Design Challenges for PoDL Coupling Circuit in 100BASE-T1 and 1000BASE-T1

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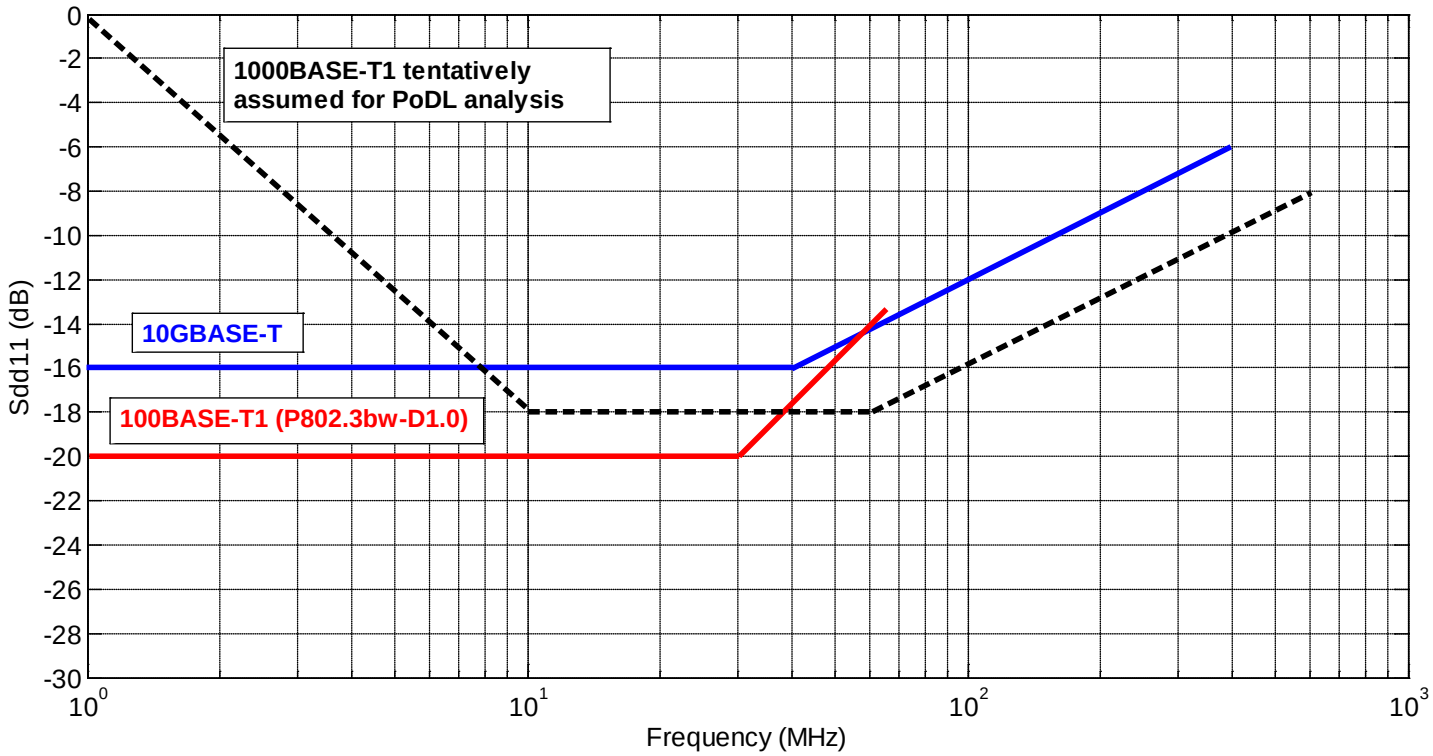
Foreword

