Power Matters

Microsemi

IEEE802.3 4P Task Force

Type 3 maximum pair current including End To End Channel P2PRUNB effect

Supporters:
Dinh Thuyen / Pulse Electronics
David Hess / CORD DATA
Fred Schindler / Seen Simply
Christian Beia
Rick Frosch / PHIHONG
Rimboim Pavlik / MSCC
Gaoling Zou / Maxim

Rev 006

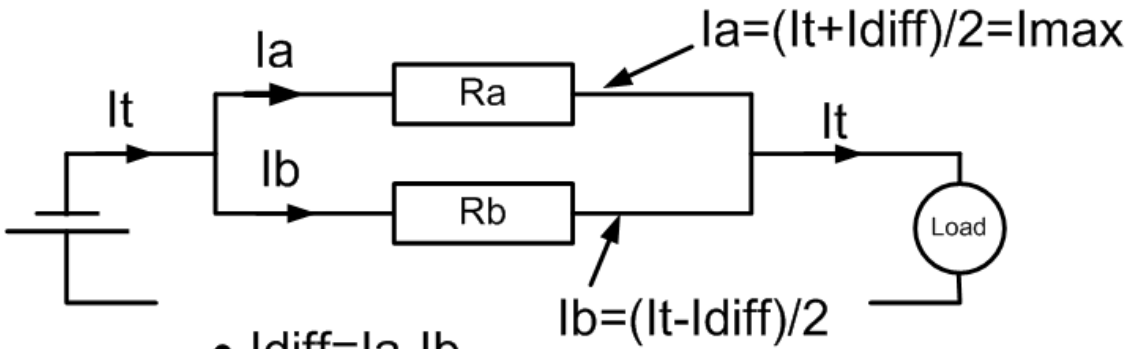
November 2014

San Antonio, TX

Yair Darshan
Microsemi
ydarshan@microsemi.com

Terms

System P2P current unbalance
between pairs of the same polarity



- Idiff=Ia-Ib
- Iunb = Runb= Idiff/It = (Ra-Rb)/(Ra+Rb)
- P2P voltage differences due to PSE and PD are embedded in Ra, Rb for simplicity
- The positive pairs of channel A and B are not shown for simplicity

- Runb in this presentation is related to the system unbalance i.e. End to End Channel Pair to Pair Resistance Unbalance=E2ECP2PRUNB.

- See Annex H for simplified electrical model. See Ref 1 for complete model details.

Objectives

- To propose base line text for Type 3 maximum pair current due to system pair to pair unbalance (Ipair_unb_2P).
  - It will allow us to:
    - Set system end to end channel P2PRUNB together with the requirements for PSE PI and PD PI unbalance.
    - Set the maximum peak current for Type 3 magnetics
    - Set the Icut/ILIM operating range.
- To investigate the conditions that allows Type 2 magnetics to be used in Type 3 systems for:
  - Fast time to market
  - Low cost
  - Same mechanical parameters.

History

- Part of this presentation was presented as part of PSE PI specification proposal on September 2014 meeting
  http://www.ieee802.org/3/bt/public/sep14/darshan_02_0914_rev%20002.pdf

- Now the Focus is on pair maximum current slides.

Background -1

See Annex A for calculation details and specification references.

Parameter per 2P	Type 2	Type 3	Notes
Icont [mA]	600	600 + Idiff/2	1. Transformer continuous current on one of the pairs of same polarity only!
Ipeak for Tcut_min=50msec	684	684 +Idiff/2	Maximum peak current. Relevant for OCL
Average/Rms Icont for 50msec, 5% duty cycle average over 1sec	600	Ia=600 + Idiff/2 Ib=600 - Idiff/2	Thermal considerations: ***Pcu[W]=(Ia^2+Ib^2)*Rw is less than with Perfect balance!*** *See slide 11 and ref 5.*
Ibias change that affect OCL	REF	0.03*Idiff/2.	Example: 1.5mA for Idiff=100mA.
ILIM_Min	**684**	**684 +Idiff/2**	**Example**
ILIM_max	**Implementation choice per figure 33-14**		
The question: What will be reasonable Ipeak for Type 3 system. It will determine Idiff, as a result, it will set the limit for system unbalance			

