TAN-067

Applications Note – R^3 Technology for T/E Carrier Redundancy Applications

Preliminary

Rev. 1.00

April 2, 2004

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I. Introduction

Implementing redundancy schemes for either T1 or DS3 applications is often a system requirement for today's designer. These schemes, however, have inherent challenges that often result in inefficiencies in size, power and reliability. The purpose of this application note is identify what these design issues are, and then demonstrate how Exar's R^3 technology can be used to resolve them. The following information applies to both T1 applications as well as DS3 applications except where otherwise noted.

- *The use of "T1" implies T1/E1/J1, while "DS3" implies DS3/E3/STS-1 for purposes of this discussion.*

II. Scope

The scope of this note focuses on T/E carrier 1+1 and N+1 redundancy approaches and design considerations for facility (card) redundancy, meaning if one card goes down, another takes over. (This is in contrast to span redundancy that is found in optical rings for example where if one *span* goes down, another takes over). It is assumed that the reader has a general understanding of basic redundancy concepts. For a background in redundancy concepts and electrical isolation, see the R^3 white paper, TWP-5. For details on maintaining high impedance during power failure (a key component for hot swap functionality), see app note TAN-56.

III. Redundancy Topologies - 1:1, 1+1, N:1, N+1

1:1 and 1+1 imply that there exists one active card and one backup card. Every active card has a dedicated backup card. N:1 and N+1 (or 1:N and 1+N) imply that there are N number of active cards and one backup card. There is only one backup card for N number of active cards. The difference between the plus sign and the colon has to do with the backup card's ability to monitor data, even though it is not actively transmitting or receiving. A colon indicates that the backup card is *disconnected* from the RX span, while a plus sign indicates that the backup card is *connected* to the RX span. (The backup card is always disconnected from the TX span). There are two advantages that 1+1 and 1+N schemes have over 1:1 and 1:N schemes. One advantage is that the backup card has the ability to monitor incoming data even though it is not "actively" transmitting or receiving. The other advantage is that 1+1 and 1+N schemes use less relays because the backup card does not need to be disconnected from the line. Because of these two advantages, we will focus our discussion on 1+1 and 1+N redundancy schemes, although everything applies to 1:1 and 1:N designs as well.

IV. What is R^3?

R^3 is "Reconfigurable Relayless Redundancy", a technology that simplifies and optimizes redundancy designs by eliminating support circuitry including passives, oscillators, relays etc.

"Reconfigurable"	Internal termination resistors and clock synthesizers allow for software selectable data rates. Also, because there is no change in passives or magnetics for various data rates, T1/E1/J1 designs can be implemented with only one bill of materials (BOM). The same is true for DS3/E3/STS-1 designs.
"Relayless"	By utilizing patented circuitry that guarantees a continual high impedance state throughout power cycling and line loading, some or all relays can be removed from the system in most every case. No relays equates to a more cost effective, space effective and more reliable design.
"True Hot Swap"	Because R^3 maintains a tri-state condition regardless of power cycling and line loading, no bit errors occur as backup cards are powered down, powered up, inserted or removed. DS3 hot swapping is finally a reality!

R^3 not only eliminates relays in 1+1 applications, but it also reduces the amount of relays in N+1 applications. This is illustrated in detail in several examples that follow .

V. Redundancy Design Challenges

Use of Relays
Mechanical relays and analog switches traditionally used in 1+1 protection applications have many disadvantages that include additional component cost, PCB real estate cost, inferior reliability and slow switching times that can cause frame hits. All these issues are compounded as the number of channels increase and as the number of boards increase. In high-density systems, the card height could be reduced substantially if the relays were not needed.

Impedance Mismatches
When attempting to avoid the use of relays to control termination impedances, the designer finds that if a single span is properly terminated with both a primary and backup card present, it is mismatched when one of those cards is removed. Likewise, if that same span is properly terminated when only the primary card is inserted, a mismatch occurs once the backup card is inserted. Also, in many redundancy designs, two line cards share a common interface card where the connector and transformer are located. The designer would like to run the data path across the backplane (or through a midplane) and into the two terminated line cards, but this causes an impedance mismatch as well.

Hot Swapping
Because this is such an important function for equipment providers, IC vendors often promote a device as having the ability to "Hot Swap" – meaning it will not take bit errors when either the primary card, backup card is inserted or removed. Often the designers find themselves on a goose chase, trying all sorts of workarounds until they realize the device does not really have this ability. The only way to truly achieve hot swapping capability is by the device being able to maintain a true tri-state condition regardless of power cycling and line loading.

Reconfigurability
An associated issue to redundancy is reconfigurability: the ability to reconfigure a device on the fly for various data rates without a PCB change. T1/E1/J1 and DS3/E3/STS-1 are two common sets of data rates needed for TDM transport applications. The designer has to typically change external components for termination as well as for the clock rates needed for these various rates.

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Below are eight typical redundancy approaches for T/E carrier applications. The pages that follow illustrate each of these along with a summary of how R^3 technology affects them. (These are just some common examples and do not represent all the possible approaches to redundancy).