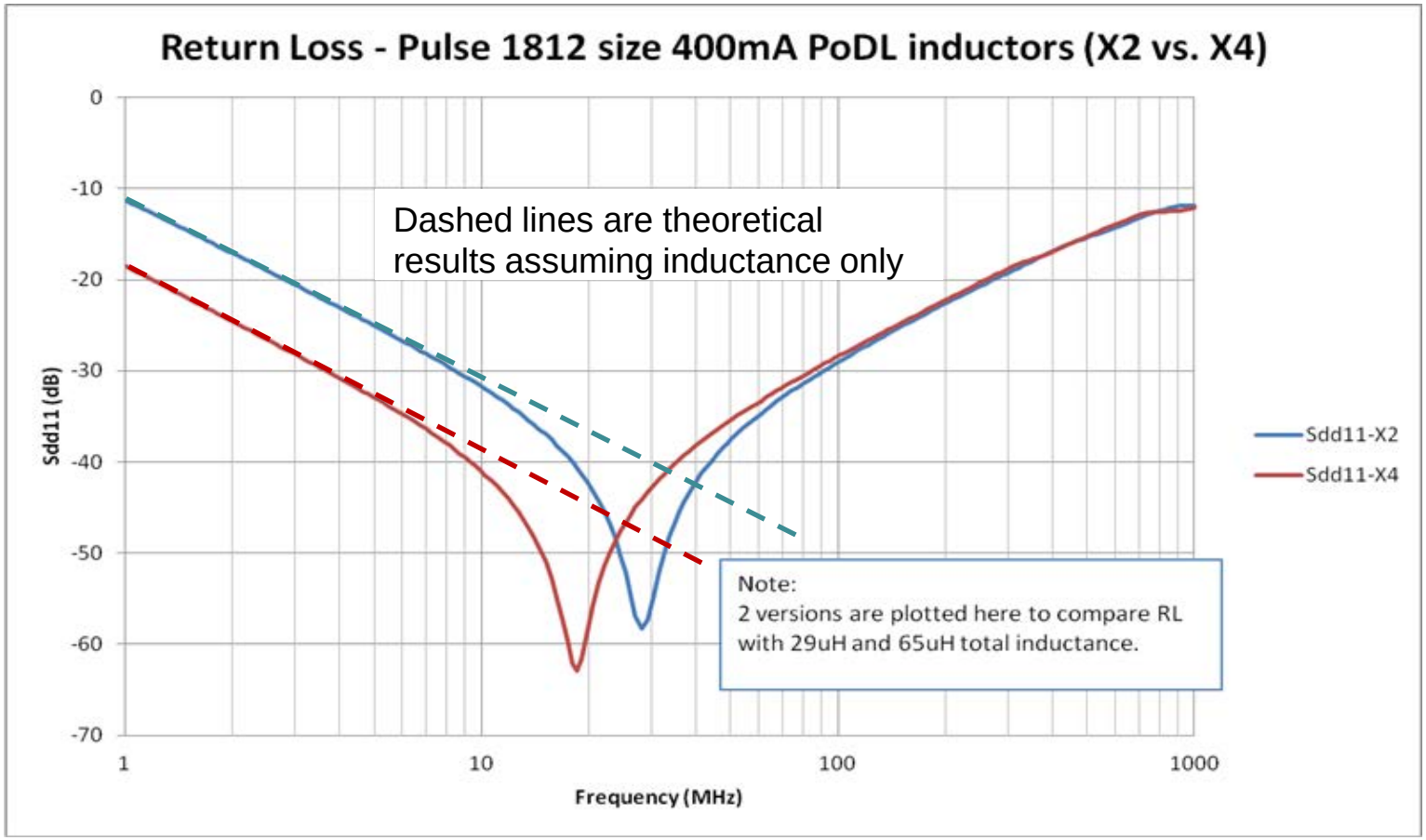
- Inductor pair used for PoDL (Power over Data Line) affects return loss and balance in 100BASE-T1 and 1000BASE-T1.
- For a given MDI return loss requirement for 100BASE-T1 and a tentative requirement for 1000BASE-T1, PoDL inductor design is discussed.
- Measured data and analysis is provided for experimental inductors made for this application. Parameters affecting the design including temperature and current are discussed.
- It is shown how the requirements affect the inductor physical size. A list of open questions on requirements is provided. Resolving the questions will help narrowing down the PoDL inductor design.

MDI Return Loss requirement



- For 1000BASE-T1, MDI RL is not specified yet. The limit shown is temporarily assumed to study PoDL inductor design. More analysis is needed to consider combined effect of passive components (PoDL inductors and CMC), PHY design and effect on mode conversion and EMC.

