MDI Return Loss for 1000BASE-T1 PoDL

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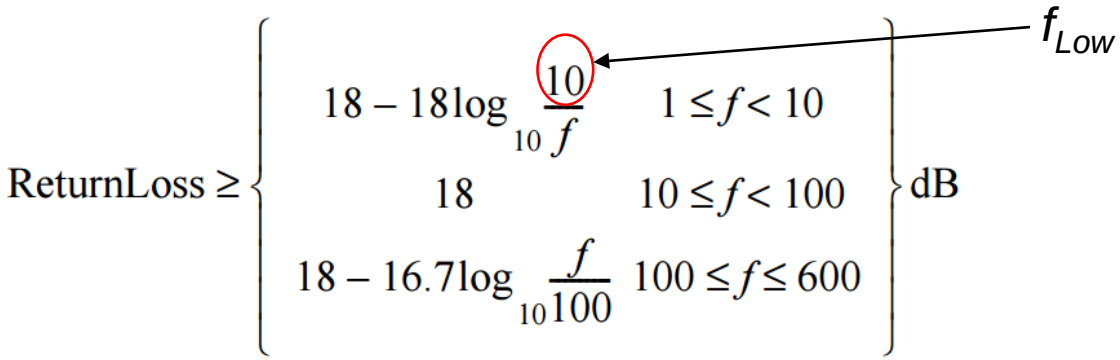
Presentation Objectives

- Review 1000BASE-T1 MDI return loss requirement and how it constrains PoDL coupling network inductors.
- Present return loss data for commercially available mutually coupled inductors.
- Propose a relaxed MDI return loss requirement for 1000BASE-T1 PoDL.

PoDL Inductance and MDI Return Loss

- The minimum value of inductance for the coupling networks is constrained by the PHY MDI return loss specification.
- The 1000BASE-T1 MDI RL is specified as:



- This translates to:

$$L_{PoDL} \geq \frac{\sqrt{\left[\left(\frac{100\Omega^2}{10^{-RL/20}}\right) + 100\Omega^2\right] \times \left[\left(\frac{100\Omega^2}{10^{-RL/20}}\right) - 100\Omega^2\right]}}{400\Omega \times 2 \times \pi \times f_{Low}}$$

where f_{Low} is the low frequency corner of the RL specification.

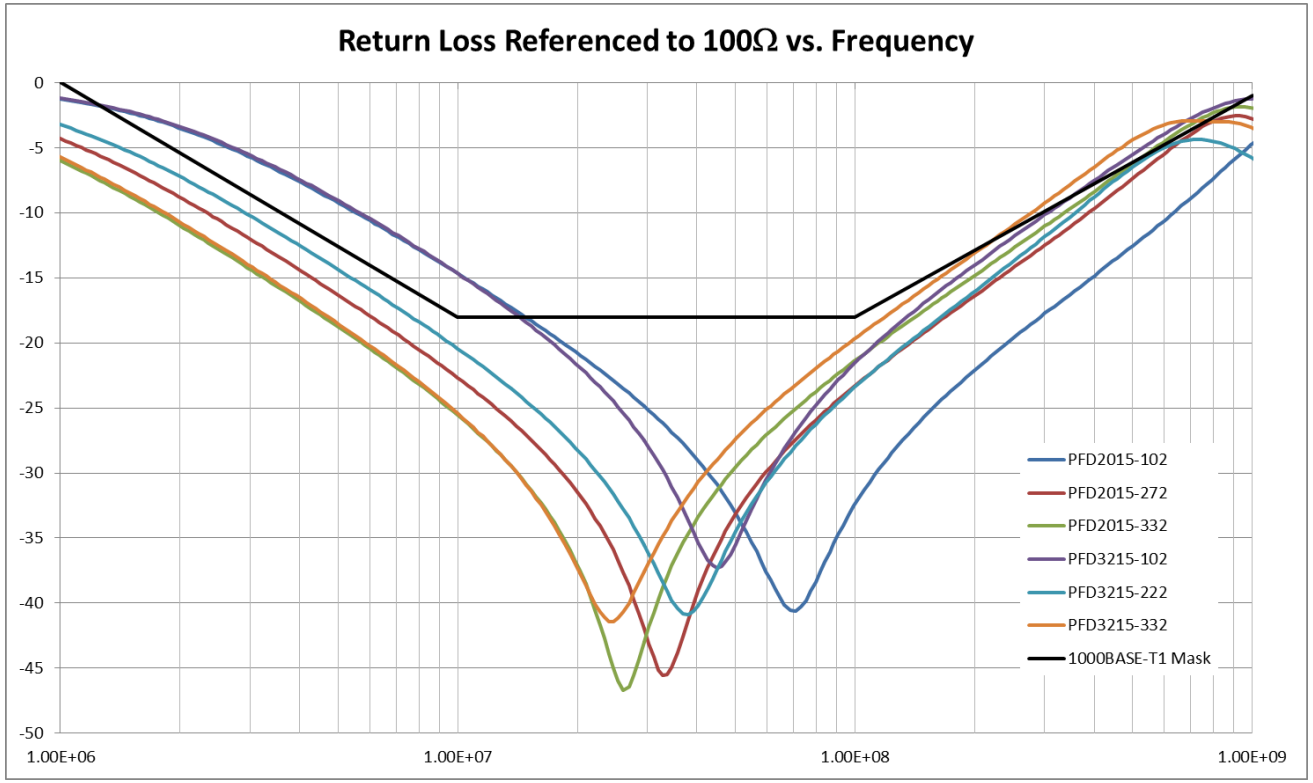
- For 1000BASE-T1, 18dB RL at f_{Low}=10MHz requires $L_{PoDL} \geq 3.14\mu H$