Some Common Redundancy Schemes:

1. T1 1+1 Shared Transformer
2. T1 1+N Shared Transformer
3. DS3 1+1 Shared Transformer / Shared Tx and Rx Terminations
4. DS3 1+1 Shared Transformer / Shared Rx Termination
5. DS3 1+1 Shared Transformer / Separate Rx Termination
6. DS3 1+1 Separate Transformer / Separate Rx Termination
7. DS3 1+N Shared Transformer / Shared Rx Termination
8. DS3 1+N Shared Transformer / Separate Termination

Please note that there are two different ground symbols that appear in these diagrams:

= Frame ground

= Board ground

Definition of terms used in diagrams:

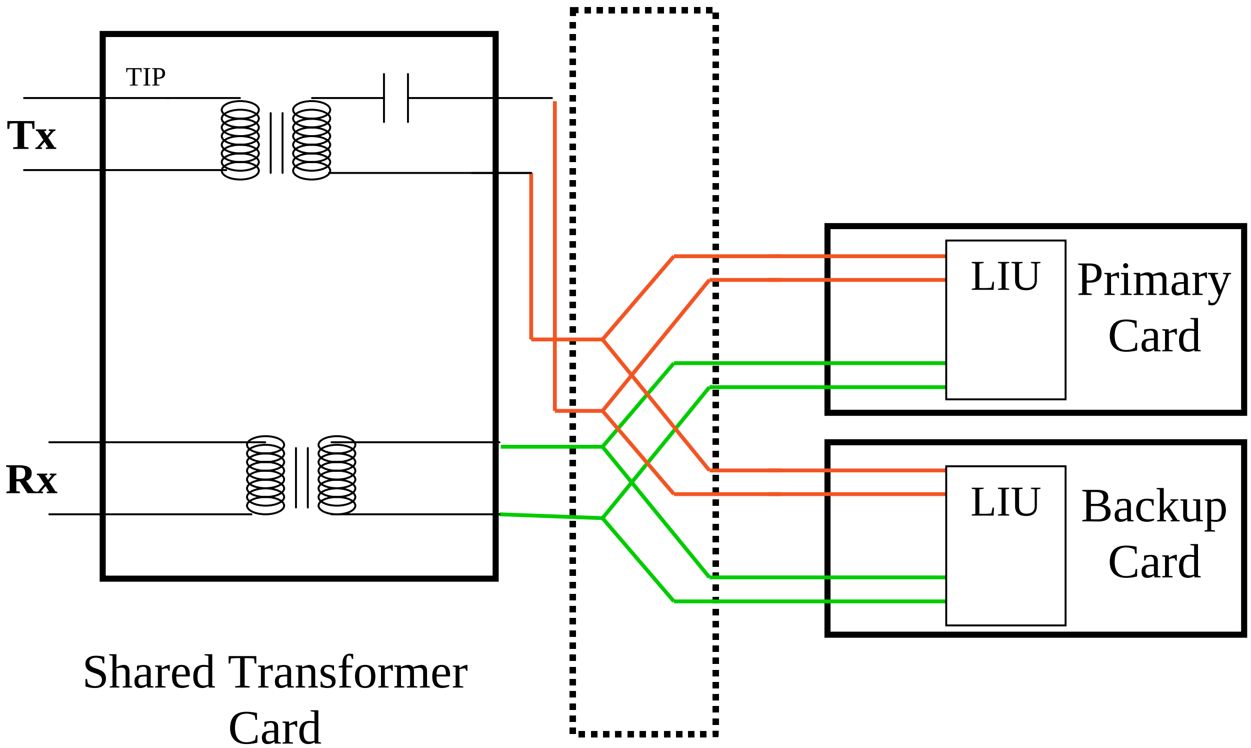
"Termination switching Relays" = Relays that switch terminations on to or off of the signal path

"Primary Disconnection Relays" = Relays that disconnect a primary card from the signal path

"Backup Disconnection Relays" = Relays that disconnect a backup card from the signal path

- N+1 applications *always* require backup disconnection relays (or an alternative approach to route each span to the backup card).
- The term "relay" is meant to imply either a mechanical relay or a telecom analog switch.
- Omron G6H-2-DC3 relay or Maxim MAX4717 analog switch are available for T/E use.

Scenario #1: T1 1+1 Shared Transformer = NO RELAYS, ALLOWS HOT SWAP



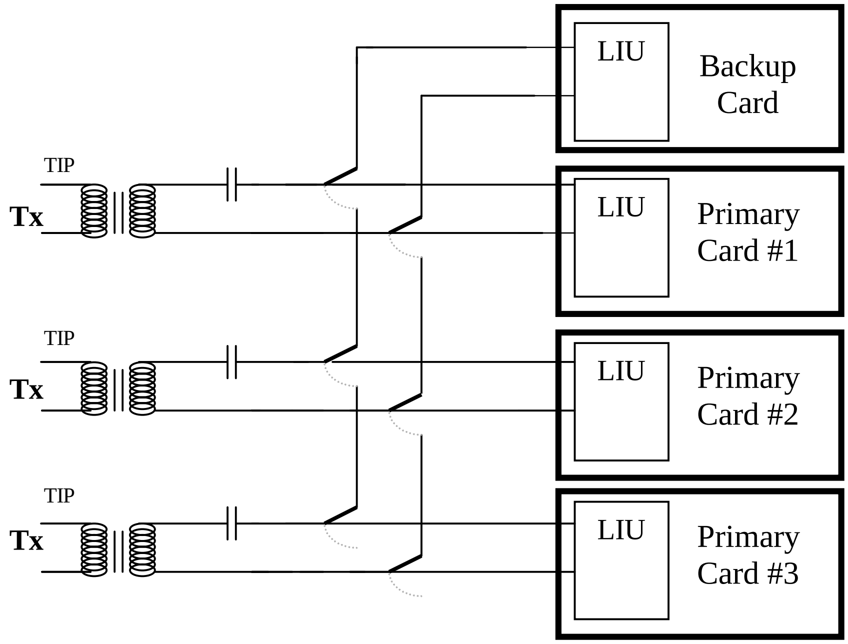
How R^3 Helps . . .

