



IEE802.3 4P Task Force
Worst Case simulation results for system P2P_lunb,
Maximum pair current and PD available power for Type 3
and 4 systems
March 2015

Rev 006a

Yair Darshan
Microsemi
ydarshan@microsemi.com

Supporters and contributors

- **Contributors**

- Ken Bennett / Sifos

- **Supporters**

- Christian Beia / ST
- Fred Schindler / Seensimply
- Belopolsky Yakov / BEL
- Rimboim Pavlik/ MSCC

- Please see Rev History slide for difference from previous versions

Objectives

- Setting Type 3 and Type 4 values for:
 - System End to End Channel Pair to Pair Resistance/Current Unbalance (E2ECP2PRUNB) at:
 - Short Cables
 - Long Cables
 - Based on Table G1 data base (Annex G1, G2 and Ref 5) that was updated per the last meetings/presentations/IEEE802.3bt draft updates.
- PD Available power.
- Maximum Pair current.
- **Using the above data to propose PSE PI P2P unbalanced spec.**
- **Approve Table G1 database item 9: Diode Vdiff and we done with adhoc data base.**
- **E2ECP2PRUNB_effective, E2EP2PRunb, System P2PRunb are equivalent terms. All address the effective End to End P2P resistance or current unbalance**

Database used to run simulation.