Implementation of the PoDL Coupling Network

- There are many constraints on the PoDL inductors:
  - OCL
  - SRF
  - DCR
  - Saturation current
  - Matching (poor matching requires more CMC OCL in order to meet the mode conversion requirement)
  - Footprint
- If possible, a mutually coupled inductor should be used to:
  - Conserve core material, i.e. OCL is multiplied by 2
  - Improve matching (matching is typically better than ±2% for a coupled inductor vs. ±10% for discrete inductors)
  - Minimize footprint
- Is it possible to realize the 1000BASE-T1 MDI RL specification with coupled inductors?

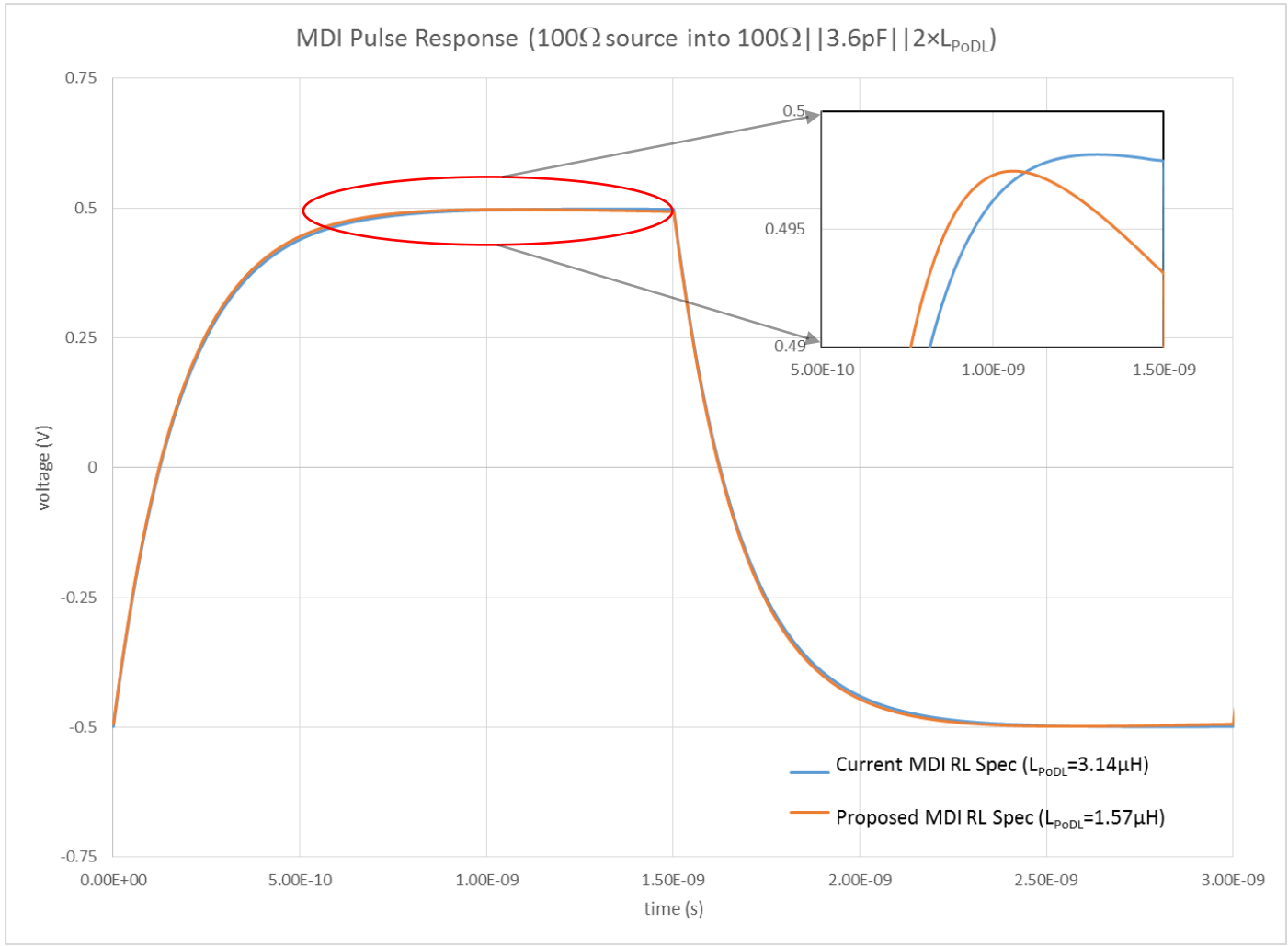
Return Loss Referenced to 100Ω for Coupled Inductors

