Transformer and Channel ad hoc

July 2008

Fred Schindler
Cisco Systems

Alan L.	Pulse
Clay Stanford	Linear Technology
David Law	3COM
Fred Schindler	Cisco Systems
George E.	Solareflare
George Zimmermann	Solarflare
Hugh Barrass	Cisco Systems
Jim C.	?
Joe Berry	Bel
Jon Dutra	National Semiconductor
Kirk Hayden	Akros Silicon
Larry Haley	Broadcom
Pat Thaler	Broadcom
Randy Rannow	Tyco Electronics
Stephan Steinke	Molex
Terry Cobb	Systimax
Thuyen Dinh	Pulse
Tom Gandy	Aquantia
Yair Darshan	Microsemi

2 ad hoc with an average attendance of 20 people since the last report.

Agenda

- **Approaches taken**
- **Update on progress**
- **Q & A**
- **Next step.**

This is a work in progress: Trends are useful, model specifics are in development.

Approaches Taken

1. **Accept IEEE 802.3at D3.0 values.**

   Y: 13 N: 7

2. **Determine an OCL value for economically feasible magnetics using the same or smaller form factor as legacy solutions. Then have PHY vendors confirm whether recent baseline wander correct methods will ensure interoperation at all required data rates.**

   Y: 18 N: 2

   Use a Modern PHY

3. **Use statistics to determine the likelihood that the transformer OCL is below 350 uH and if that value is below ??? consider the system interoperable at the parameter levels selected.**

   Y: 16 N: 2

   Statistics Method

4. **Alternative A Midspan PSEs continue to be out of scope.**

   Y: 2 N: 13

The Task Force supports options 2 and 3.

The age of the universe is generally considered to be 14B years.

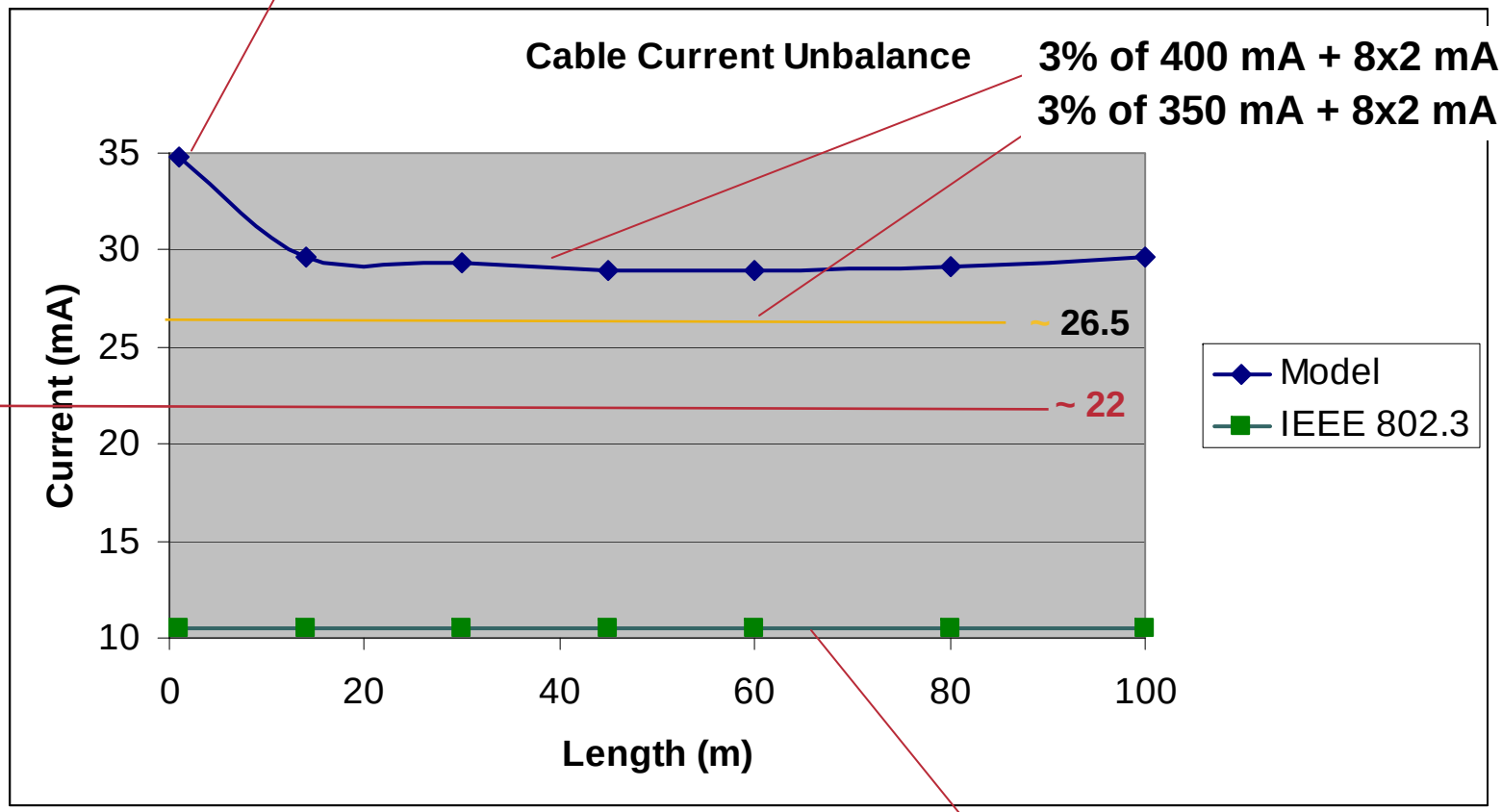
Existing PoE Worst-case Analysis

Connectors and transformer resistance predominate unbalance.
Reduced to ~30 mA with stats on connectors and transformer Rt.