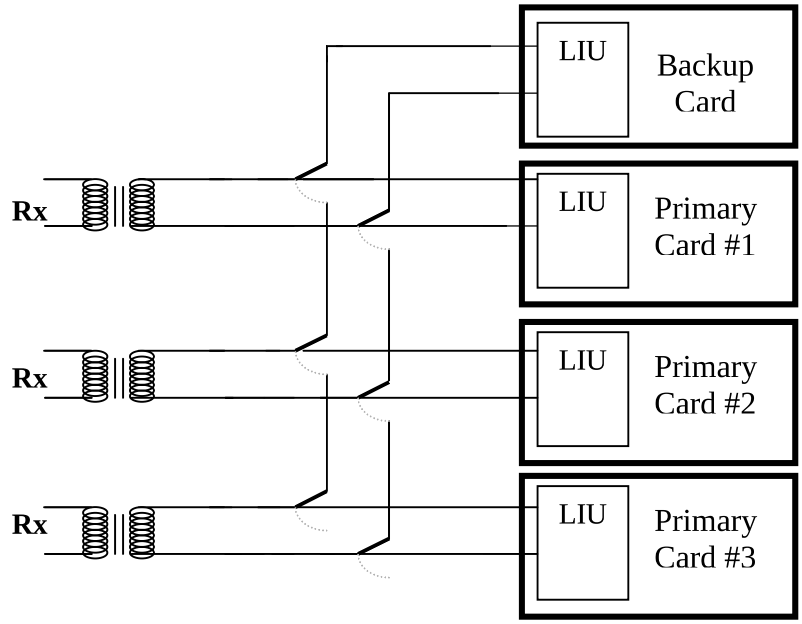
- Integrated termination resistors eliminate termination switching relays.
- High Z Tx outputs and Rx inputs eliminate primary/backup disconnection relays.
- Allows the backup card to continually monitor traffic.
- Allows hitless hot swap insertion/extraction.
- Using single frequency mode (SFM), only one reference clock is needed for T1/E1/J1 rates which are in turn generated and selected internally via software. (not shown)
- 1 BOM for T1/E1/J1

Scenario #2: T1 1+N Shared Transformer = LESS RELAYS, ALLOWS HOT SWAP

How R3 Helps . . .

- Integrated termination resistors eliminate termination switching relays.
- High Z Tx outputs and Rx inputs eliminate primary disconnect relays.
- Allows the backup card to continually monitor traffic.
- Allows hitless hot swap insertion/extraction.
- Using single frequency mode (SFM), only one reference clock is needed for T1/E1/J1 rates which are in turn generated and selected internally via software. (not shown)
- 1 BOM for T1/E1/J1





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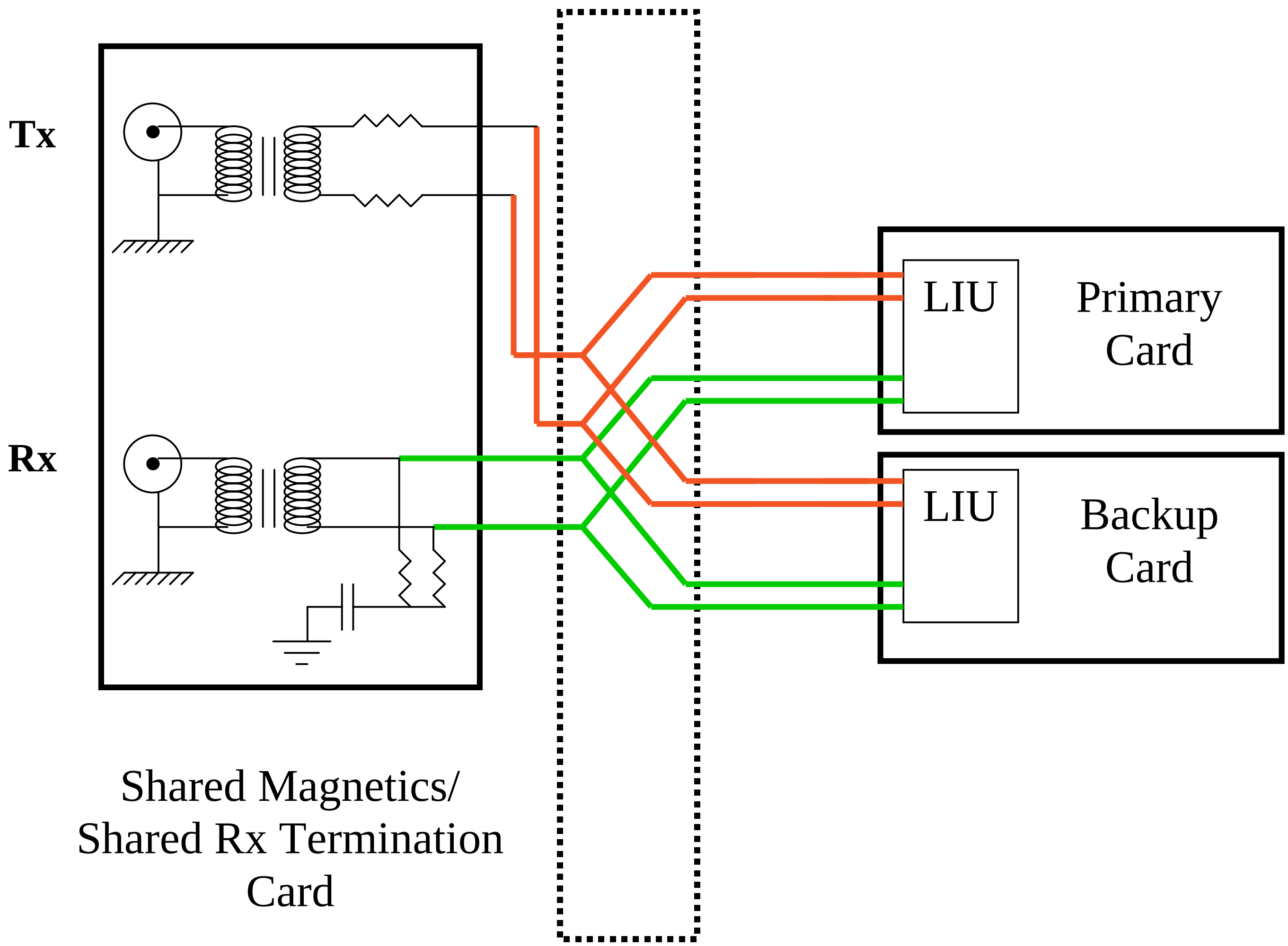
Scenario #3: DS3 1+1 Shared Transformer Shared Terminations = **No Relays**



How R^3 Helps . . .