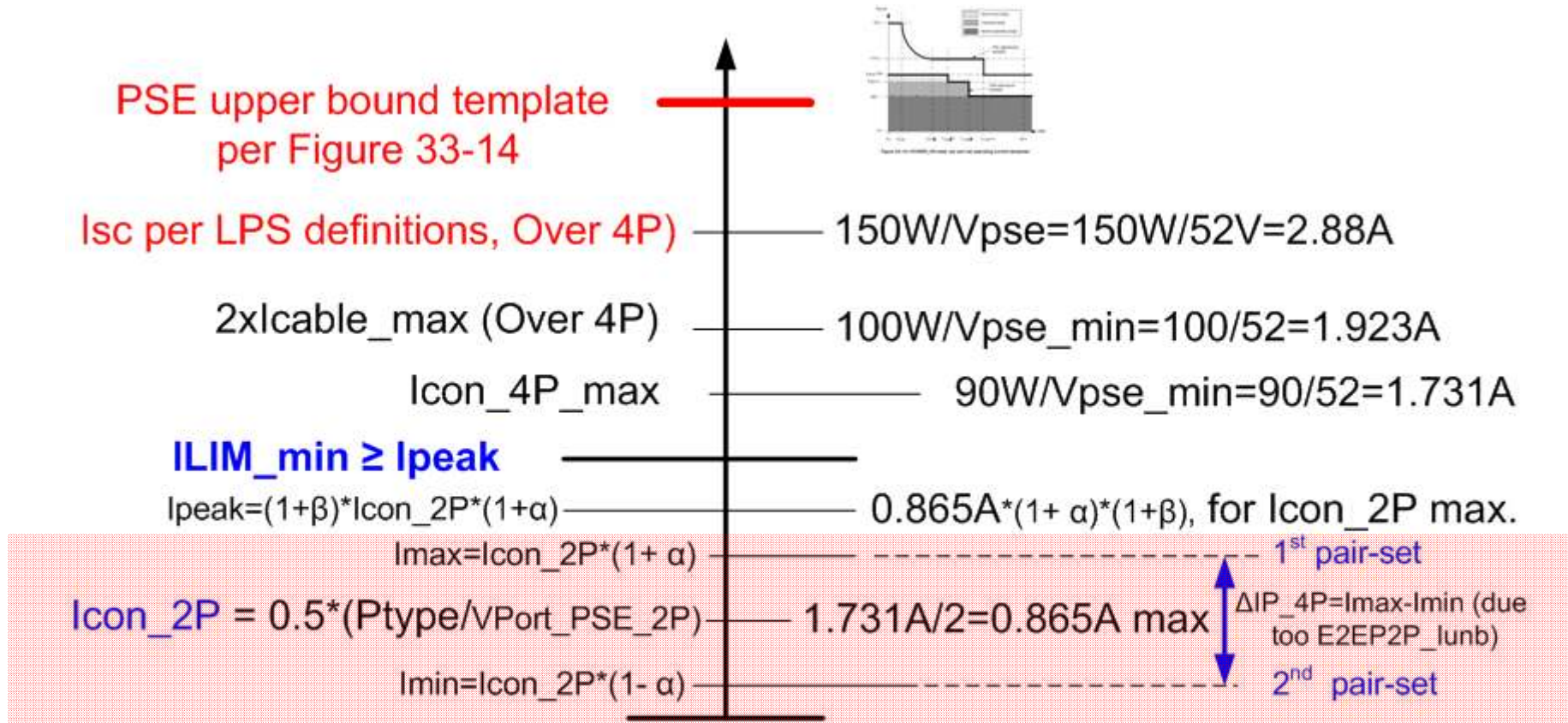
Based on Table G1 + Latest updates

Parameter	Data set	References
Channel Length and number of connectors	100m with 4 connectors (ref 4). 4m with 1 connector (generates channel P2PRunb=7.5%) , 2.65m with no connectors (generate 0.1Ω minimum per pair).	1,5,Annex G3.
Cable Runb	2%	1
Cable P2PRUNB	5%	2
Channel P2PRUNB	7.5% or 0.1Ω whichever is lower	3, 4
Cordage Resistivity (wire)	0.0926Ω/m	5
Cable Resistivity (wire)	0.074Ω/m	5
Connector resistance, Rconn.	Rconn_min=0.03Ω, Rconn_max=0.05	5
Total Cable Resistivity	Length*{0.1*Cordage Resistivity + 0.9*Cable Resistivity}	5, 9
Total channel resistivity (wire)	Case 1: Total Cable Resistivity + N*Rconn. Case 2: 12.5Ω	5
Transformers	Rt_min=0.12Ω, Rt_max=0.13Ω	5
Sense Resistor	Rsense_max=0.25Ω. Rsense_min=0.98*Rsense_max	5
Rdson	RDson_max=0.1Ω. RDson_min=0.07*RDson_max	5, 6
PSE Vdiff and PD Vdiff.	PSE: 2mV (ref 7) , PD=58mV (ref 8). Total 60mV (ref 8).	7, 8
PD Load power	51W, 71.3W, Ptype (at 2.65m ,0.24Ω per wire)	9
Unless otherwise noted, all numbers are worst case minimum possible values for generating worst case unbalance. As a result, maximum values that are defined by cable and connector standard were not used due to irrelevancy for the objectives. Examples: Connectors 0.2Ω values or cables with 0.098Ω/m defined by TIA were not used. See reference 4 for details.		

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Terms

See also Annex L.



$$I_{min}=I_{cont_2P_unb_min}$$

$$I_{max}=I_{cont_2P_unb_max}$$

- Focusing on I_{max}, I_{min}. I_{max}+I_{min}=Total load current.
- α =System P2P_lunb effect at I_{max} value. β = Current ripple contribution

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Additional data

- Pair current is not limited to 600mA during P2P_lunb event.
 - As a result, we will get 51W at Type 3 PD.
 - In general, we will get same PD power with and without P2P_lunb effect (Type 4 or any)

- All results are worst case values.
- Numbers may relaxed with statistical analysis for PSE and PD PI components only. Channel is given as 7.5% or 0.1Ω which ever is greater so
 - at short channel the statistical analysis will not help.
 - No components.
 - At long channel P2P_lunb I is low anyway but I_{max} may be high so it will help some.

- Statistical analysis will be the last tool to use.

Summary -1

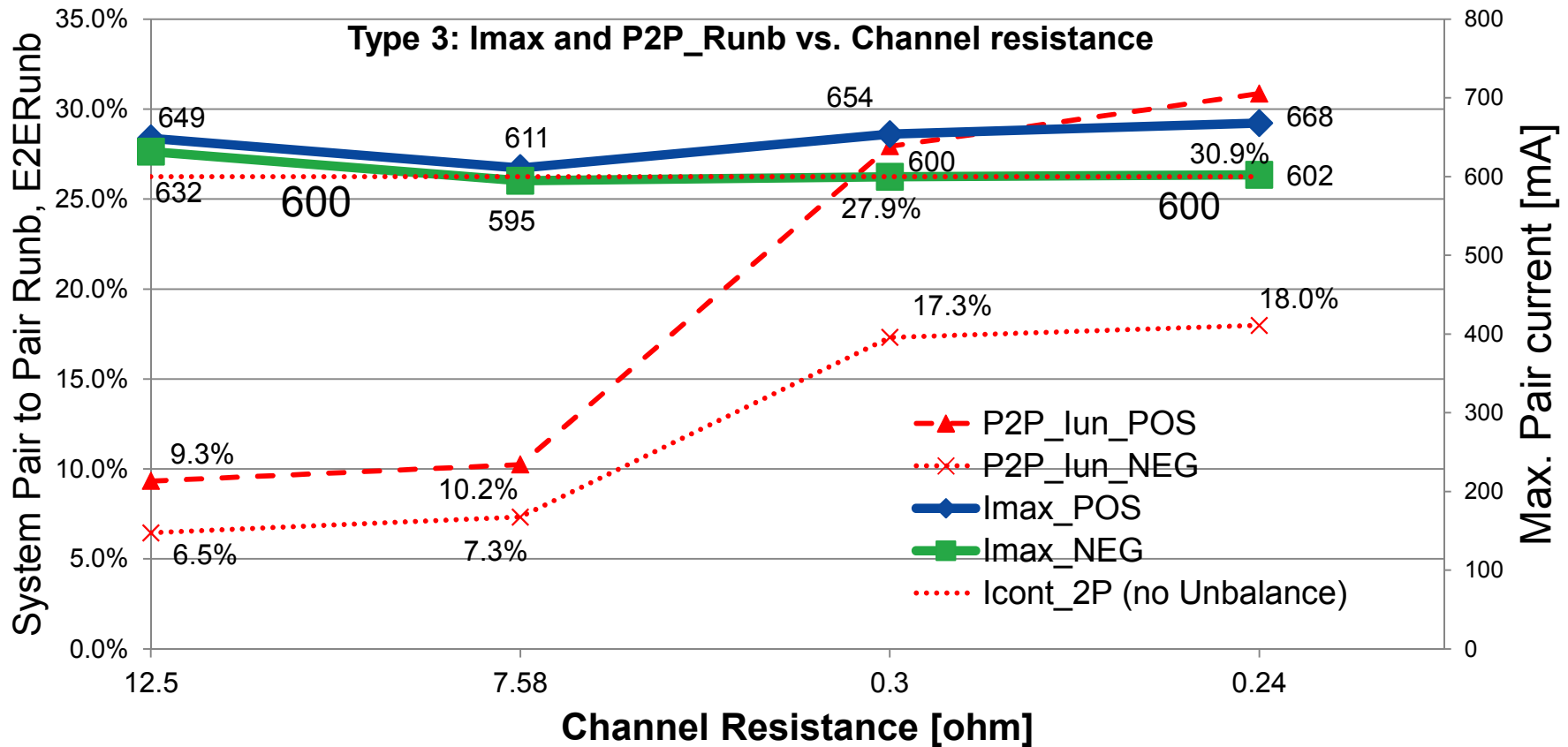
See simulation details at the backup slides.