Background -2

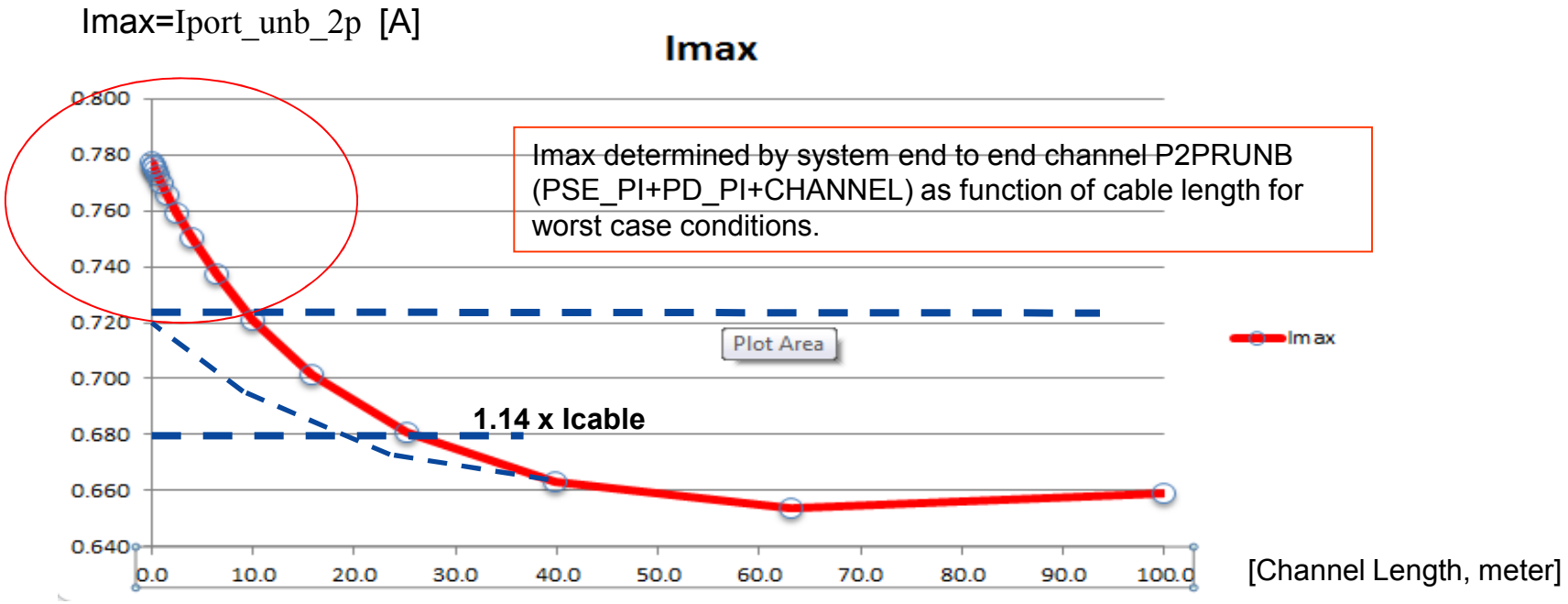
- The question: What will be reasonable Ipeak for Type 3 system.
- Ipeak [mA] (Type 3) =686+Idiff/2 ➔ Idiff=2*(Ipeak-686)
  - Idiff is determined by the overall system unbalance (PSE PI+PD PI + Channel).
    - Iunb=Idiff/It =Runb ➔ Idiff=It*Runb
- The channel P2PRUNB is defined (7.5% or 0.1 ohm which ever is greater).
- PSE PI and PD PI need to be agreed.
  - Based on what we will get the agreement on PSE PI and PD PI?
    - Base on data in Annex G1 adhoc table that represents worst case PSE and PD implementations
    - We need to conclude Diodes real unbalance. We OK with the rest of components data.