System Failure

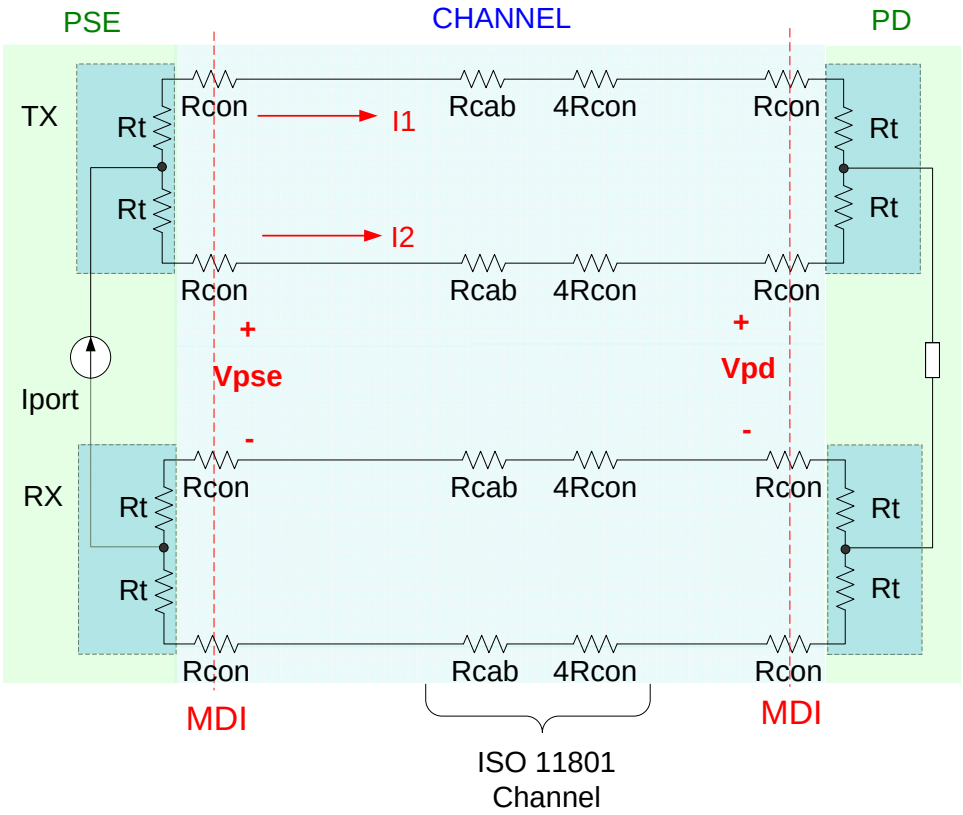
Vendor Average

Interoperability



Legacy systems interoperate.

The Channel Models: Detailed IEEE 802.3



$$I_1 = I_{cable} \frac{\sum R_{\max} // \sum R_{\min}}{\sum R_{\max}}$$

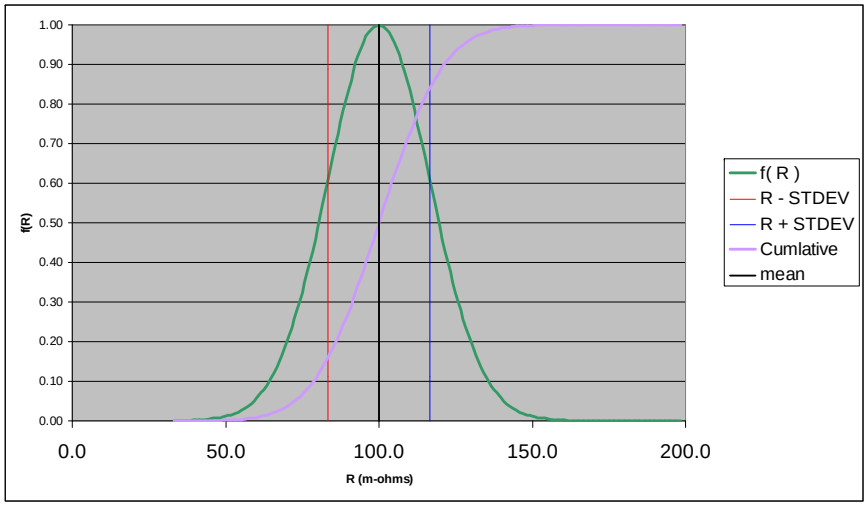
$$I_2 = I_{cable} \frac{\sum R_{\max} // \sum R_{\min}}{\sum R_{\min}}$$

$$I_{UNBAL} = I_{cable} \times \sum R_{\max} // \sum R_{\min} \left(\frac{1}{\sum R_{\min}} - \frac{1}{\sum R_{\max}}\right)$$

The worst-case current unbalance is modeled by combining the ISO channel resistance unbalance with an MDI connections and transformer resistance.

a // b => Replace with the resistance of “a” in parallel with “b”.