Vpse	Channel Length [M]	N	Channel Resistance [OHM]	I _{max} _POS [A]	I _{max} _NEG [A]	P2P_lun_ _{POS} [%]	P2P_lun_ _{NEG} [%]	Vpd_AVG	Ppd_Available
Type 3									
50	100	4	12.5	649	631	9.3%	6.5%	43.0	50.99
50	100	4	7.58	611	594	10.2%	7.3%	46.0	50.99
50	4	1	0.3	654	599	27.9%	17.3%	49.9	50.99
50	2.65	0	0.24	668	602	30.9%	18.0%	50.0	50.99
50	0	0	0	709	612	39.2%	20.1%	50	50.99
Type 4									
52	100	4	12.5	931	906	9.1%	6.2%	41.8	71.29
52	100	4	7.58	845	823	9.9%	7.0%	46.4	71.29
52	4	1	0.3	862	795	25.1%	15.5%	51.8	71.28
52	2.65	0	0.24	877	798	27.6%	16.0%	51.8	71.28
52	0	0	0	928	809	35.2%	17.9%	52	71.28

1. Type 3: I_{max}>600mA at 0.24m (0.3Ω) and 100m(12.5 Ω) channel length.
2. Type 4: I_{max}>865mA at 0.24m (0.3Ω) and 100m(12.5 Ω) channel length
3. Lower I_{max} and P2P_lunb at the pairs with separate Rsense and RDson per pair-set
4. <2.65m case is filtered. 3m min was assumed in TIA model to meet RL.

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

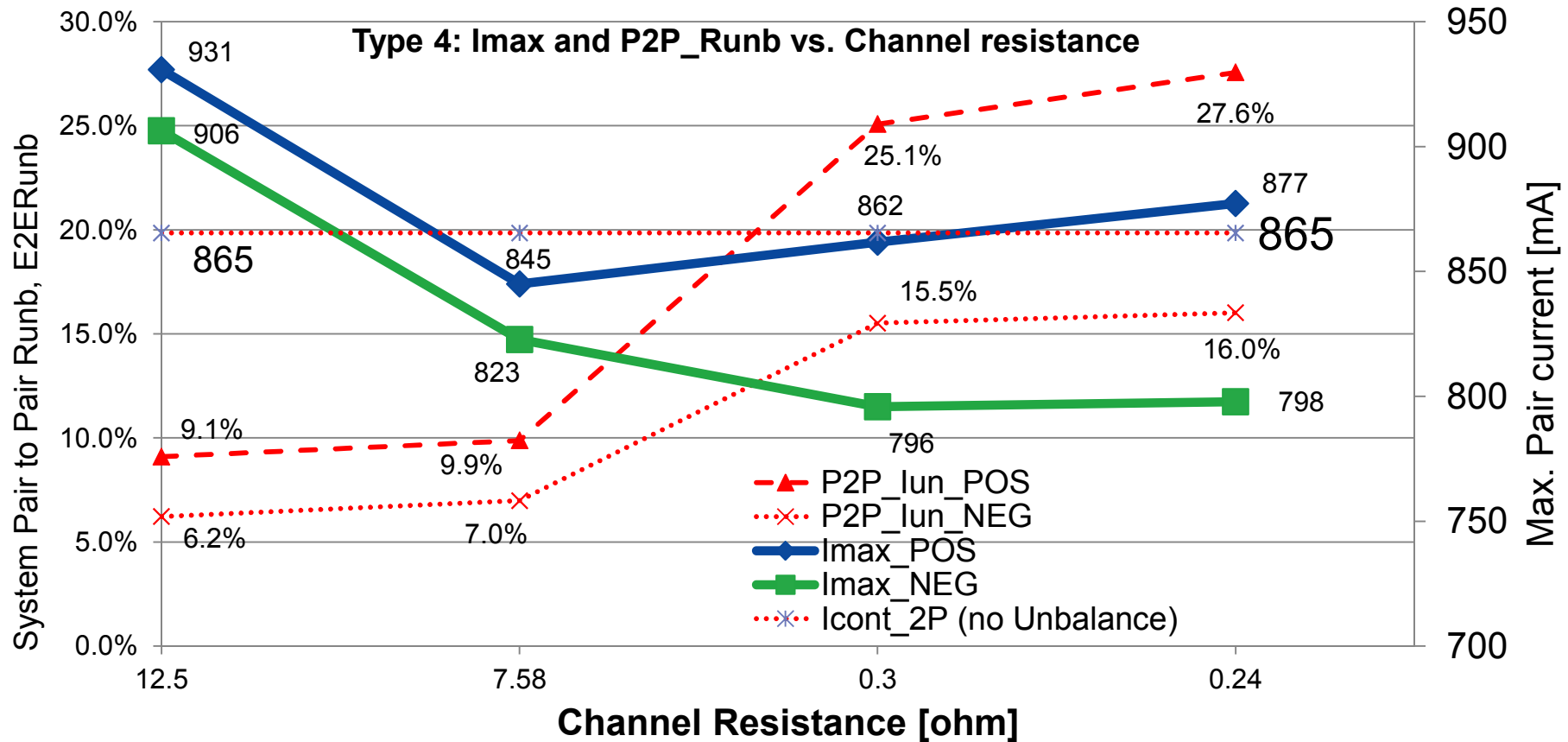
Type 3 summary: I_{max}[mA] and E2E_P2PRunb[%]



