = 0.18\text{nsec}$$

© Eric Bogatin 2005 www.BeTheSignal.com

Bogatin Enterprises, L.L.C.

Simulations of Delay Adder



C = 1, 2, 3, 4, 5 pF
RT = 0.1 nsec
Delay adder expected ~ 80 psec

Bogatin Enterprises, L.L.C.

Summary of Design Guidelines For Capacitive Discontinuities

For C in pF and RT in nsec

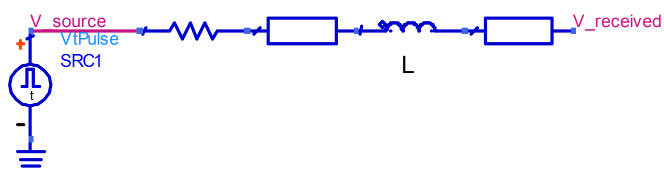
- Reflection noise ~ -2.5% x C/RT
- For < 10% reflected noise, keep C < 4 x RT
- Delay adder is 50%RT ~ 0.03 x C

$$RT_{output} = \sqrt{RT_{incident}^2 + RT_{cap}^2}$$

Bogatin Enterprises, L.L.C.

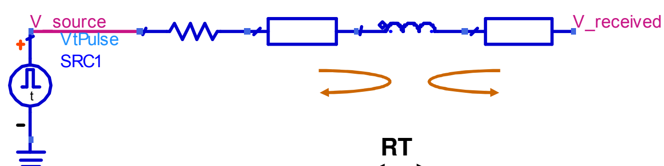
Series L Discontinuities

- Examples
  - ✓ Via transition
  - ✓ Wire bond
  - ✓ Connector lead
  - ✓ Engineering change wire
  - ✓ Gap in the return path

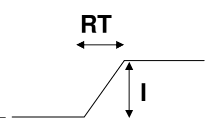


Bogatin Enterprises, L.L.C.

Impact from Series Inductor



$$Z_{inductor} = \frac{V}{I} = \frac{L}{I}\frac{dI}{dt} = \frac{L}{RT}$$

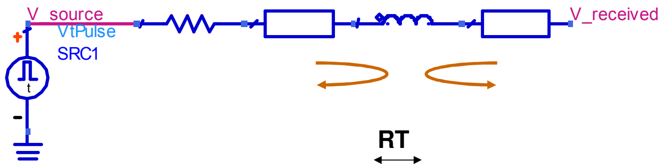


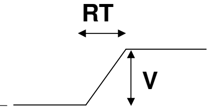
Series impedance

Examples:
RT = 1 nsec, L = 10 nH, Z_L ~ 10 Ohms
RT = 0.1 nsec, L = 10 nH, Z_L ~ 100 Ohms

Bogatin Enterprises, L.L.C.

Reflections from Series L Discontinuities





$$Z_{inductor} = \frac{V}{I} = \frac{L}{I}\frac{dI}{dt} = \frac{L}{RT}$$

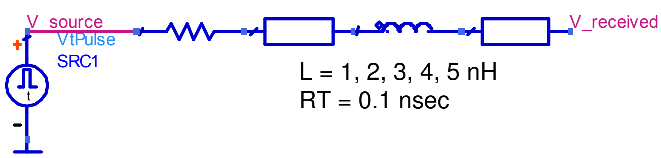
$$rho = \frac{(Z_L + Z_0) - Z_0}{(Z_L + Z_0) + Z_0} \sim \frac{Z_L}{2Z_0} \sim \frac{Z_L}{100}$$

Examples:
RT = 1 nsec, L = 1 nH, rho ~ 1%
RT = 0.1 nsec, L = 1 nH, rho ~ 10%

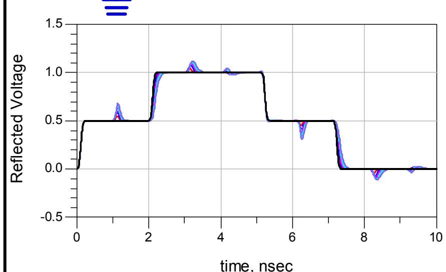
$$rho \sim \frac{L}{100 \, x RT}$$

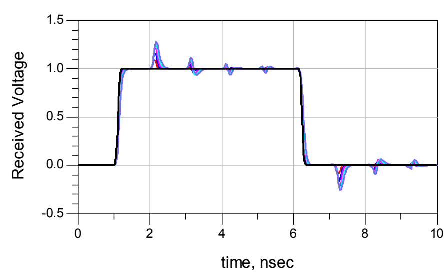
Bogatin Enterprises, L.L.C.