Statistics Method



Use statistics to determine the likelihood that the transformer OCL is below 350 uH and if that value is below ??? consider the system interoperable at the parameter levels selected.

Statistics Review

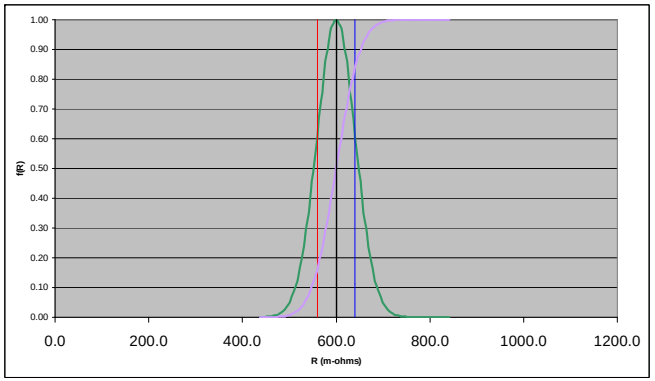
- **Assume the a resistor has a mean value of R, and a standard deviation = σ_1**

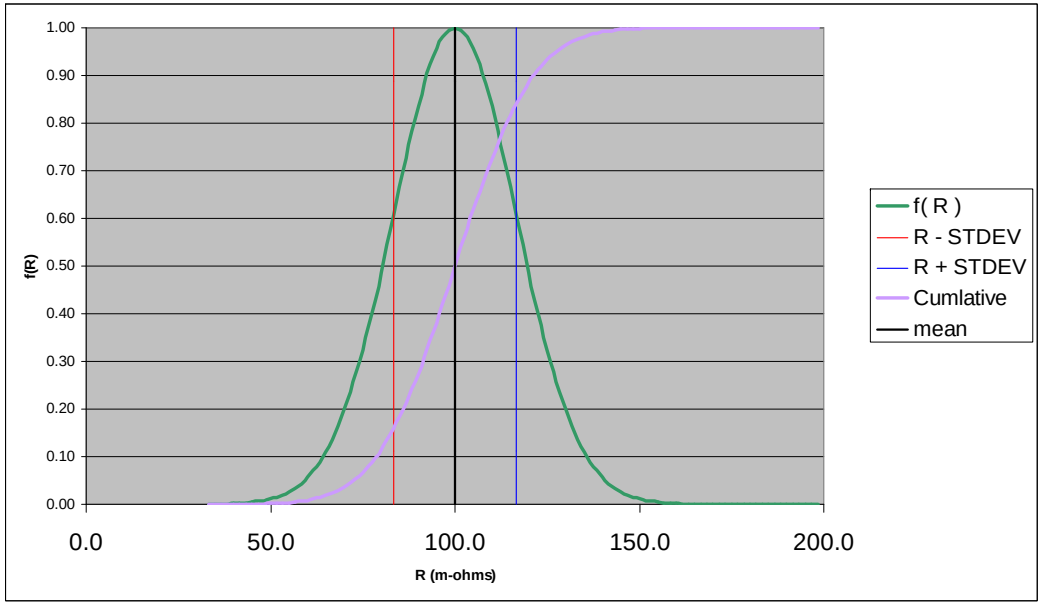
- **6 resistors in series have**

$R_{six} = 6 \times R$

$$\sigma_6 = \sqrt{6\sigma_1^2}$$

- **A single resistor and the 6 resistors in series have the same population size captured within the same number of standard deviations about their mean.**



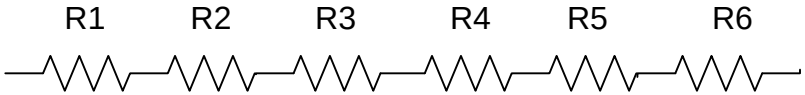


- **The graph shows a normal distribution with:**
R = 100 m-ohms, standard deviation (STDEV) = 200/12 m-ohms