Return Loss – 1812-size sample inductors (X2 vs. X4)



Measurement results provided by Pulse Electronics

- Measured plots are for two different core materials (X2 and X4) but same physical size. The results are for two inductors.
- The inductance determines RL on the lower frequency end.

Pulse X4 Inductance (uH), Temperature and Current effect

Current →

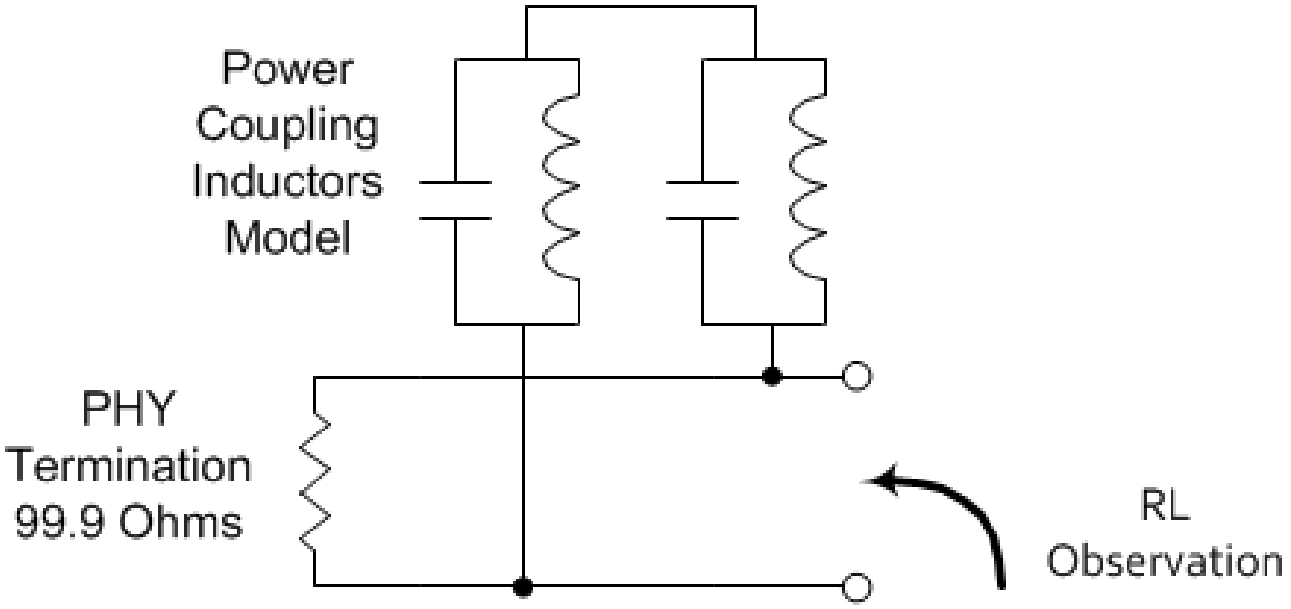
Temperature ↓

	0 mA	100 mA	150 mA	200 mA	250 mA	300 mA	350 mA	400 mA
-45	31.0	31.8	31.7	31.5	31.1	30.5	29.8	29.3
-35	31.4	32.0	32.0	31.8	31.4	30.7	29.9	28.5
-25	31.9	32.4	32.3	32.0	31.5	30.8	29.8	28.5
-15	32.0	32.5	32.5	32.2	31.7	30.9	30.0	28.3
-5	32.5	32.7	32.5	32.1	31.5	30.5	29.3	28.0
5	32.8	32.9	32.8	32.2	31.5	30.5	29.1	27.2
15	33.0	33.1	32.8	32.2	31.5	30.3	28.8	26.7
25	33.2	32.6	32.3	31.6	31.1	30.0	28.4	26.2
35	33.5	33.6	33.3	32.7	31.9	30.4	28.4	25.5
45	33.8	33.9	33.5	32.9	31.8	30.1	27.8	24.2
55	34.0	34.1	33.7	32.9	31.7	29.7	27.0	22.7
65	34.2	34.3	33.8	32.8	31.4	29.1	25.6	20.1
75	34.4	34.4	33.7	32.7	30.9	28.1	23.6	15.9
85	34.5	34.4	33.7	32.3	30.3	26.5	19.8	10.1
95	34.6	34.4	33.5	31.9	28.9	23.0	13.1	5.2
105	34.8	34.4	33.1	30.9	25.4	13.5	4.9	2.8
115	34.9	34.1	32.2	27.5	15.1	5.2	2.9	1.9
125	34.9	33.3	28.9	12.9	4.5	2.6	1.9	1.6