- Shared Rx termination resistors eliminate Rx termination switching relay.
- Tx High Z mode eliminates Tx disconnect relays.
- Constant High Z Rx inputs eliminate Rx disconnect relays for hot swapping
- Allows the backup card to continually monitor traffic.
- Allows hitless hot swap insertion/extraction.
- Using single frequency mode (SFM), only one reference clock is needed for DS3/E3/STS-1 rates which are in turn generated and selected internally via software. (not shown)
- 1 BOM for DS3/E3/STS-1

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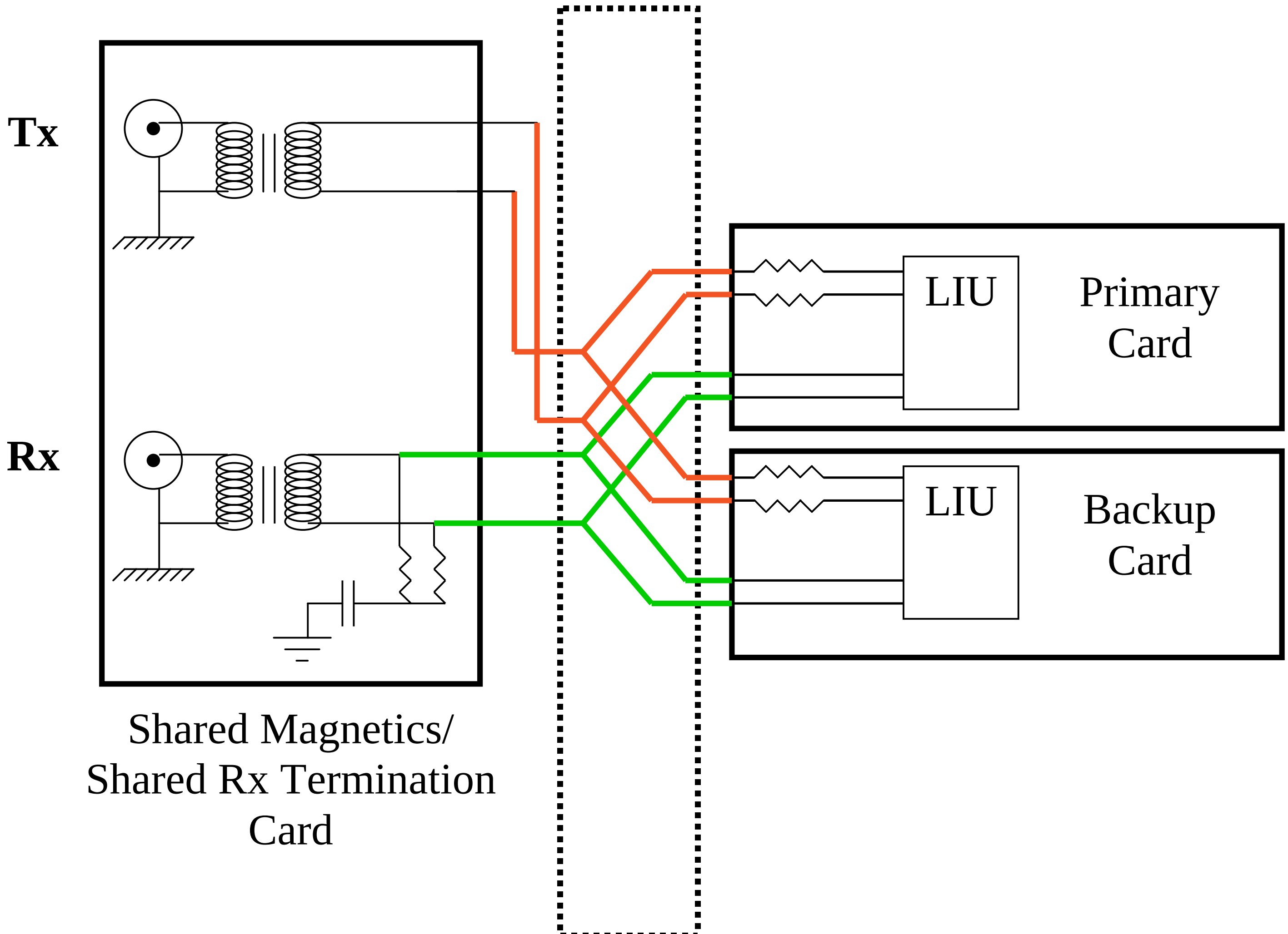
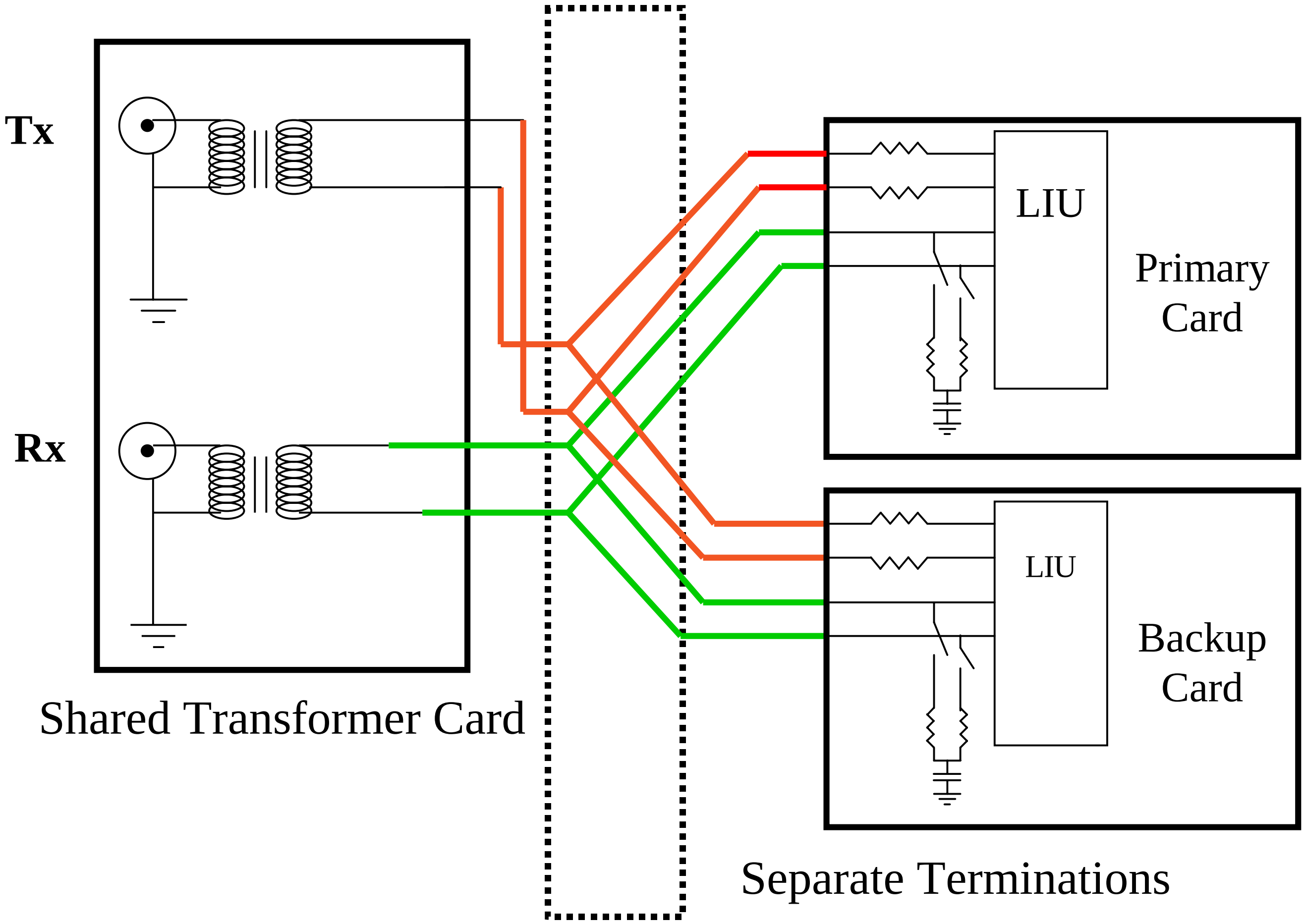
Scenario #4: DS3 1+1 Shared Transformer Shared Rx Termination = **No Relays**