- I_{max} is the main parameter. P2P_Runb is the cause.
- System P2P_Runb=31% max. at 2.65m. I_{max}=668mA. Worst Case Analysis.
- It is possible to assign different values for positive and negative pairs.

Type 3 and 4 Worst Case results for system P2P_Iunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Type 4 summary: I_{max}[mA] and E2E_P2PRunb[%]



- I_{max} is the main parameter. P2P_Runb is the cause.
- System P2P_Runb=27.6% max. at 2.65m. I_{max}=931mA at P2P_Runb=9.1%. Worst Case Analysis.
- It is possible to assign different values for positive and negative pairs.

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Summary

Parameter	Values	Conditions	Type	Notes
I _{max} =I _{cont_2p} , α=0	600mA	E2ERunb=0	3	
	865mA		4	
I _{max} =I _{cont_2P} *(1+α)	663mA	R _{ch} =0.1Ω. α=31%	3	Pair current capability per pair-set. Total 4P current: Type 3: 1.2A Type 4: 1.73A
	931mA	R _{ch} =12.5Ω α=9.1% α _{max} =27.6%	4	
E2ERunb=α. (R _{sense} and R _{DSON} is OUT of the E2ERunb loop). See Annex A2.	31%		3	
	27.6%		4	
E2ERunb=α (R _{sense} and optionally R _{DSON} is IN the E2ERunb loop). See Annex A2.	18%		3	This is just example to show the importance of how PSE PI internal components can reduce E2EP2P _{Runb} below the 31% worst case value
	16%		4	

- We have final worst case Type 3 and 4 E2E_Runb and I_{max} values.
- Both I_{max} and PSE R_{max} as function of R_{min} (determines PI P2P_R/C_unb) are required to finalize the spec.
- It is desired that the specifications will supply the tool for PSE to design for lower E2ERunb_max and I_{max} for significantly flexible design.

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Conclusions

- We have final worst case Type 3 and 4 E2EP2P_{Runb} and I_{max}.
- Worst case analysis I_{max} can be supported.
 - Statistical analysis may result in lower number for long channel, smaller benefit for short channels.
- PD available power will not be affected by P2P_{Iunb}. **See details in Annex E.**
 - Old news and good news: Negative pairs has significant lower P2P_{Iunb} if separate R_{sense} and R_{Dson} over each pair-set is used. **See 2014 Adhoc slides.**
- Optional Different limits of P2P_{Iunb} and I_{max} can be used for pairs with current sensing means e.g. Negative Pairs. Rationale:
 - Positive pair's values: for worst case transformer design (higher P2P_{Iunb}).
 - Negative pairs: lower values. Helps with setting lower I_{peak}, and ILIM_{MIN} for increased design margin.
- Specification items that must be defined: (See proposed baseline for PSE PI P2P_{Runb})
 - I_{max} (due to P2P_{Iunb}) for PSE and PD.
 - The ratio between R_{max} and R_{min} of the PSE PI P2P Unbalance requirements as function of system worst case constants. (See Annex A3-A5).
 - **R_{max} and R_{min} are defined by implementer.**
- **Next steps: We are ready to define PSE PI and PD PI P2P_{Runb} parameters.**

Type 3 and 4 Worst Case results for system P2P_{Iunb}, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

PSE PI P2PRunb/lunb baseline text principles

- We need to define the following parameters in Table 33-11.
 - PSE Vdiff – Done. See D0.2.
 - I_{max}=maximum pair current due to E2ERunb. Now we have the numbers
 - PSE PI R_{max}, R_{min} that meets $R_{max} \leq U \cdot R_{min} + K_{pse}$.
 - U and K_{pse} are constants representing worst case conditions per the curves showed for Type 3 and 4 on the positive pairs for E2ERunb.
 - This will ensure that the PSE will not cause violating I_{max} and E2ERunb for any channel and any PD.
 - R_{max} and R_{min} will be measured by test setup TBD.
 - This will ensure that the PSE will not exceed I_{max} and E2ERunb_max for any channel and any PD at maximum P_{type}.