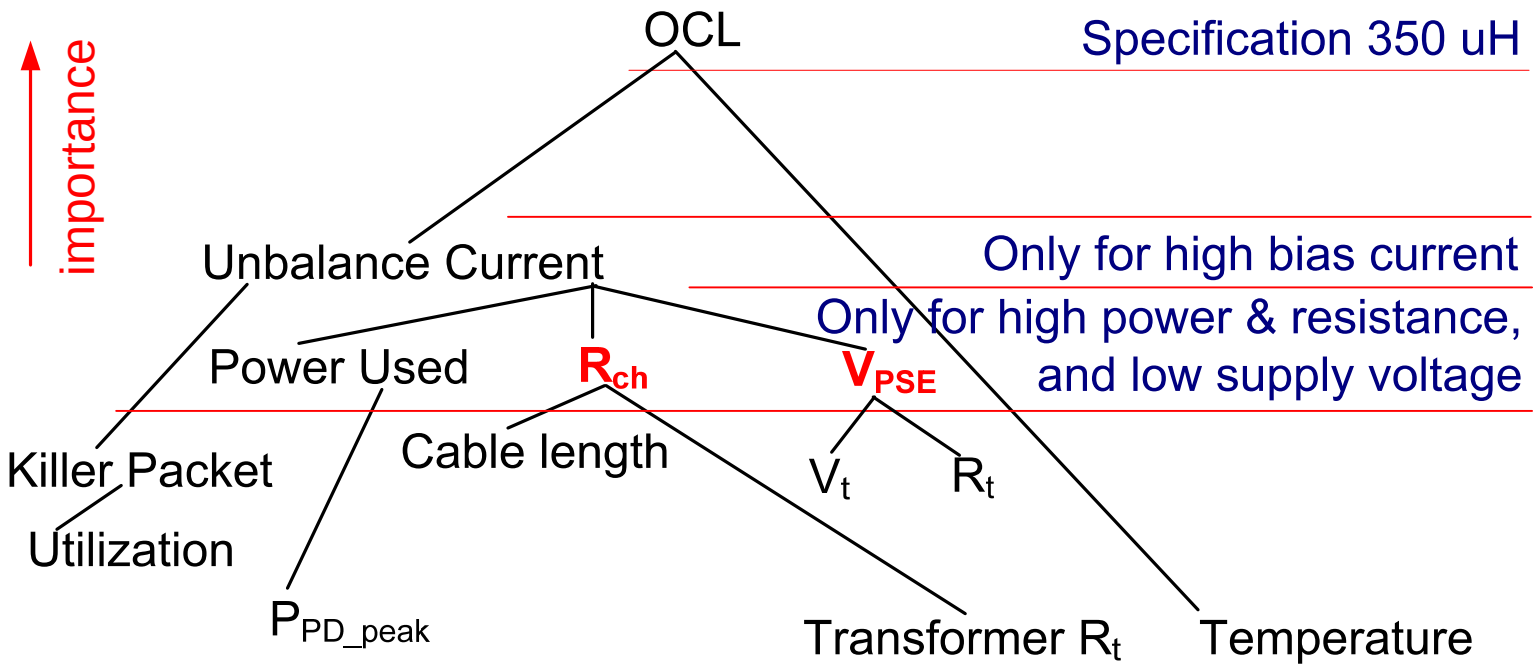
- **68% of the populations is within 1 standard deviation of the mean.**
1 in 3 samples are outside this region.

- **99.7% of the population is within 3 standard deviations of the mean.**
1 in 370 samples are outside this region

- **99.9…% of the population is within 6 standard deviations of the mean.**
1 in 570 M samples are outside this region



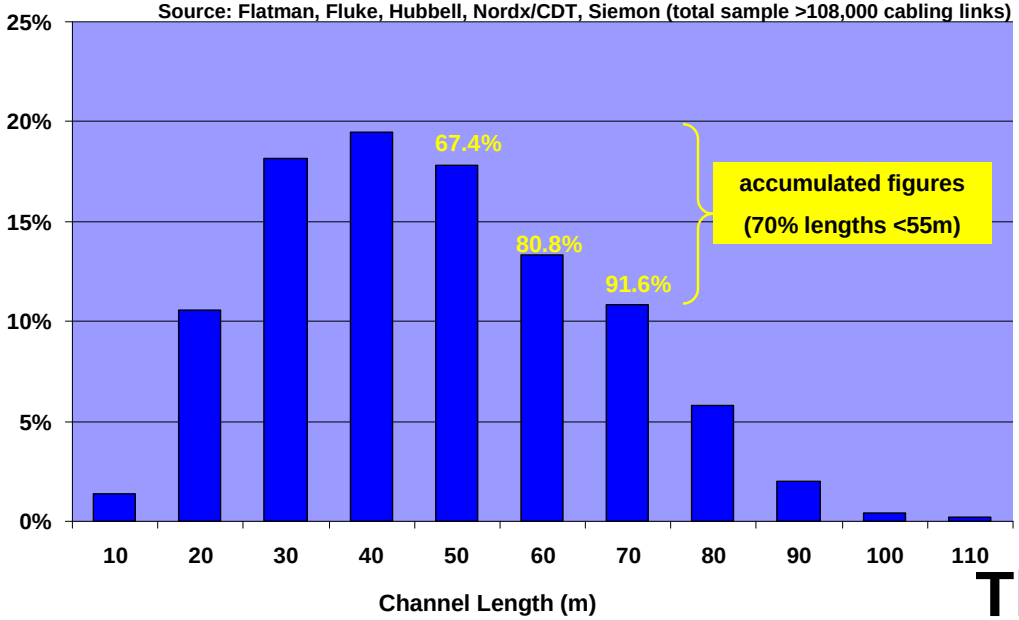
OCL Affecting Parameters



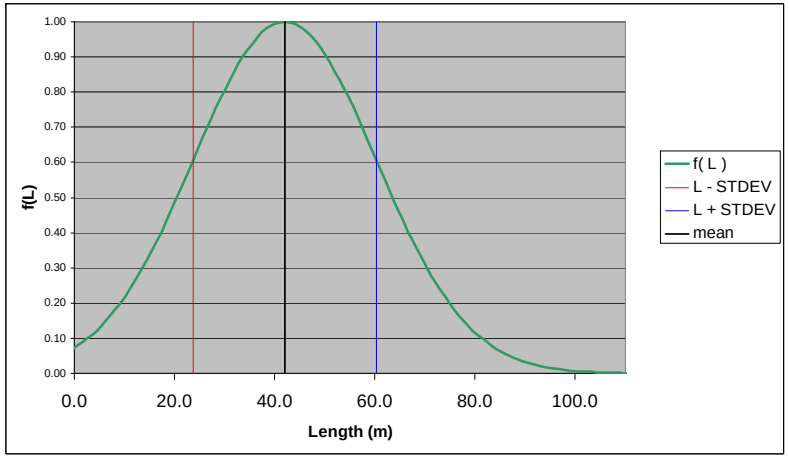
The next few pages will focus on R_{ch} and V_{pse} only.