Simulating Inductive Discontinuities: source series terminated



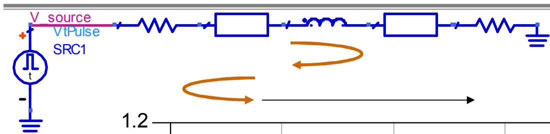
L = 1, 2, 3, 4, 5 nH
RT = 0.1 nsec



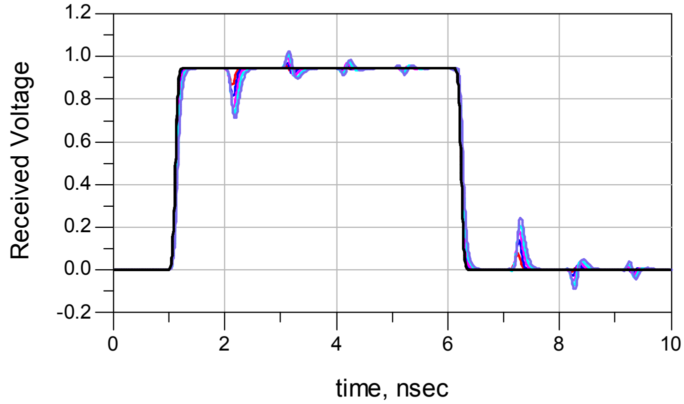


Be The Signal · MYTHS · Bogatin Enterprises, L.L.C.

Far End Terminated Circuit



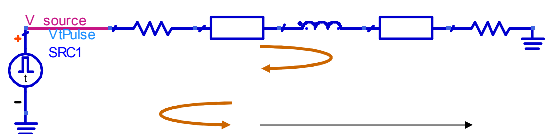
L = 1, 2, 3, 4, 5 nH
RT = 0.1 nsec



Be The Signal · MYTHS · Bogatin Enterprises, L.L.C.

Impact from Reflected Signal

$$rho \sim \frac{L}{100 x RT}$$



For noise < 10%,

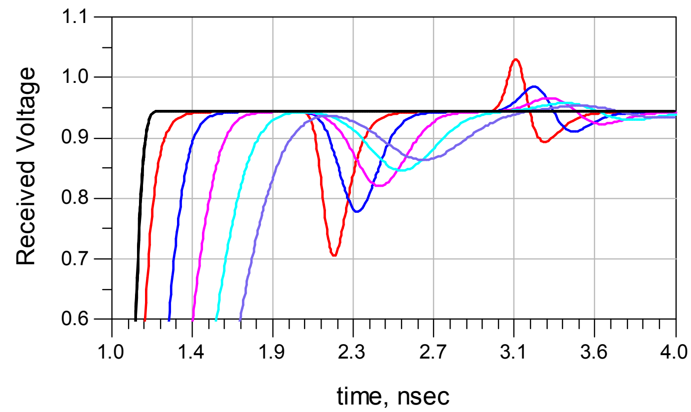
L < 10 x RT

Examples:
If RT = 1 nsec, keep L < 10 nH
If RT = 0.1 nsec, keep L < 1 nH

Be The Signal MYTHS Bogatin Enterprises, L.L.C.