Background -3

- **The following Curve is based on worst case data using worst case analysis with the existing data in Table G1.**
- At short channel, Imax gets to 0.78A >0.6A due too high unbalance over one pair only.
- New data regarding diodes behavior at high current is expected be available at this meeting showing more reasonable diode unbalance as a result, Imax will be <0.78A.
- Lab results showed actual values <=0.5 worst case analysis at high current. (In reality not all components are max or min on the same pair).
- As a result, setting Imax to 0.72A max for Type 3 is reasonable starting point.
- Therefore 0.72A (TBD) is suggested to be considered by the group.
- Next slide shows current worst case analysis with data taken from Table in Annex G1

Proposed Imax vs. Worst case system End to End CP2PRUNB

- Below (red curve) is the maximum pair current in the presence of end to end channel P2PRUNB of with worst case Rmax/Rmin per table G1 from September 2014 adhoc report.
- For Type 3 systems we can be below the blue curve for TLIM.
- The red circle area is handled by specifying PSE PI and PD PI unbalance budget that will guarantee Imax to be 720mA (or lower, TBD).
- **Imax** is the pair maximum current of the pair with minimum total resistance. Imax is function of the end to end channel pair to pair resistance unbalance.



Can we use Type 2 Magnetics with Type 3 Systems

- It need to be checked per part number/vendor per the table shown in slide 5.
- The key conclusions are:
  - OCL need to be met for Ipeak (e.g. 0.72A)
    - OCL need to be met for 684mA anyway by the current spec.
      - Should not be an issue since I bias is change by 1.26mA max for the additional 84mA to 600mA.
  - Continuous DC current, Power loss and temperature Rise.
    - I=600mA+Idiff/2=672mA
      - Depend if system shut off at 684mA after 50msec.
      - If Yes: I=600mA+Idiff/2=672mA. (Idiff =72mA).
      - If NO: I=720mA . Negligible probability since PD is required to consume max average 600mA averaged over 1sec! ➔ I=600mA+Idiff/2=672mA
        - For worst case when PSE allows current up 684 continuous, the part need to be reviewed for thermal consideration.
  - The current increase due to unbalance, will not create thermal issue for a **total even number** of components in the package (power loss will be lower or the same). **The individual** core need to be verified for meeting OCL.
- **There are parts of Type 2 that can be used for Type 3.**

How to calculate Icut, ILIM etc. ?

- See Background -1 slide, Annex A and B for detailed example.

What is the effect of current unbalance on cable and components power loss?

- There are no implications on:
  - Cable **total** power
  - Any other component with DC resistance

- Total AVERAGE and RMS current per 4pairs cable stay the same during overload and unbalance effect.
  - See slide 11 at http://www.ieee802.org/3/4PPOE/public/nov13/darshan_02_1113.pdf

Which its main conclusion is:

$$Ra \cdot \left(\frac{It + Idiff}{2}\right)^2 + Rb \cdot \left(\frac{It - Idiff}{2}\right)^2 \le (Ra + Rb) \cdot \left(\frac{It}{2}\right)^2$$

Summary

- New parameter of pair maximum current due to system unbalance need to be added to Table 33-11.
  - Set system unbalance together with PSE and PD PI requirements
  - It is required for designing magnetics, setting Icut/ILIM
    - The value can be 720mA (TBD) or TBD until we complete PSE PI and PD PI requirements.

- Note: 720mA supports exiting PSE and PD PI components per Table G1 however we can leave the number TBD in the proposed baseline text.

Proposal

Item	Parameter	Symbol	Unit	Min	Max	PSE Type	Additional Information
TBD	Pair current of the pair with minimum resistance in the POWER_ON state due to system end to end pair to pair current unbalance.	Iport_unb_2p	mA		0.72 (TBD)	3	See 1,2,3.
		Iport_unb_2p			TBD	4	

Add to Table 33-11. Add similar item to Table 33-18.

Additional information column:

(1) Includes Ipeak effect as specified by Table 33-11 items 4 and 9.

(2) This is the maximum current over one of the pairs with the same polarity. The total average current of both pair-set shall not exceed 2xIcable as defined for the PSE type.

(3) Continuous DC current: Will be defined separately (TBD).

Reference Material

Annex A

Derivation of minimum current at the magnetic component center tap for Type 2 systems per the overall requirements of IEEE802.3-2012

Table 1: The facts from the IEEE802.3-2012 (for 2P)			
Parameter	Reference	Value	Units
Vpse	Table 33-11 item 1	50	V
Rch	Table 33-1 row 2	12.5	Ohm
Icable	Table 33-1 row 1	600	mA
Pclass_PD	Table 33-18 item 4	25.5	W
Ppeak_PD	1.11*Pclass_PD per Table 33-18 item 7	28.3	W
Ipeak	1. Table 33-11 item 4. 2. Eq 33-4 in 33.2.7.4	682.6	mA
ILIM_MIN	Table 33-11 item 9: = 1.14*Icable	684	mA