OCL = Open Circuit Inductance of the Ethernet transformer.

Cable Reach



http://www.ieee802.org/3/10GBT/public/nov03/10GBASE-T_tutorial.pdf

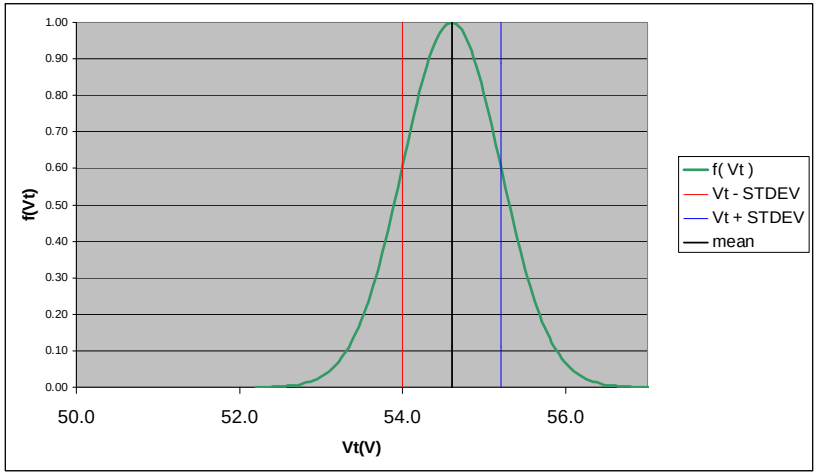


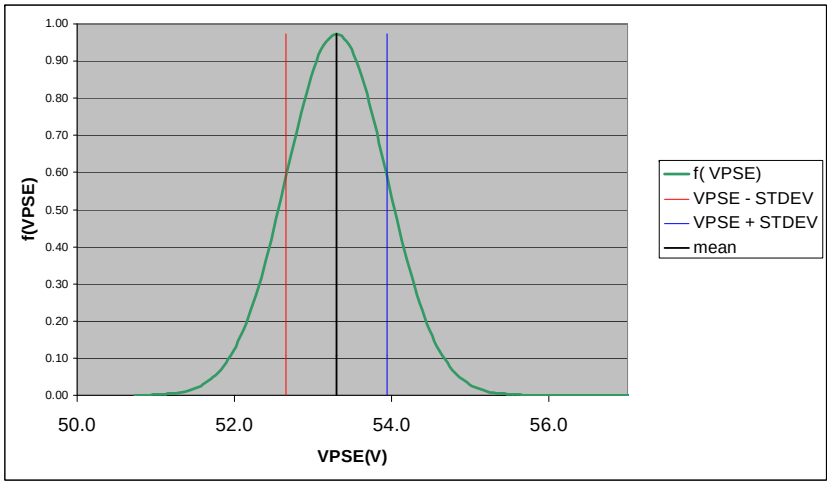
The Curve fit to this data has a mean of 42 m and a standard deviation of 18 m.