How R^3 Helps . . .

- Shared Rx termination resistors eliminate Rx termination switching relay.
- Tx High Z mode eliminates Tx disconnect relays.
- Constant High Z Rx inputs eliminate Rx disconnect relays for hot swapping.
- Allows the backup card to continually monitor traffic.
- Allows hitless hot swap insertion/extraction.
- Using single frequency mode (SFM), only one reference clock is needed for DS3/E3/STS-1 rates which are in turn generated and selected internally via software. (not shown)
- 1 BOM for DS3/E3/STS-1

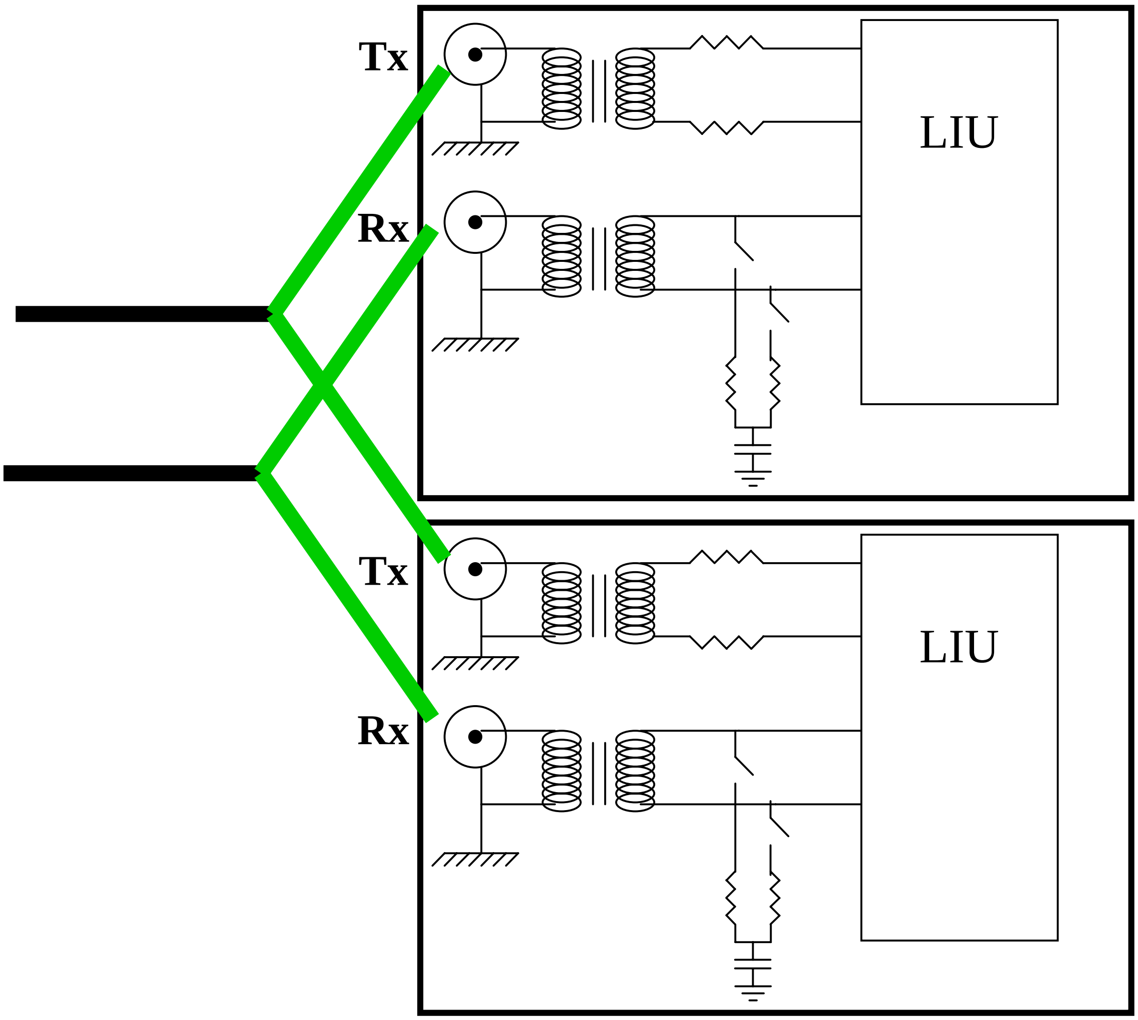
Scenario #5: DS3 1+1 Shared Transformer Separate Rx Termination = 2 Relays



How R³ Helps . . .

- Tx High Z mode eliminates Tx disconnect relays.
- Constant High Z Rx inputs eliminate Rx disconnect relays for hot swapping.
- Allows the backup card to continually monitor traffic.