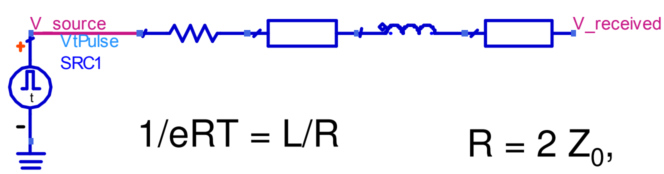
Effect of the Rise Time: far end terminated

L = 5 nH
Expected rho @ RT = 0.5 nsec = 10%
RT = 0.1, 0.2, 0.3, 0.4, 0.5 nsec



Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Delay Adders with Inductive Discontinuities



1/eRT = L/R

R = 2 Z_0,
1/eRT = L/(2Z_0)

0-50% RT ~ 1.2 x L/2Z_0 ~ 0.012 x L (L in nH, RT in nsec)

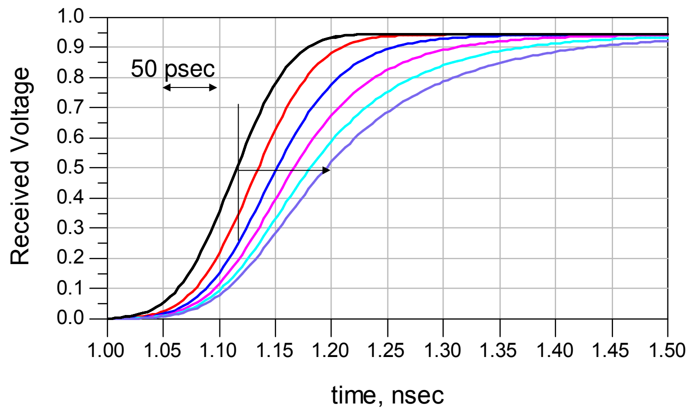
Example: 10 nH inductor: 50%RT ~ 0.012 x 10 nH = 0.12 nsec

$$RT_{output} = \sqrt{RT_{incident}^2 + RT_{cap}^2}$$

$$RT_{output} = \sqrt{0.1^2 + 0.12^2} = 0.16 nsec$$

Be The Signal — MYTHS — Bogatin Enterprises, L.L.C.

Simulating Delay Adders with Inductive Discontinuity



L = 2, 4, 6, 8, 10 nH
RT = 0.1 nsec
Delay adder ~ 60 psec

Be The Signal — MYTHS — Bogatin Enterprises, L.L.C.

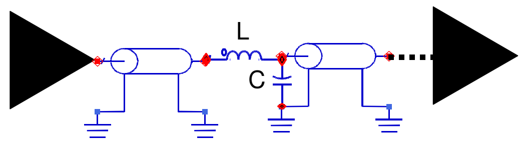
Summary of Design Guidelines For Inductive Discontinuities

- A series L is a problem for far end terminated lines
- Reflection noise ~ L/(100 x RT)
- For < 10% reflected noise, keep L < 10 x RT
- The L creates a rise time filter with 50%RT ~ 0.012 x L

© Eric Bogatin 2005
www.BeTheSignal.com

Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Principles of Compensation

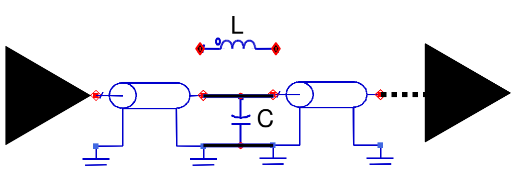


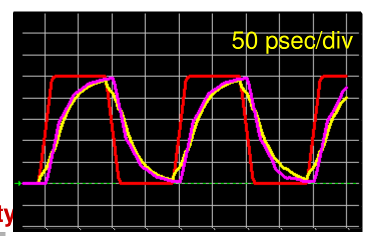
$$\sqrt{\frac{L}{C}} = Z_0$$

$$L = C \times Z_0^2 \qquad C = \frac{L}{Z_0^2}$$

Be The Signal MYTHS Bogatin Enterprises, L.L.C.