The R_{ch} is proportional to the cable length.
Rch_mean = 5.3 ohms
σ = 2.3 ohms

VPSE Distribution

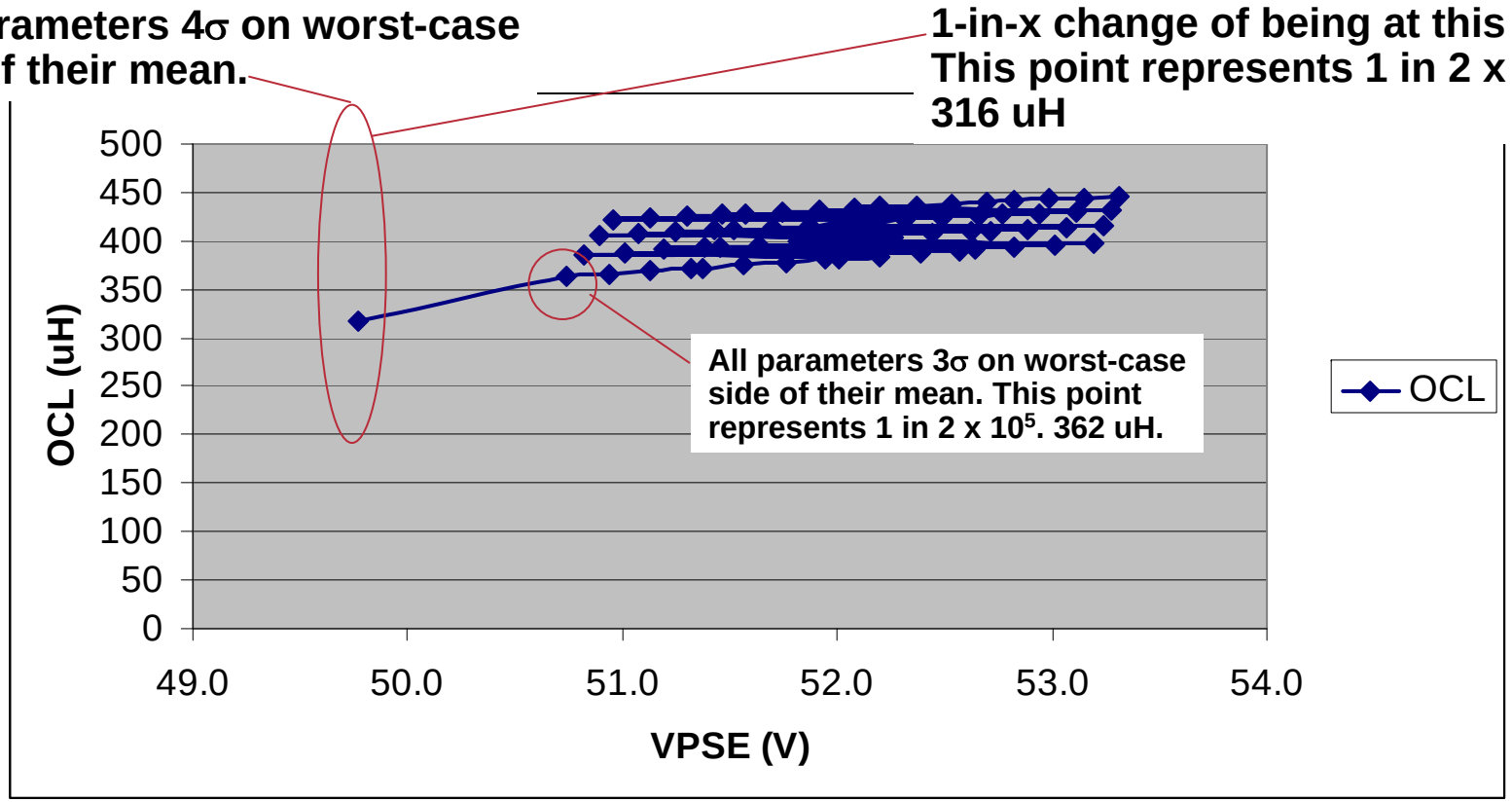
- **The Vport ad hoc created a model that is suppose to represent the broader market.**
- **The model can be simplified into a Thevenin equivalent circuit R_t = 2.1 ohms mean σ = 0.28 ohms with a voltage mean of V_t = 54.6 V and a σ = 0.6 V (±4σ between extremes). Therefore, V_{PSE} depends on V_t and the load current.**





The Vport ad hoc evaluation occurred from May 2006 to January 2008.

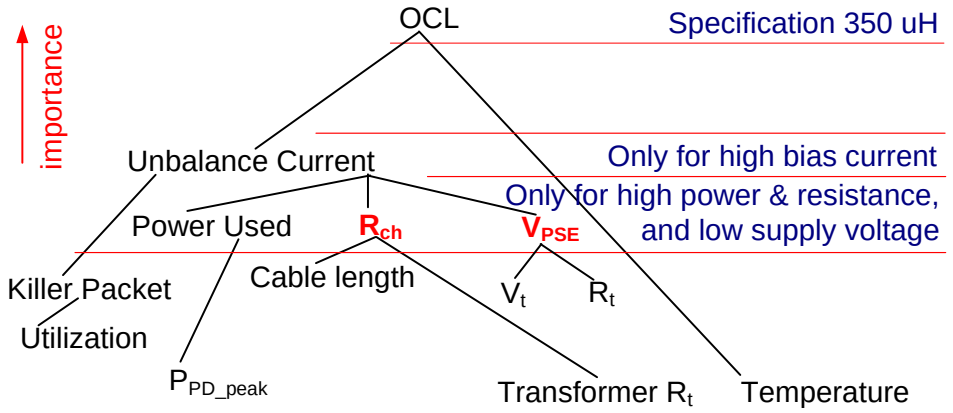
OCL vs V_{PSE} for Legacy Transformers



V_{PSE} and R_{ch} distribution with a 28.4 W PD peak load for an IEEE 802.3at system. This encompasses a cable reach from 0 to 115 m, and assumes a worst-case 3% channel resistance unbalance. No allowance for BLW induced bias current. Worst-case temperature.

Other parameters affecting OCL

- **Typical design practices ensure specification extremes are not normally reached.**
- **At least six other parameters significantly affect OCL.**
- **When all system parameters are considered having an OCL below 350 uH is not probable.**



Proposed Text

- **Modify Table 33-9, item 21, page 49**

Item	Parameter	Symbol	Unit	Min	Max	PSE Type	Additional information
21	Current unbalance	I_{unb}	mA		3 % × I_{Cable}	1, 2	See 33.2.9.13