Discussion

- Discussion

- Next steps:
 - Propose to accept PSE PI P2PRunb/lunb baseline text **principles**.

 - See attached **base line text** for PSE PI P2PRunb specifications at darshan_07_0315.pdf

- Housekeeping:

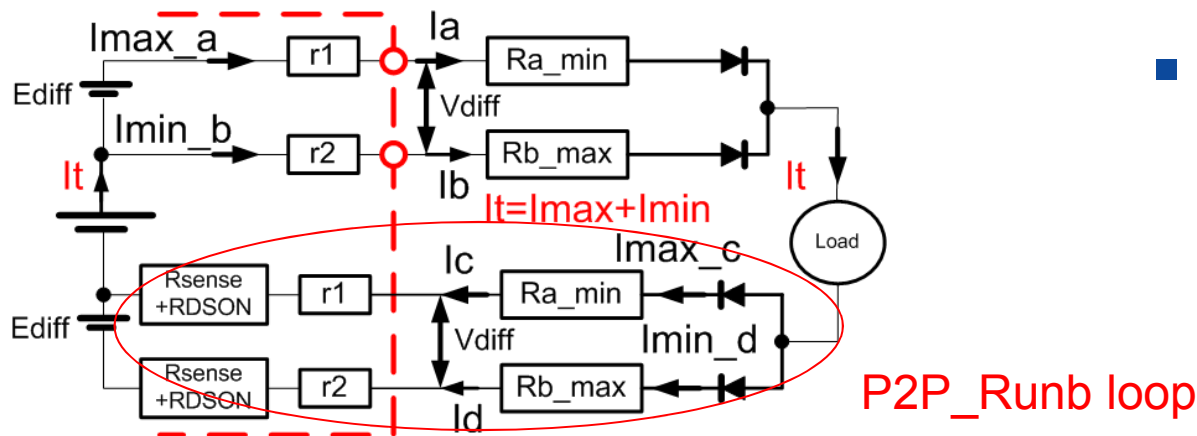
Propose that group to accept updated Table G1/G2 for next P2P unbalance activities.

Thank You

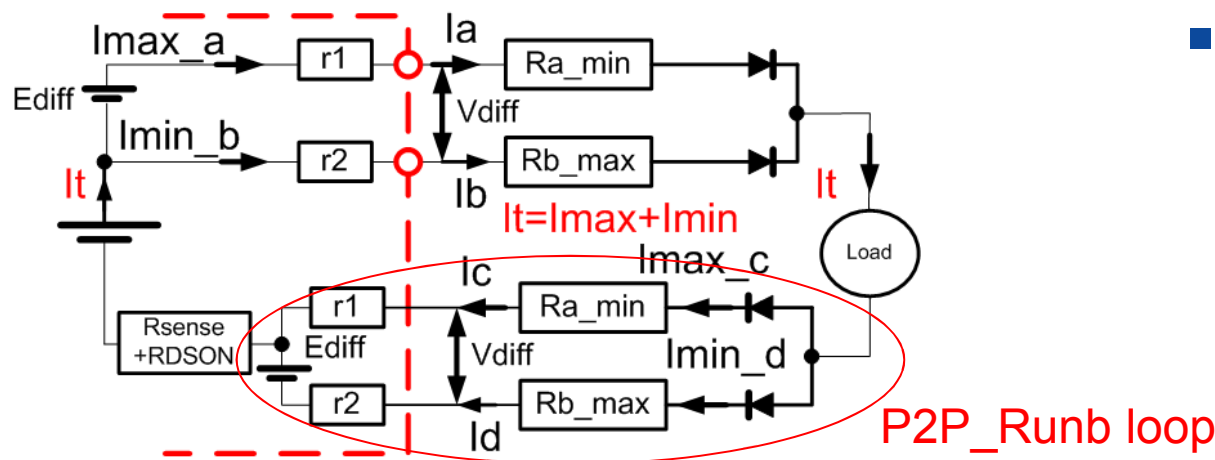
Annex A1 – PSE PI Base Line proposal

- See attached base line text for PSE PI P2PRunb specifications at darshan_07_0315.pdf
- For derivation of the mathematical relationship between R_{max} and R_{min} , please see:
 - Annex A3 and A4 for the short version.
 - For detailed version please see darshan_08_0315.

Annex A2 – Elements in and out the E2EP2PRunb loop



- Current sense and control circuitry is IN the P2P_Runb loop



- Current sense and control circuitry is OUT of the P2P_Runb loop

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Annex A3: Derivation of PSE PI and PD PI Equations

See details in Ref 5 and 11.