Time Domain Impact From C, L Discontinuities





20 psec RT, No Discontinuity

1 pF C Discontinuity

2.5 nH L Discontinuity

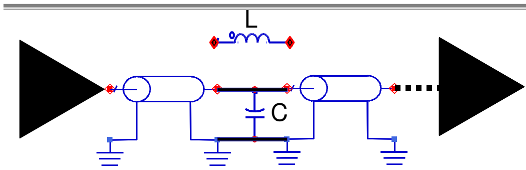
Rise Time Degradation

10%-90% RT = 2.2 x RC = 2.2 x ½ x Z_0 x C ~ Z_0 x C = 50 x 1 pF ~ 50 psec

10%-90% RT = 2.2 x L/R = 2.2 x L/(2 x Z_0) ~ L/Z_0 = 2.5 nH/50 ~ 50 psec

Be The Signal · MYTHS · Bogatin Enterprises, L.L.C.

Estimating Compensation L, C



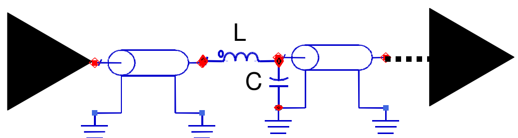
1 pF C Discontinuity $L = C \times Z_0^2$ L = 2.5 nH

2.5 nH L Discontinuity $C = \frac{L}{Z_0^2}$ C = 1 pF

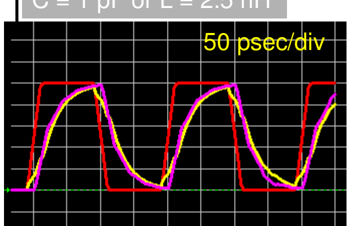
$$\sqrt{\frac{2500\,pH}{1\,pF}} = 50\ Ohms$$

Be The Signal · MYTHS · Bogatin Enterprises, L.L.C.

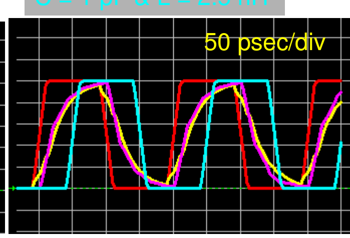
Lumped Discontinuity Compensation: Magic!



C = 1 pF or L = 2.5 nH



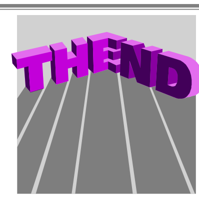
C = 1 pF & L = 2.5 nH

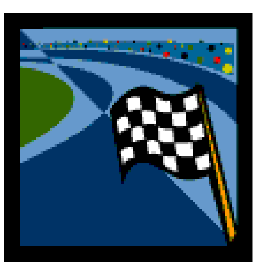


$$\sqrt{\frac{2500\,pH}{1\,pF}} = 50\ Ohms$$

Summary of the Design Guideline Rules of Thumb

- For series transmission line discontinuities
  - ✓ Keep the impedance variation within +/- 10 ohms of the line impedance
  - ✓ Keep the length, in inches, shorter than the rise time, in nsec
- For stubs
  - ✓ Try for as high an impedance as possible
  - ✓ Keep the length, in inches, shorter than the rise time, in nsec
- For capacitive discontinuities
  - ✓ Keep the capacitance in pF, less than 4 x RT in nsec
- For inductive discontinuities
  - ✓ Keep the inductance, in nH, less than 10 x RT, in nsec
- For compensation, add extra L or C to keep $\sqrt{\frac{L}{C}} = Z_0$





Thanks for listening!

射 频 和 天 线 设 计 培 训 课 程 推 荐

易迪拓培训(www.edatop.com)由数名来自于研发第一线的资深工程师发起成立，致力并专注于微波、射频、天线设计研发人才的培养；我们于 2006 年整合合并微波 EDA 网(www.mweda.com)，现已发展成为国内最大的微波射频和天线设计人才培养基地，成功推出多套微波射频以及天线设计经典培训课程和 ADS、HFSS 等专业软件使用培训课程，广受客户好评；并先后与人民邮电出版社、电子工业出版社合作出版了多本专业图书，帮助数万名工程师提升了专业技术能力。客户遍布中兴通讯、研通高频、埃威航电、国人通信等多家国内知名公司，以及台湾工业技术研究院、永业科技、全一电子等多家台湾地区企业。