- Allows hitless hot swap insertion/extraction.
- Using single frequency mode (SFM), only one reference clock is needed for DS3/E3/STS-1 rates which are in turn generated and selected internally via software. (not shown)
- 1 BOM for DS3/E3/STS-1

Scenario #6: DS3 1+1 Separate Transformer Separate Rx Termination = 2 Relays



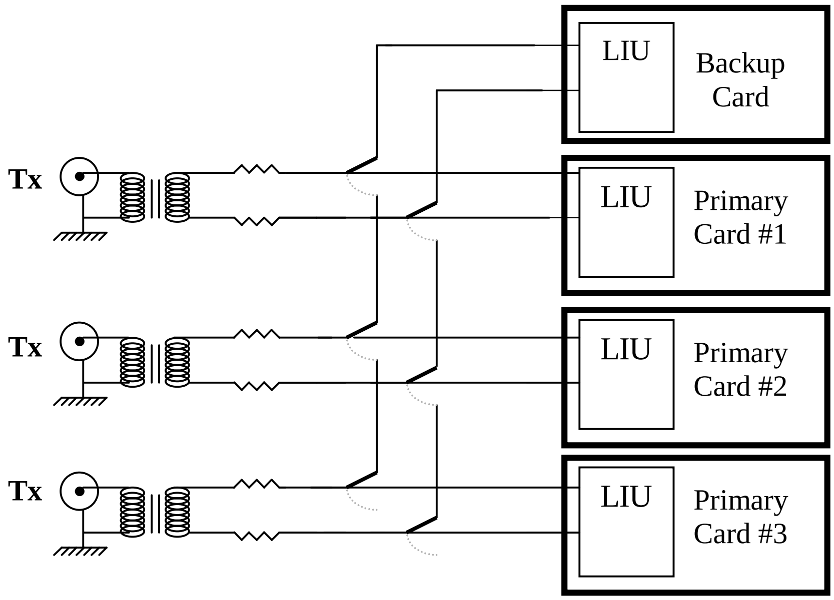
How R³ Helps . . .

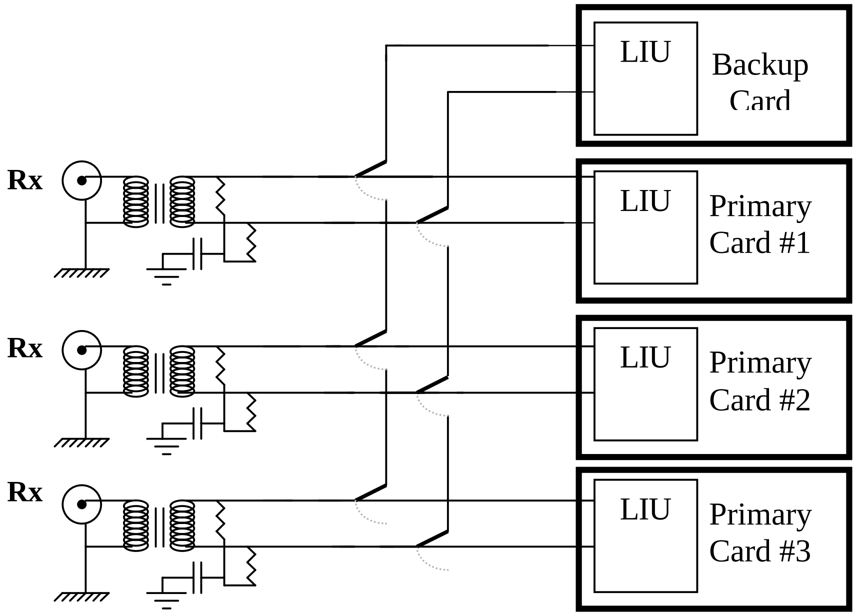
- Tx High Z mode eliminates Tx disconnect relays.
- Constant High Z Rx inputs eliminate Rx disconnect relays for hot swapping.
- Allows the backup card to continually monitor traffic.
- Allows hitless hot swap insertion/extraction.
- Using single frequency mode (SFM), only one reference clock is needed for DS3/E3/STS-1 rates which are in turn generated and selected internally via software. (not shown)
- 1 BOM for DS3/E3/STS-1