- (A) System E2E_P2PRUNB

$$E2E_P2PRunb = \frac{\left(\sum_{R_{max}} PSE - \sum_{R_{min}} PSE\right) + \left(\sum_{R_{max}} PD - \sum_{R_{min}} PD\right) + \left(\sum_{R_{max}} CH - \sum_{R_{min}} CH\right)}{\left(\sum_{R_{max}} PSE + \sum_{R_{min}} PSE\right) + \left(\sum_{R_{max}} PD + \sum_{R_{min}} PD\right) + \left(\sum_{R_{min}} CH + \sum_{R_{max}} CH\right)}$$

- (B) PSE PI P2PRUNB

$$PSE_P2PRunb = \frac{\left(\sum_{R_{max}} PSE - \sum_{R_{min}} PSE\right)}{\left(\sum_{R_{max}} PSE + \sum_{R_{min}} PSE\right)}$$

- (C) PSE PI P2PRUNB contribution:

$$PSE_P2PRUNB_contribution = \frac{\left(\sum_{R_{max}} PSE - \sum_{R_{min}} PSE\right)}{\left(\sum_{R_{max}} PSE + \sum_{R_{min}} PSE\right) + \left(\sum_{R_{max}} PD + \sum_{R_{min}} PD\right) + \left(\sum_{R_{min}} CH + \sum_{R_{max}} CH\right)}$$

- We can see that PSE contribution (C) to E2E_P2PRunb is different than PSE PI P2PRunb (B).
- As a result ,PSE PI P2PRunb need to be transformed to PSE PI contribution in order to have the correct weight in the whole system (End to End).

Annex A4: Derivation of PSE PI and PD PI Equations

See details in Ref 5 and 11.

System End to End Pair to Pair Runb:
$$\frac{\sum R_{max} - \sum R_{min}}{\sum R_{max} + \sum R_{min}} = E2ER_{unb}$$

The above E2ERunb equation can be expressed in the following form:

$$U \cdot \sum R_{min} - \sum R_{max} = 0, \quad \text{Where } U = \frac{1 + E2ER_{unb}}{1 - E2ER_{unb}}$$

Separating the contributors results in:

$$(U \cdot R_{PSEmin} - R_{PSEmax}) + (U \cdot R_{CHmin} - R_{CHmax}) + (U \cdot R_{PDmin} - R_{PDmax}) = 0$$

Each contributor is a constant in the worst case model: $C_{PSE} + C_{CH} + C_{PD} = 0$

And a contributor can be solved independently to meet an E2ERunb limit, given the

worst case scenario: $U \cdot R_{PSEmin} - R_{PSEmax} = -C_{CH} - C_{PD}$

Solving for Rmax results in: $R_{PSEmax} = U \cdot R_{PSEmin} + C_{CH} + C_{PD}$

$$R_{PSEmax} = U \cdot R_{PSEmin} + (U \cdot R_{CHmin} - R_{CHmax}) + (U \cdot R_{PDmin} - R_{PDmax})$$

Where: U is a constant determined by the target balance, and

C_{pse} is a constant derived for the PSE contribution to the worst case E2ERunb.

Annex A5: Derivation of PSE PI Constants

E2ERunb	$U=(1+E2ERunb)/(1-E2ERunb)$	Type
0.31	1.894	3
0.276	1.762	4

Type 3	Cpse calculation	Measured channel and PD effective Rmin and Rmax			
	Cch+Cpd at 2.65m	Rmin	Rmax	U*Rmin	Kpse=U*Rmin-Rmax
		0.634	1.253	1.200	-0.052
Type 4					
	Cch+Cpd at 2.65m	Rmin	Rmax	U*Rmin	Kpse=U*Rmin-Rmax
		0.531	0.978	0.936	-0.042

Constants are under review. March 2015.

Annex B1: Conclusions—To be addressed during next comment resolution

- Table 33-11 item 20: $I_{diff} = TBD[\%] * I_{peak}$
- Need clarified and modified to prevent false interpretation of active current sharing needs.
- $TBD\% * I_{peak}$ is not well defined. I_{peak} is defined for 2P but I_{unb_p2p} is defined for total load current of the 4P.
- I_{peak} per equation 33-4 already contain P2P_ I_{unb} effect in draft D0.2 so we need to use one definition in one place and sync all numbers according to it. Will be done during comment resolution.