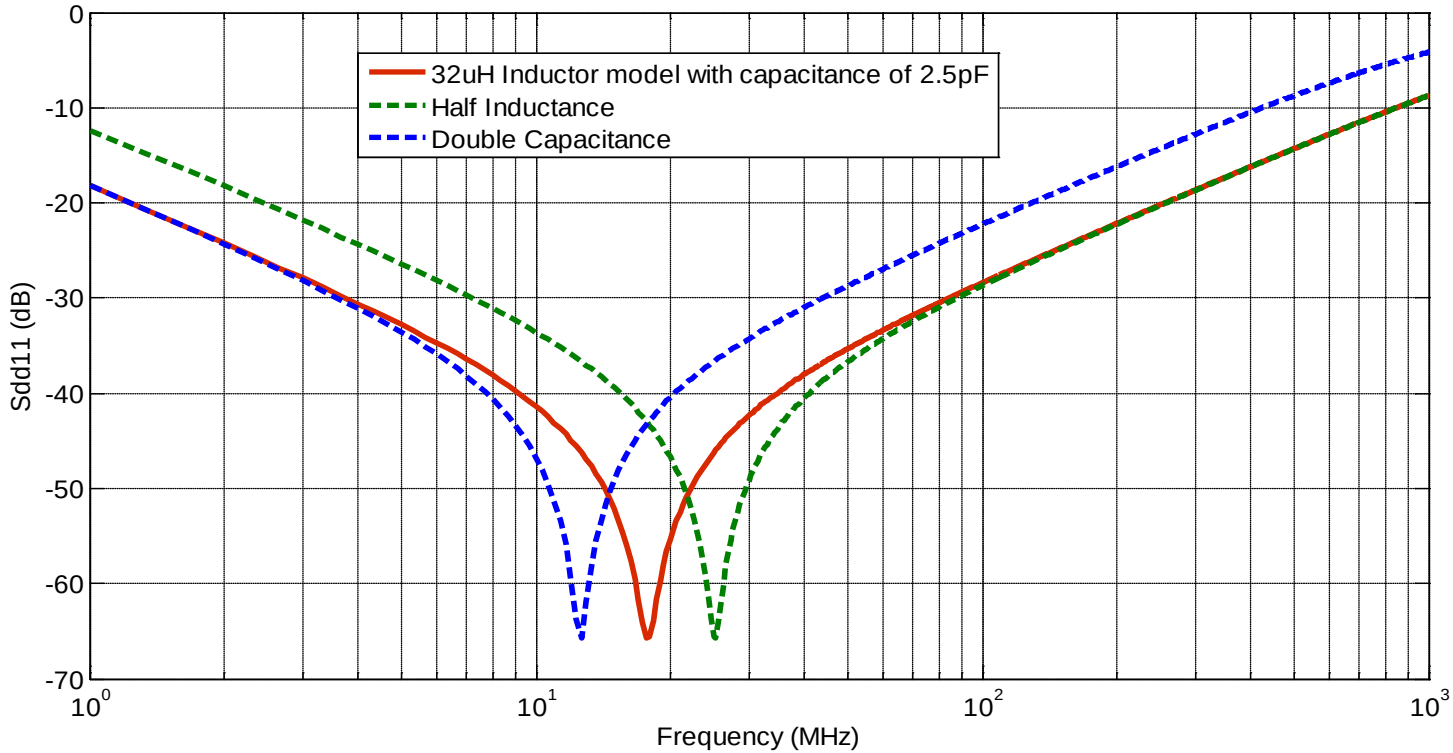
Measurement results provided by Pulse Electronics

- Available inductance decreases significantly with DC bias and with the temperature. The highlighted section of table shows more than 50% reduction in inductance.
- Results are for the used core materials in 1812 size. Other materials may behave differently.