Scenario #7: DS3 1+N Shared Transformer Shared Rx Termination

How R^3 Helps . . .

- Shared Rx termination resistors eliminate Rx termination switching relay.
- Tx High Z mode eliminates Tx primary disconnect relays.
- Constant High Z Rx inputs eliminate Rx primary disconnect relays for hot swapping.
- Allows the backup card to continually monitor traffic.
- Allows hitless hot swap insertion/extraction.
- Using single frequency mode (SFM), only one reference clock is needed for DS3/E3/STS-1 rates, which are in turn generated and selected internally via software. (not shown)
- 1 BOM for DS3/E3/STS-1

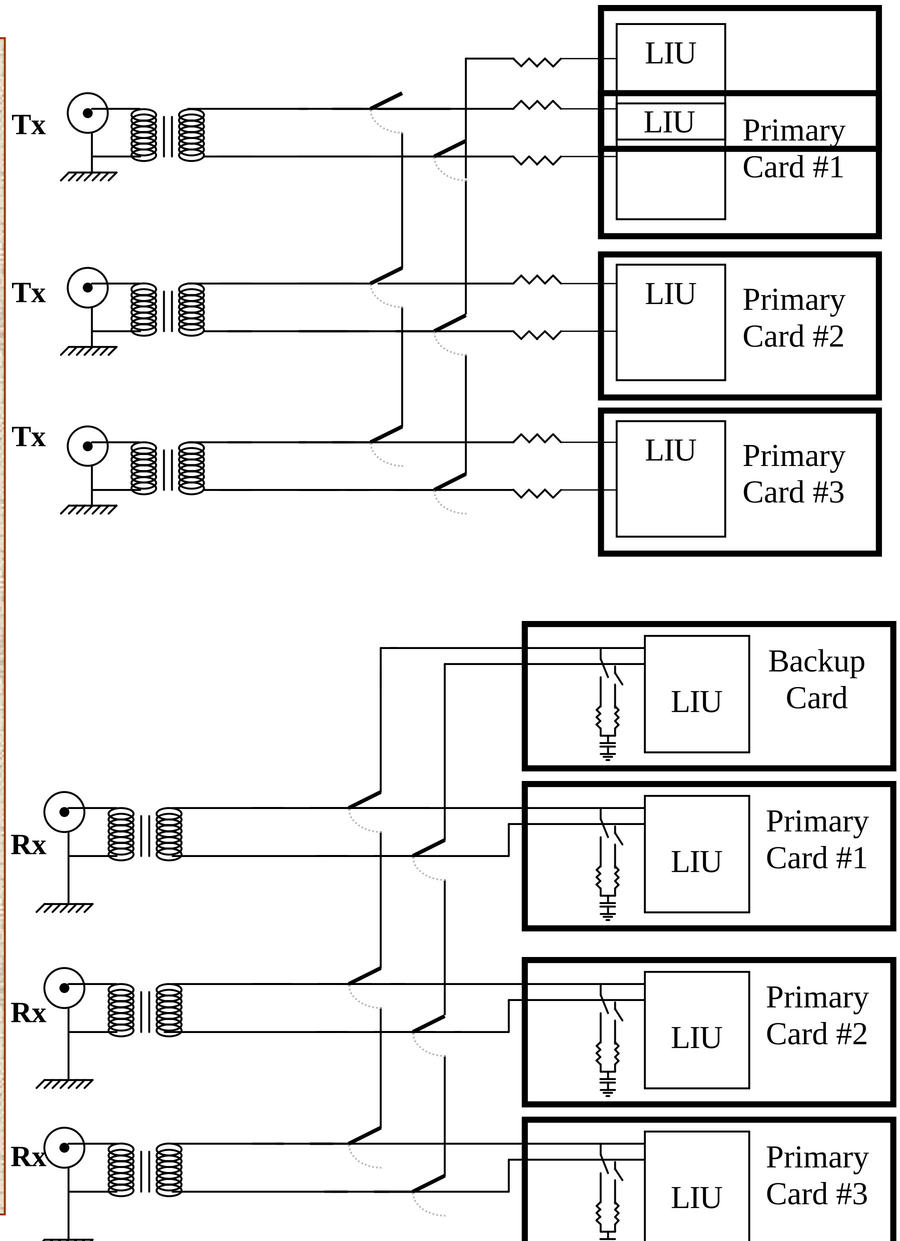




Scenario #8: DS3 1+N Shared Transformer Separate Termination

How R3 Helps . . .