Table 2: Calculating Icut, ILIM AND Imax for the pair with minimum resistance (For 2P). **Example**			
Parameter	Reference	Value	Units
Iport=Icable=Icut_min	At maximum load=25.5W , Vpse=50V	600	mA
Icut_max	=ILIM_MIN	684	mA
Icut_th	(600+684)/2	642	mA
ILIM_max	=(450mA/400mA)*684mA=769.5mA (770mA) (Keeping same ratio as in Type 1)	770	mA
ILIM_threshold	(769.5mA+684mA)/2=726.8mA (727mA)	727	mA

Annex B

Table 3: Calculating Icut, ILIM for 4P system. **Example**			
Parameter	Reference	Value	Units
ILIM threshold for Type 2 PSE		**727**	**mA**
Proposal for Ipair_unb maximum due to end to end channel pair to pair resistance. For reusing Type 2 transformers.		**720 (or lower, TBD)**	**mA**
Icut Iport=Icable=Icut_min	At maximum load=25.5W , Vpse=50V	600	mA
Icut_max	Now it is higher to include Imax (684mA) and pair to pair current unbalance effect maximum (=720-684=36mA).	720	mA
Icut_th	(600+720)/2=660mA	660	mA
ILIM_max	=(450mA/400mA)*720mA=810mA (770mA) (Keeping same ratio as in Type 1)	810	mA
ILIM_threshold	(810mA+720mA)/2=765mA	765	mA

Comparison between Type 2 and 3 systems:

	2P	4P
Icut_th	642mA	**660mA**
Ilim_th	727mA	**765mA**
Ipair_DC (continuous)	600mA	600mA+Idiff/2
Ipeak (for 50msec)	684mA	684mA+Idiff/2
Ipair_max (for E2ECP2PRUNB>0)	684mA	684mA++Idiff/2=720mA

ANNEX C: Example for Existing PSE PD PI P2PRUNB Source: (*). PSE PI Vdiff=0.

- Reqv=The resistance equivalent caused by P2P voltage difference on the E2E_C_P2PRUNB
- Rd_eqv=The resistance equivalent caused by PD diode voltage difference and Diode dynamic resistance difference
- The following example is with PSE PI Vdiff=0.

	PSE PI POS								
	Traces	Rt	Rc			Reqv	Sum	Rdiff	P2PRUNB
Rmin [ohm]	0.01	0.12	0.03			0	0.16	0.031	8.83%
Rmax [ohm]	0.011	0.13	0.05			0	0.191		
	PSE PI NEG								
	Traces	Rt	Rc	Rsense	RDSon	Reqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03	0.098	0.05/0.099	0	0.308/0.357	0.083/0.034	11.87%/4.55%
Rmax	0.011	0.13	0.05	0.1	0.1/0.1	0	0.391/0.391		
	PD PI POS								
	Traces	Rt	Rc			Rd_eqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03			0.25	0.41	0.281	25.52%
Rmax	0.011	0.13	0.05			0.5	0.691		
	PD PI NEG								
	Traces	Rt	Rc	Rsense	RDSon	Rd_eqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03	0	0	0.25	0.41	0.281	25.52%
Rmax[ohm]	0.011	0.13	0.05	0	0	0.5	0.691		

(*) http://www.ieee802.org/3/bt/public/sep14/darshan_01_0914.pdf

Annex D: Example for Existing PSE PD PI P2PRUNB
Source: (*). PSE PI Vdiff>0.

- Reqv=The resistance equivalent caused by P2P voltage difference on the E2E_C_P2PRUNB
- Rd_eqv=The resistance equivalent caused by PD diode voltage difference and Diode dynamic resistance difference
- The following example is with PSE PI Vdiff>0. P2PRUNB=(Rmax-Rmin)/(Rmax+Rmin)