- **3% x I_{Cable}, for PSE type 1.**

- **TBD (18 mA), for PSE type 2.**
- **Modify 33.2.9.13, page 53 as follows,**

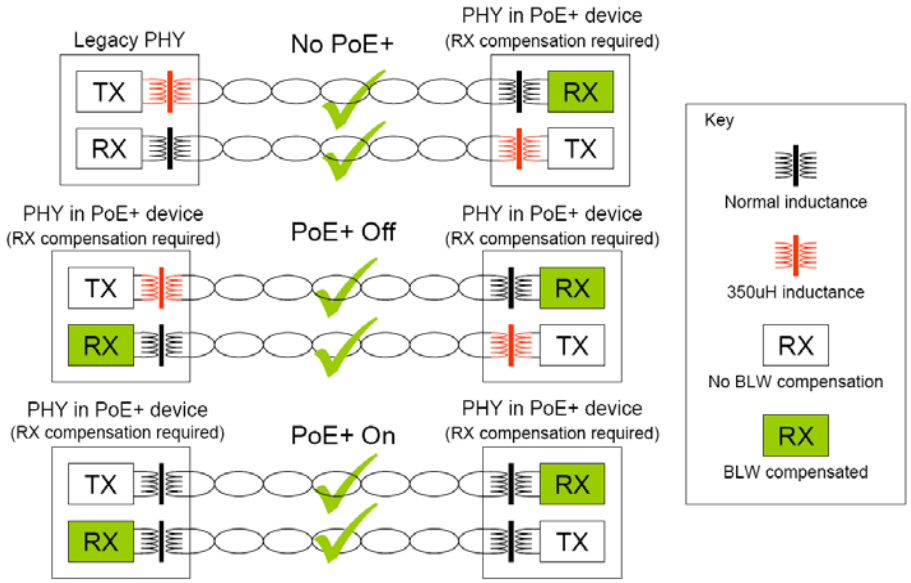
33.2.9.13 Current unbalance

The specification for I_{unb} in Table 33–9 shall apply to the current unbalance between the two conductors of a power pair over the current load range. ~~The values are based on a simulated output current unbalance of 3%.~~

Next step for the statistical method

- **Obtain data on channel resistance unbalance distribution.**
- **Obtain BLW probability.**
- **Refine OCL calculation to take into account the above two additional parameters.**
- **Refine proposed text.**
- **Make a motion for acceptance.**

Use a Modern PHY Method



- **Determine an OCL value for economically feasible magnetics using the same or smaller form factor as legacy solutions. Then have PHY vendors confirm whether recent baseline wander correct methods will ensure interoperation at all required data rates.**

- **Require a a modern PHY that has BLW compensation.**

http://grouper.ieee.org/groups/802/3/at/public/nov07/law_1_1107.pdf

PHY Baseline Wander Correction

- **Baseline wander correction provides low frequency gain at the receiver to improve data recovery.**
- **The correction is not done at the transmitter because larger voltages are not easily accommodated.**
- **Baseline wander correction has been done on most PHYs since 100BASE-TX was ratified in 1995.**
- **Some PHY vendors improved baseline wander to accommodate PoE testers and midspan PSEs. These support a cascade of transformers. A single transformer can have its inductance lower by more than a factor of 2 and interoperate at 100 MBPS.**
- **UNH test sponsored by Solarflare show some historic PHYs interoperate at 40 uH TX OCL.**
- **Test at Cisco show historic (~2003) PHYs interoperate at 100 uH TX OCL.**

PHY baseline wander correction provides a significant benefit to transformer OCL.

Detailed Requirements

- **Modify PSE section 33.2.8, page 44.**

A PSE shall meet one of the allowable classification permutations listed in Table 33–5.

- **Add "Type 2 end-span PSEs shall meet the requirements of clause 25.x in the presence of Iunbal/2."**

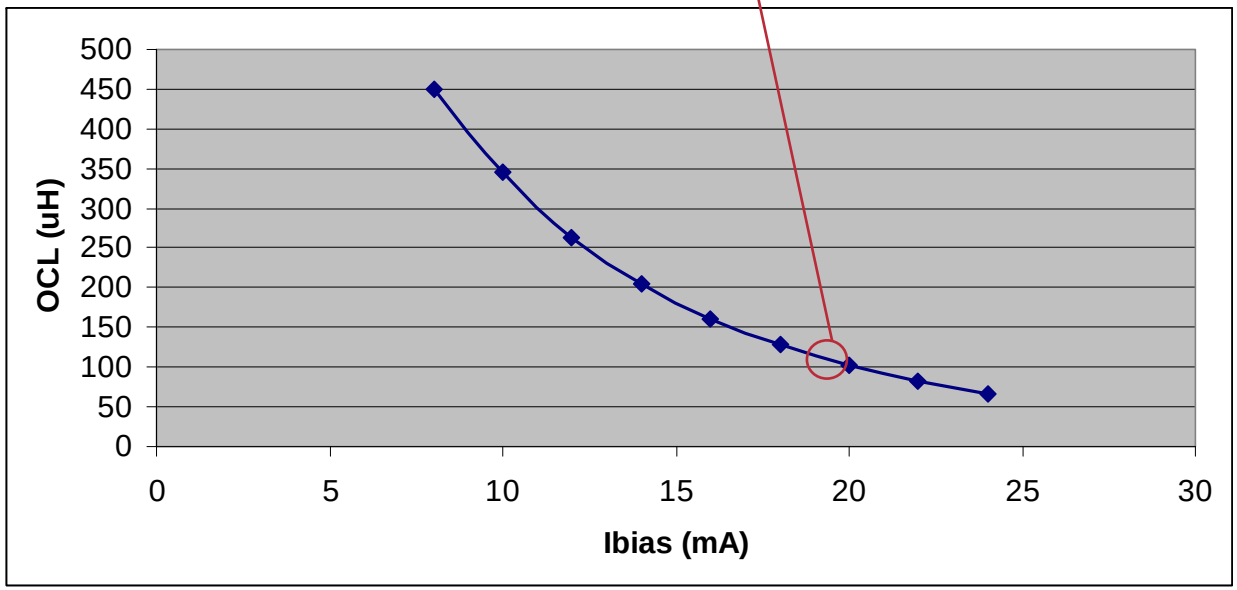
- **Modify PD section 33.3.5, page 63.**

Type 2 PDs shall implement both 2-Event class signature (see 33.3.5.2) and Data Link Layer classification (see 33.7).