易迪拓培训课程列表：http://www.edatop.com/peixun/rfe/129.html

射频工程师养成培训课程套装

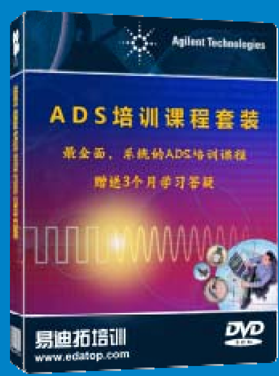
该套装精选了射频专业基础培训课程、射频仿真设计培训课程和射频电路测量培训课程三个类别共 30 门视频培训课程和 3 本图书教材；旨在引领学员全面学习一个射频工程师需要熟悉、理解和掌握的专业知识和研发设计能力。通过套装的学习，能够让学员完全达到和胜任一个合格的射频工程师的要求…

课程网址：http://www.edatop.com/peixun/rfe/110.html

ADS 学习培训课程套装

该套装是迄今国内最全面、最权威的 ADS 培训教程，共包含 10 门 ADS 学习培训课程。课程是由具有多年 ADS 使用经验的微波射频与通信系统设计领域资深专家讲解，并多结合设计实例，由浅入深、详细而又全面地讲解了 ADS 在微波射频电路设计、通信系统设计和电磁仿真设计方面的内容。能让您在最短的时间内学会使用 ADS，迅速提升个人技术能力，把 ADS 真正应用到实际研发工作中去，成为 ADS 设计专家...

课程网址： http://www.edatop.com/peixun/ads/13.html



HFSS 学习培训课程套装

该套课程套装包含了本站全部 HFSS 培训课程，是迄今国内最全面、最专业的 HFSS 培训教程套装，可以帮助您从零开始，全面深入学习 HFSS 的各项功能和在多个方面的工程应用。购买套装，更可超值赠送 3 个月免费学习答疑，随时解答您学习过程中遇到的棘手问题，让您的 HFSS 学习更加轻松顺畅…

课程网址：http://www.edatop.com/peixun/hfss/11.html

CST 学习培训课程套装

该培训套装由易迪拓培训联合微波 EDA 网共同推出，是最全面、系统、专业的 CST 微波工作室培训课程套装，所有课程都由经验丰富的专家授课，视频教学，可以帮助您从零开始，全面系统地学习 CST 微波工作的各项功能及其在微波射频、天线设计等领域的设计应用。且购买该套装，还可超值赠送 3 个月免费学习答疑…

课程网址：http://www.edatop.com/peixun/cst/24.html

HFSS 天线设计培训课程套装

套装包含 6 门视频课程和 1 本图书，课程从基础讲起，内容由浅入深，理论介绍和实际操作讲解相结合，全面系统的讲解了 HFSS 天线设计的全过程。是国内最全面、最专业的 HFSS 天线设计课程，可以帮助您快速学习掌握如何使用 HFSS 设计天线，让天线设计不再难…

课程网址：http://www.edatop.com/peixun/hfss/122.html

13.56MHz NFC/RFID 线圈天线设计培训课程套装

套装包含 4 门视频培训课程，培训将 13.56MHz 线圈天线设计原理和仿真设计实践相结合，全面系统地讲解了 13.56MHz 线圈天线的工作原理、设计方法、设计考量以及使用 HFSS 和 CST 仿真分析线圈天线的具体操作，同时还介绍了 13.56MHz 线圈天线匹配电路的设计和调试。通过该套课程的学习，可以帮助您快速学习掌握 13.56MHz 线圈天线及其匹配电路的原理、设计和调试…

详情浏览：http://www.edatop.com/peixun/antenna/116.html

我们的课程优势：

※ 成立于 2004 年，10 多年丰富的行业经验，

※ 一直致力并专注于微波射频和天线设计工程师的培养，更了解该行业对人才的要求

※ 经验丰富的一线资深工程师讲授，结合实际工程案例，直观、实用、易学

联系我们：

※ 易迪拓培训官网：http://www.edatop.com

※ 微波 EDA 网：http://www.mweda.com

※ 官方淘宝店：http://shop36920890.taobao.com