	PSE PI POS								
	Traces	Rt	Rc			Reqv	Sum	Rdiff	P2PRUNB
Rmin [ohm]	0.01	0.12	0.03			0	0.16	0.131	29.05%
Rmax [ohm]	0.011	0.13	0.05			0.1	0.291		
	PSE PI NEG								
	Traces	Rt	Rc	Rsense	RDSon	Reqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03	0.098	0.05	0	0.308	0.183	22.90%
Rmax	0.011	0.13	0.05	0.1	0.1	0.1	0.491		
	PD PI POS								
	Traces	Rt	Rc			Rd_eqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03			0.25	0.41	0.281	25.52%
Rmax	0.011	0.13	0.05			0.5	0.691		
	PD PI NEG								
	Traces	Rt	Rc	Rsense	RDSon	Rd_eqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03	0	0	0.25	0.41	0.281	25.52%
Rmax[ohm]	0.011	0.13	0.05	0	0	0.5	0.691		

(*) http://www.ieee802.org/3/bt/public/sep14/darshan_01_0914.pdf

Annex E: Example for Existing PSE PD PI P2PRUNB Source: (*). PSE PI Vdiff=0, PD Match diodes.

- Reqv=The resistance equivalent caused by P2P voltage difference on the E2E_C_P2PRUNB
- Rd_eqv=The resistance equivalent caused by PD diode voltage difference and Diode dynamic resistance difference
- The following example is with PSE PI Vdiff=0 and PD using matched diodes. With ideal diode bridge PDE PI P2PRUNB may be a bit higher due to lower resistance and process.

	PSE PI POS								
	Traces	Rt	Rc			Reqv	Sum	Rdiff	P2PRUNB
Rmin [ohm]	0.01	0.12	0.03			0	0.16	0.031	8.83%
Rmax [ohm]	0.011	0.13	0.05			0	0.191		
	PSE PI NEG								
	Traces	Rt	Rc	Rsense	RDSon	Reqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03	0.098	0.05/0.099	0	0.308/0.357	0.083/0.034	11.87%/4.55%
Rmax	0.011	0.13	0.05	0.1	0.1/0.1	0	0.391/0.391		
	PD PI POS								
	Traces	Rt	Rc			Rd_eqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03			0.225	0.385	0.056	6.78%
Rmax	0.011	0.13	0.05			0.25	0.441		
	PD PI NEG								
	Traces	Rt	Rc	Rsense	RDSon	Rd_eqv	Sum	Rdiff	P2PRUNB
Rmin[ohm]	0.01	0.12	0.03	0	0	0.225	0.385	0.056	6.78%
Rmax[ohm]	0.011	0.13	0.05	0	0	0.25	0.441		

(*) http://www.ieee802.org/3/bt/public/sep14/darshan_01_0914.pdf

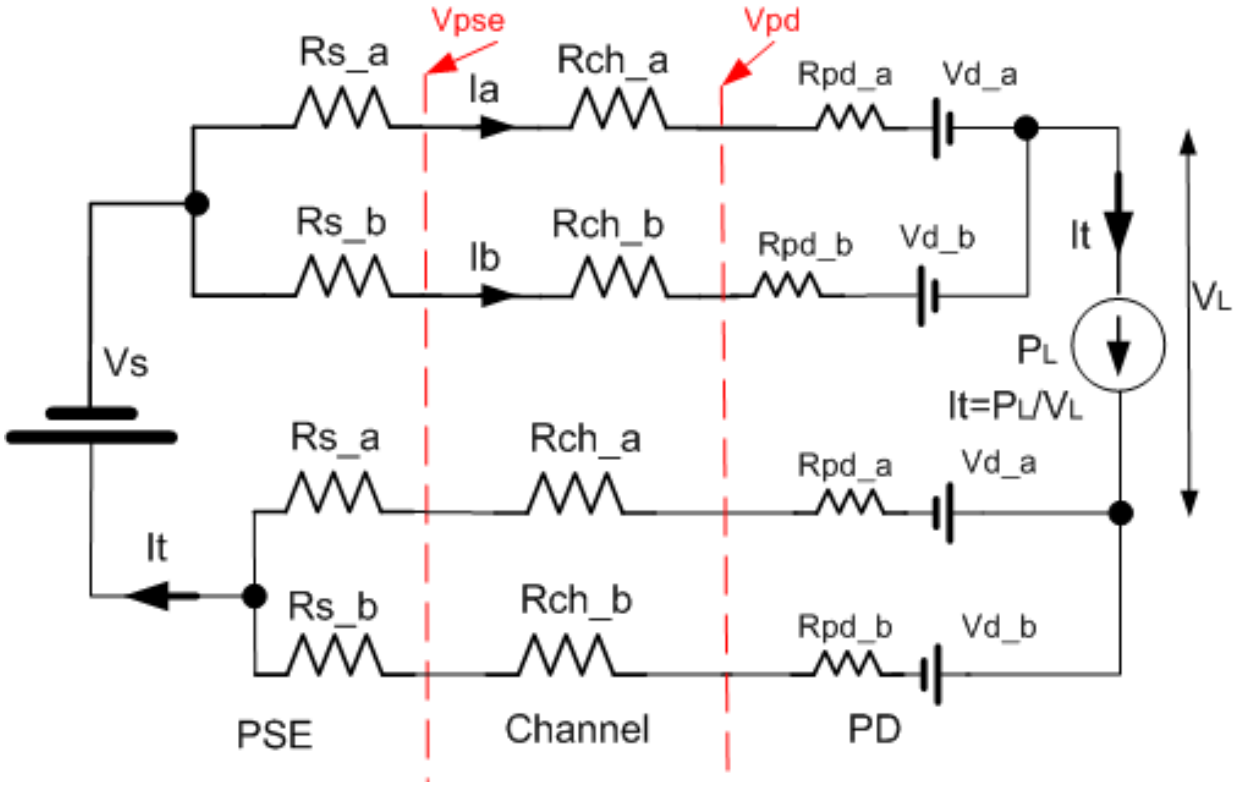
Annex G1:Worst Case Data Base. See Ref 1.