- **Add "Type 2 PDs shall meet the requirements of clause 25.x in the presence Iunbal/2"**

The equivalent worst-case OCL

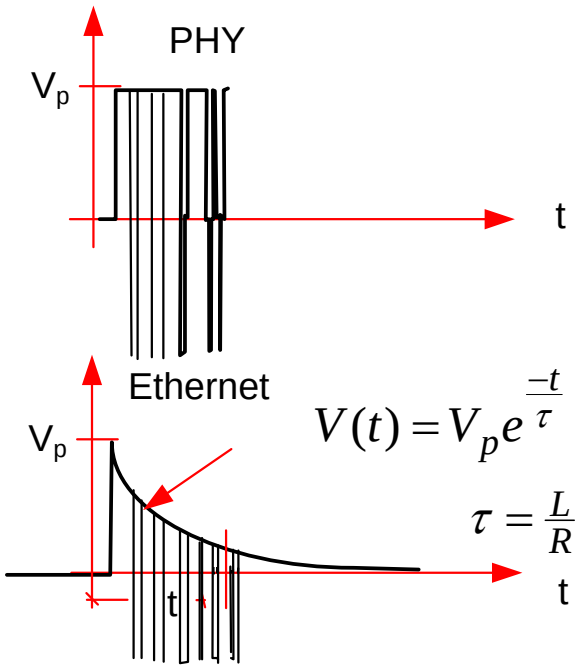
Parameters 4σ or more on worst-case side of their mean. Ibias = 18.8 mA, OCL = 120 uH. With parameters 3σ or more on worst-case side of their mean. Ibias = 18.0 mA, OCL = 135 uH. Ibias = Iunbal/2 + 8 mA

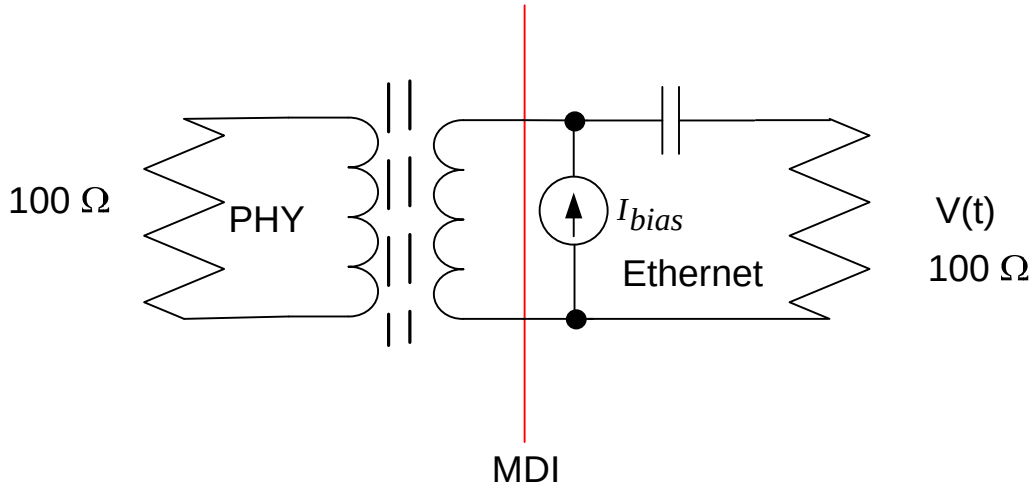


Have PHY vendors determine if PHYs released since June 2003 can interoperate with a TX OCL of 120 uH.

This model produce 350 uH OCL at 10.2 mA bias current.

New Section TBD text Development





The time constant of RC >> L/R.

- **Require a minimum running digital sum over a specific time period.**
- **Calculate an equivalent system time constant τ.**
- **The time constant must exceed 120uH/50Ω=2.4us.**
- **This approach facilitates multiple design choices.**
  ex/ Increased L, or PHY TX change.

New Section TBD Text

A PoE Plus PHY shall meet the OCL requirement of paragraph 9.1.7 of ANSI 263-1995 or have an equivalent system time constant that exceeds 2.4 us (PSE), and 7.0 us (PD) when transmitting the DDJ packet of Annex A.2 of ANSI X.3.263-1995.

Clause 25.4.x

Combined Methods

The statistics and PHY methods are related.

If the statistics method makes interoperation probable then using a modern PHY is expected to make interoperation a virtual certainty.

Q & A

Proposed text to PHY vendors:

Please determine if your 10BASE-T/100BASE-TX/1000BASE-T PHYs released since June 2003 will achieve a 10^{-8} or better BER while transmitting data with BLW with a transmitter (TX) open circuit inductance (OCL) of 120 uH. If not, at what value of TX OCL can a 10^{-8} or better BER be ensured?

The BER for 100BASE-TX operation is not specified but normally assumed to be 10^{-8}.

Is the above text acceptable? OCL acceptable?

Concerns with the approaches taken?

Note that the 120 uH assumes Ibias includes the BLW current component (8 mA). The OCL is 316 uH when no BLW is present.

Next Step

- **Get PHY vendor input on interoperability with low TX OCL.**
- **Refine proposed text.**
- **Make a motion for acceptance.**