Model used for PoDL Inductors Return Loss simulation

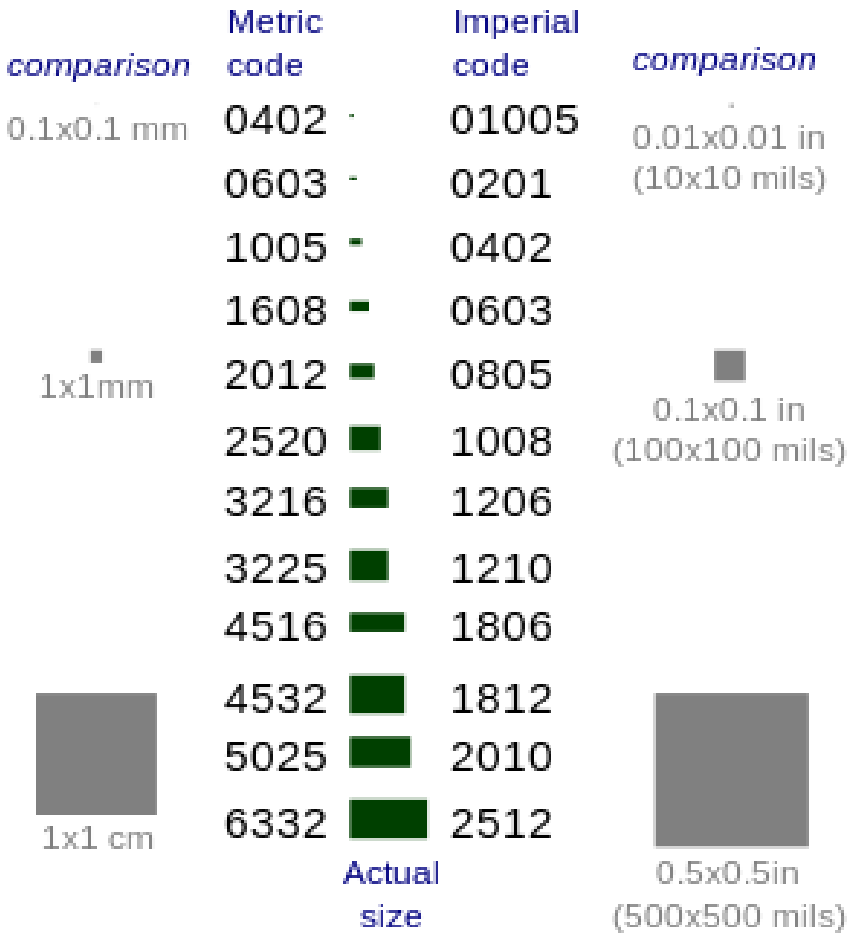


Simulated Return Loss based on inductors LC model

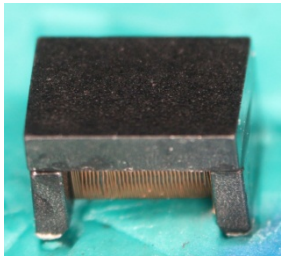


- Reduction in inductance affects RL at lower end of frequency spectrum.
- Increase in capacitance affects RL at higher end of frequency spectrum.
- To improve RL at both lower and higher frequency bands (higher inductance and lower capacitance), the size of inductors generally has to increase.

Components Size Chart



	1210		1812	
	inches	**mm**	**inches**	**mm**
Length	.120 ± .010	3.05 ± .25	.180 ± .010	4.57 ± .25
Width	.100 ± .010	2.54 ± .25	.120 ± .010	3.05 ± .25
Height	.080 ± .010	2.03 ± .25	.100 ± .010	2.54 ± .25



Enlarged 1812 inductor

Experimental sample made by Pulse Electronics

From: http://en.wikipedia.org/wiki/Surface-mount_technology

Conclusion

- **It is shown how some of system requirements affect PoDL inductors size, cost and feasibility. The following questions need to be answered before good solutions can be reached.**
  - What is MDI RL specification for 1000BASE-T1?
  - What is current (power) requirement for PoDL? (Are there different classes?)
  - What are the supported Voltages ?
  - What is the desired size for different applications ? (1210 or 1812, or even smaller and larger sizes)
  - What is differential balance requirement? (Mode conversion loss) Is this achievable with two separate inductors?