Annex C1: Detailed Summary of w.c simulation results

Ppd W	Vpse (In simulations to generate 50V and 52V at PSE PI) Vdc	Channel Length m	N	Channel Resistance Ω	Imax_ POS ma	Imax_ NEG ma	Total Pair Current ma	P2P_lun_ POS %	P2P_lu n_NEG %	Vpd Vdc	Ppd_ Available W	Notes
Type 3												
51	50.3	100	4	12.5	649	632	1187	9.3%	6.5%	43.0	50.99	
51	50.3	100	4	7.58	611	595	1108	10.2%	7.3%	46.0	50.99	
51	50.3	4	1	0.3	654	600	1022	27.9%	17.3%	49.9	50.99	
51	50.3	2.65	0	0.24	668	602	1021	30.9%	18.0%	50.0	50.99	
51	50.3	0	0	0	709	612	1019	39.2%	20.1%	50.0	50.99	Not realistic.
59.8	50.3	2.65	0	0.24	773	700	1199	29.0%	16.9%	49.9	59.78	Extended Power
Type 4												
71.3	52.314	100	4	12.5	931	906	1706.41	9.1%	6.2%	41.8	71.29	
71.3	52.314	100	4	7.58	845	823	1538.08	9.9%	7.0%	46.4	71.29	
71.3	52.314	4	1	0.3	862	796	1377.83	25.1%	15.5%	51.8	71.28	
71.3	52.314	2.65	0	0.24	877	798	1375.37	27.6%	16.0%	51.8	71.28	
71.3	52.314	0	0	0	928	809	1371.94	35.2%	17.9%	52.0	71.28	Not realistic.
89.6	52.314	2.65	0	0.24	1087	994	1732.31	25.4%	14.8%	51.7	89.57	Extended Power

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Annex C2: Detailed Summary of w.c simulation results

1	Current at 100m, 12.5 OHMS 51W is a bit lower than 1200mA DUE TO THE FACT THAT CHANNEL RESISTANCE IS ABIT LOWER THAN 12.5 OHM DUE TO Runb
2	Current at 2.65m, 0.24 ohm and ~60W load is close to 1200mA since channel resistance is very low so it is not a factor. The factor is that now Ppd is maximum equal to Ppse resulting with maximum current.
3	As power increase, P2P_Runb is decreased.
4	Negative pairs has much better P2P_Runb due to additional resistance in the channel due to Rsense and RDSO
5	I _{max} at extended power (Ppd=~P _{type}) is higher at short channel with Ppd=51W or Ppd=71.3, due to the fact that we have now both short channel (high P2P_Runb) and higher Ppd=P _{type} . So no surprises here.
As a result:	
6	Total pair current for Type 3 is 1200mA (as we know) and for Type 4 is 1730mA as we know for P _{type} =90W.
7	I _{max} need to be designed for 773mA for Type 3 and 1087mA for Type 4. (Need to be allowed and optional).
8	I _{max} for the default operation range is 668mA for Type 3 and 931mA for Type 4.

Annex D1: Ppd=51W, 100m, **12.5Ω**, N=4, Vpse=50V

Results

- Total port current is 1187mA < 1200mA. It is due to Channel P2PRUNB that effectively reduce loop resistance ($R_{max} || R_{min} < R_{max}/2$).
- Max P2P_lunb=9.3%.
- Lower P2P_lunb at negative pairs due to separate Rsense and Rdson per pair-set.
- Maximum pair current: 649mA > 600mA due to P2P_lunb. (positive pairs)
- Easily works with ILIM_MIN for Type 3. (See negative pairs)

			Pair current	Total port current	Idiff	lunb[%]	Ppd	Vpd
		Units	mA	mA	mA	mA	W	V
Pair A+	Minimum Resistance	I(R41)	648.65	1186.58	110.72	9.3%	50.99	42.98
Pair B+	Maximum resistance	I(R42)	537.93					
Pair A-	Minimum Resistance	I(R20)	631.56	1186.58	76.55	6.5%		
Pair B-	Maximum resistance	I(R19)	555.02					

Annex D2: Ppd=51W, 100m, 7.58Ω, N=4, Vpse=50V.

Results

- Total port current=1109mA<1200mA (lower cable resistance at 100m)
- Max P2P_lunb=10.2%.
- Lower P2P_lunb at negative pairs due to separate Rsense and Rdson per pair-set.
- Maximum pair current: 611mA>600mA due to P2P_lunb. (positive pairs)
- Easily works with ILIM_MIN for Type 3. (See negative pairs)

			Pair current	Total port current	Idiff	lunb[%]	Ppd	Vpd
		Units	mA	mA	mA	mA	W	V
Pair A+	Minimum Resistance	I(R41)	610.98	1108.46	113.4 9	10.2%	50.99	46.01
Pair B+	Maximum resistance	I(R42)	497.49					
Pair A-	Minimum Resistance	I(R20)	594.84	1108.46	81.22	7.3%		
Pair B-	Maximum resistance	I(R19)	513.62					

Annex D3: Ppd=51W, 4m, 0.3Ω, N=1, Vpse=50V

Results

- Total port current <1020mA as expected. (short channel/low resistance).
- Max P2P_lunb=28.4%. (positive pairs).
- Significantly lower P2P_lunb at negative pairs due to separate Rsense and Rdson per pair-set <12.1%.
- Maximum pair current: 630.5mA due to P2P_lunb. (Positive pairs).
- Easily works with ILIM_MIN for Type 3. (See negative pairs)

			Pair current	Total port current	Idiff	lunb[%]	Ppd	Vpd
		Units	mA	mA	mA	mA	W	V
Pair A+	Minimum Resistance	I(R41)	653.98	1022.40	285.5 6	27.9%	50.99	49.89
Pair B+	Maximum resistance	I(R42)	368.42					
Pair A-	Minimum Resistance	I(R20)	599.68	1022.40	176.9 6	17.3%		
Pair B-	Maximum resistance	I(R19)	422.72					