- Return loss data for a variety of commercially available coupled inductors in the 1µH to 3.3µH OCL range was provided by Coilcraft.
- Two devices (PFD2015 2.7uH and PFD3215 2.2uH) were able to meet the spec, albeit with less than 1dB of margin at 600MHz.
- The PFD2015 1µH coupled inductor was easily able to meet the high frequency RL requirement, however.
- Is it possible to relax the MDI return loss f_{Low} specification for 1000BASE-T1 PoDL applications from 10MHz to 20MHz?



What Happens in the Time Domain if the MDI RL f_{Low} is increased from 10MHz to 20MHz?

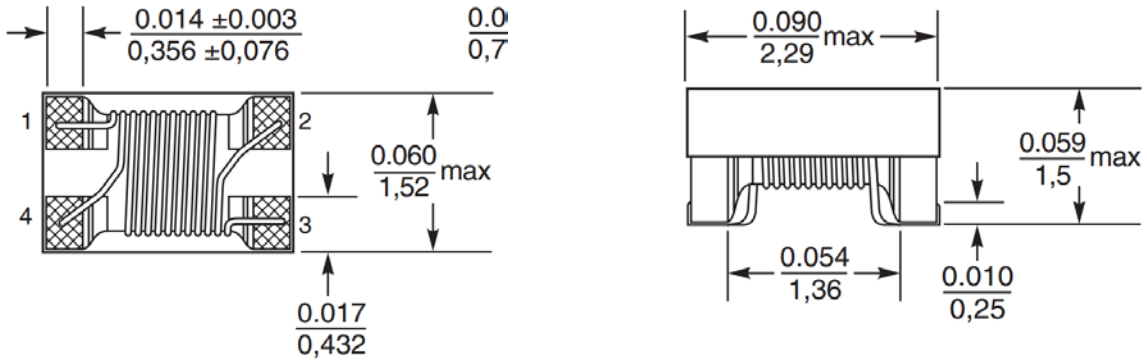
- MDI RL f_{Low} impacts the droop voltage of a symbol.
- For example, in a 1.5ns period the droop would increase by ~1% if f_{Low} was increased from 10MHz to 20MHz.
- This represents a reduction in SNR of only ~0.1dB for the PHY!



Other Benefits of Relaxing MDI RL f_{Low}

- Smaller OCL yields higher saturation current and lower DCR for the same footprint.
- For example, going from 2.7uH to 1uH in the PFD2015 device form factor yields a 31% increase in saturation current and a whopping 65% reduction in DCR!

Part number[1]	Inductance[2] ±20% (µH)	DCR max[3] (Ohms)	SRF typ[4] (MHz)	Coupling coefficient typ	Leakage inductance[5] typ (µH)	Isat (A)[6] 10% drop	Isat (A)[6] 20% drop	Isat (A)[6] 30% drop	Irms (A) both windings[7]	Irms (A) one winding[8]
PFD2015-102ME_	1.0	0.165	380	0.97	0.065	0.85	1.10	1.30	0.800	1.13
PFD2015-122ME_	1.2	0.175	310	0.97	0.071	0.80	1.05	1.20	0.750	1.06
PFD2015-182ME_	1.8	0.294	265	0.97	0.110	0.70	0.85	1.00	0.490	0.690
PFD2015-272ME_	2.7	0.477	220	0.97	0.162	0.65	0.82	0.88	0.410	0.580



Proposal

- Incorporate a MDI return loss specification into Clause 104 for 1000BASE-T1 PoDL applications as follows:

  A 1000BASE-T1 PoDL system shall meet or exceed Equation (104-TBD) for all frequencies from 2MHz to 600MHz (with a 100Ω reference impedance) under all operating conditions and at all times when the PHY is transmitting data or control symbols.

$$Return\ Loss \geq \begin{cases} 18 - 18log_{10}\dfrac{20}{f} & 2 \leq f < 20 \\ 18 & 20 \leq f < 100 \\ 18 - 16.7log_{10}\dfrac{f}{100} & 100 \leq f < 600 \end{cases} dB \qquad (104 - \text{TBD})$$

Questions?