- Tx High Z mode eliminates Tx primary disconnect relay.
- Constant High Z Rx inputs eliminate Rx primary disconnect relays for hot swapping.
- Allows the backup card to continually monitor traffic.
- Allows hitless hot swap insertion/extraction.
- Using single frequency mode (SFM), only one reference clock is needed for DS3/E3/STS-1 rates, which are in turn generated and selected internally via software. (not shown)
- 1 BOM for DS3/E3/STS-1



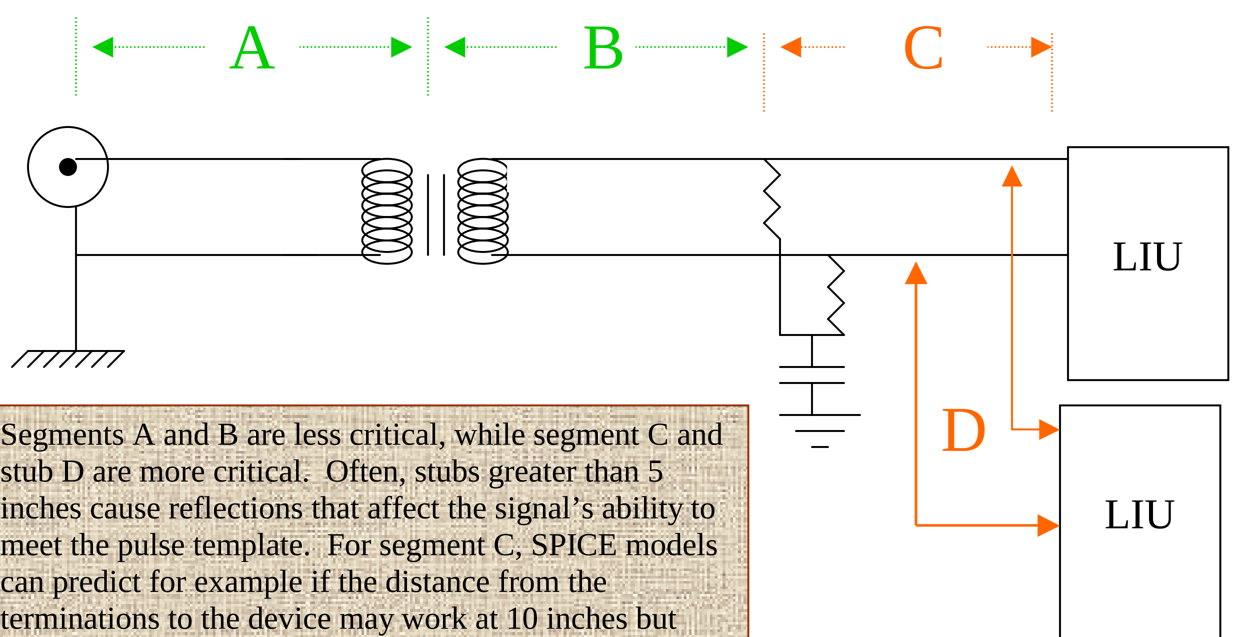
VII. What about Trace Lengths?

Often the most common challenge to face when designing for redundancy is establishing adequate trace lengths that meet the physical distance requirements across a mid-plane or back-plane while maintaining signal integrity, specifically pulse template. For T1 designs, this is much less of an issue while DS3 designs are greatly affected. Because of the variety of parameters that contribute to each individual application, it is virtually impossible (not to mention inappropriate) for the LIU vendor to specify maximum lengths of segments in a customer's redundancy design. With this in mind, the following information regarding trace lengths is provided as a general guideline or reference point in which to start considering this issue. Ultimately, the designer should model their specific application, for example using SPICE, to determine what the limitations are for layout. Exar provides encrypted SPICE models for their DS3 LIUs to enable the designer to accurately assess their particular application.

Below we show an example of a DS3 1+1 Rx path.

There are basically four segments that the signal path traverses on the PCB:

1. Between the BNC/SMB connector and the transformer, shown as segment "A".
2. Between the transformer and the termination, shown as segment "B".
3. Between the termination and the device, shown as segment "C".
4. Stubs located anywhere, here shown as segment "D".



Segments A and B are less critical, while segment C and stub D are more critical. Often, stubs greater than 5 inches cause reflections that affect the signal's ability to meet the pulse template. For segment C, SPICE models can predict for example if the distance from the terminations to the device may work at 10 inches but fail at 20".

VIII. A Comment on DS3 Over Voltage Protection

Unlike T1/E1 that supports an isolated pair approach, DS3 and E3 signals are referenced to earth ground through the coax shield > connector > frame/chassis. This provides a natural over-voltage protection with the only addition being a high voltage capacitor between frame ground and board ground. At DS3 type rates, there is not a large margin for added capacitance before the signal will fail the pulse mask. Occasionally a designer, who is experienced with T1 design but new to DS3, will begin to place over-voltage protection components on their circuit. Even if the added capacitance from these components does not take the signal out of mask, it depletes the capacitance margin that could have been used for stub lengths that occur in redundancy applications. We do suggest a high voltage cap between board ground and frame ground (~.1uF)

For information on GR-1089 ramifications for DS3, see tech brief TAB-xx
For more information on T1 over voltage protection, see applications note TAN-54
For more information on T1 redundancy, see applications note TAN-53

R^3 is a Winner!

Impedance mis-matches are a thing of the past and true hot swapping is finally achievable, even in DS3 systems where there has not been a solution until now. On board terminations and clock synthesizers mean full reconfigurabilty. Only 1 BOM is needed for T1/E1/J1 applications and only one BOM is needed DS3/E3/STS1 applications. This results in a simpler, more cost effective and space effective design.

IX. Devices that use R^3 technology

DS3/E3/STS-1 Product Families

XRT75Rxx	LIU/JA
XRT73Rxx	LIU
XRT79Lxx	LIU/JA/Multi-service framer

T1/E1/J1 Product Families

XRT83xxx	LIU
XRT86Lxx	LIU/Framer

- Please see your local Exar representative for specific device availability

Appendix A. R^3 Lab Measurements (To be provided in next update of this document)