#	Parameter	Data set 1	Data set 2
1	Cordage resistivity[1]	0.14Ω/m	
		0.09262Ω/m for AWG#24 for worst case analysis	
2	Horizontal cable resistivity option 1[2]	11.7Ω/100m=(12.5Ω - 4*0.2Ω) / 100m which is the maximum resistance resulting with maximum Iport.	7.4Ω/100m to 7.92Ω/100m (CAT6A, AWG23) This is to give us maximum P2PRunb
3	option 2[3]	0.098Ω/m.	
4	Unbalance parameters	• Cable Pair resistance unbalance: 2%. Channel pair resistance unbalance: 3% • Cable P2P Resistance Unbalance: 5%. Channel P2P Resistance Unbalance: 0.2Ω/6% max TBD.	
5	Channel use cases to check. See figure 1 for what is a channel.	A. 6 inch (0.15 m) of cordage, no connectors. B. 4 m channel with 1 m of cordage, 3 m of cable, 2 connectors C. 23 m channel with 8 m of cordage, 15 m of cable, 4 connectors D. 100m channel with 10 m of cordage, 90 m of cable, 4 connectors	
6	End to End Channel[6]	The Channel per figure 1 + the PSE and PD PIs.	
7	Transformer winding resistance	120mOhm min, 130mOhm max	
8	Connector resistance[8]	40mOhm min, 60mOhm max	30mOhm min, 50mOhm max
9	Diode bridge[9]	Discreet Diodes: 0.39V+0.25Ω*Id min; 0.53V+0.25Ω*id max. (TBD)	
10	PSE output resistance [10]	0.25+0.1 Ohm min, 0.25+0.2 Ohm max	0.1+0.05 Ohm min, 0.1+0.1 Ohm max

Ad-hoc response, June 24, 2014. Adhoc accept this table

Source: Yair Darshan, Christian Beia, Wayne Larsen

Annex H: Simplified 4P system model



- PD diode voltage differences Vd_a, Vd_b.

#	Reference	Notes
1	http://www.ieee802.org/3/bt/public/sep14/darshan_01_0914.pdf	Adhoc
2	http://www.ieee802.org/3/bt/public/unbaladhoc/Channel%20Pair%20To%20Pair%20Resistance%20Unbalance%20Specification-What%20is%20the%20preferred%20concept.pdf	comparision
3	http://www.ieee802.org/3/bt/public/unbaladhoc/PI%20Balance%20Specifications%20rev%202.pdf	PSE PI spec.
4	http://www.ieee802.org/3/bt/public/unbaladhoc/Analzing_Channel_Pair_To_Pair_Resistance_Unbalance_use_cases_rev_6.1.pdf	Channel spec
5	http://www.ieee802.org/3/4PPOE/public/nov13/darshan_02_1113.pdf	Thermal
6	http://www.ieee802.org/3/bt/public/sep14/darshan_02_0914_rev%20002.pdf	PSE PI spec.