Annex D4: Ppd=51W, 2.65m, **0.24Ω** , N=0, Vpse=50V

Results

- Total port current <1021mA as expected. (short channel/low resistance).
- Max P2P_lunb=30.9% (positive pairs).
- Significantly lower P2P_lunb at negative pairs due to separate Rsense and Rdson per pair-set <18%.
- Maximum pair current: 668mA due to P2P_lunb. (Positive pairs).
- Easily works with ILIM_MIN for Type 3. (See negative pairs)

			Pair current	Total port current	Idiff	lunb[%]	Ppd	Vpd
		Units	mA	mA	mA	mA	W	V
Pair A+	Minimum Resistance	I(R41)	668.02	1021.00	315.04	30.9%	50.99	49.95
Pair B+	Maximum resistance	I(R42)	352.98					
Pair A-	Minimum Resistance	I(R20)	602.27	1021.00	183.54	18.0%		
Pair B-	Maximum resistance	I(R19)	418.73					

Annex D5: Ppd=71.3W, 100m, 12.5Ω, N=4, Vpse=52V.

- Results
- Total port current 1706mA.
- Max P2P_lunb=9.1%.
- Lower P2P_lunb at negative pairs due to separate Rsense and Rdson per pair-set
- Maximum pair current: 931mA **instead of 853mA** due to P2P_lunb.

			Pair current	Total port current	Idiff	lunb[%]	Ppd	Vpd
		Units	mA	mA	mA	mA	W	V
Pair A+	Minimum Resistance	I(R41)	930.70	1706.19	155.22	9.1%	71.29	41.79
Pair B+	Maximum resistance	I(R42)	775.49					
Pair A-	Minimum Resistance	I(R20)	906.20	1706.19	106.21	6.2%		
Pair B-	Maximum resistance	I(R19)	799.99					

Annex D6: Ppd=71.3W, 100m, 7.58Ω, N=4, Vpse=52V

- Results
- Total port current =1538mA <1.73A (lower cable resistance at 100m)
- Max P2P_lunb=9.9%.
- Lower P2P_lunb at negative pairs due to separate Rsense and Rdson per pair-set =7%.
- Maximum pair current: 843mA **instead of 769mA** due to P2P_lunb.

			Pair current	Total port current	Idiff	lunb[%]	Ppd	Vpd
		Units	mA	mA	mA	mA	W	V
Pair A+	Minimum Resistance	I(R41)	845.00	1538.08	151.91	9.9%	71.29	46.36
Pair B+	Maximum resistance	I(R42)	693.08					
Pair A-	Minimum Resistance	I(R20)	822.77	1538.08	107.46	7.0%		
Pair B-	Maximum resistance	I(R19)	715.31					

Annex D7: Ppd=71.3W, 4m, 0.3Ω, N=1, Vpse=52V

- Results
- Total port current <1378 due to short channel result with very low channel resistance.
- Max P2P_lunb=25.1%.
- Significantly lower P2P_lunb at negative pairs due to separate Rsense and Rdson per pair-set 15.5%.
- Maximum pair current: 848mA instead of 688mA due to P2P_lunb.

			Pair current	Total port current	Idiff	lunb[%]	Ppd	Vpd
		Units	mA	mA	mA	mA	W	V
Pair A+	Minimum Resistance	I(R41)	861.67	1377.83	345.50	25.1%	71.28	51.75
Pair B+	Maximum resistance	I(R42)	516.16					
Pair A-	Minimum Resistance	I(R20)	795.82	1377.83	213.82	15.5%		
Pair B-	Maximum resistance	I(R19)	582.00					

Annex D8: Ppd=71.3W, 2.65m, **0.24Ω** , N=0, Vpse=52V

- Results
- Total port current <1376 due to short channel result with very low channel resistance.
- Max P2P_lunb=27.6%.
- Significantly lower P2P_lunb at negative pairs due to separate Rsense and Rdson per pair-set 16%.
- Maximum pair current: 877mA instead of 688mA due to P2P_lunb.

			Pair current	Total port current	Idiff	lunb[%]	Ppd	Vpd
		Units	mA	mA	mA	mA	W	V
Pair A+	Minimum Resistance	I(R41)	877.18	1375.37	379	27.6%	71.28	51.84
Pair B+	Maximum resistance	I(R42)	498.18					
Pair A-	Minimum Resistance	I(R20)	797.82	1375.37	220.3	16.0%		
Pair B-	Maximum resistance	I(R19)	577.54					

Annex E: Total PD load current is not affected by system P2P_lunb (E2ECP2PRUNB)

$$I_{p_{4P}} = I_{2P}^{Max} + I_{2P}^{M \min} = \left(\frac{I_{p_{4P}}}{2} + \frac{\Delta I}{2} \right) + \left(\frac{I_{p_{4P}}}{2} - \frac{\Delta I}{2} \right) = I_{p_{4P}}$$

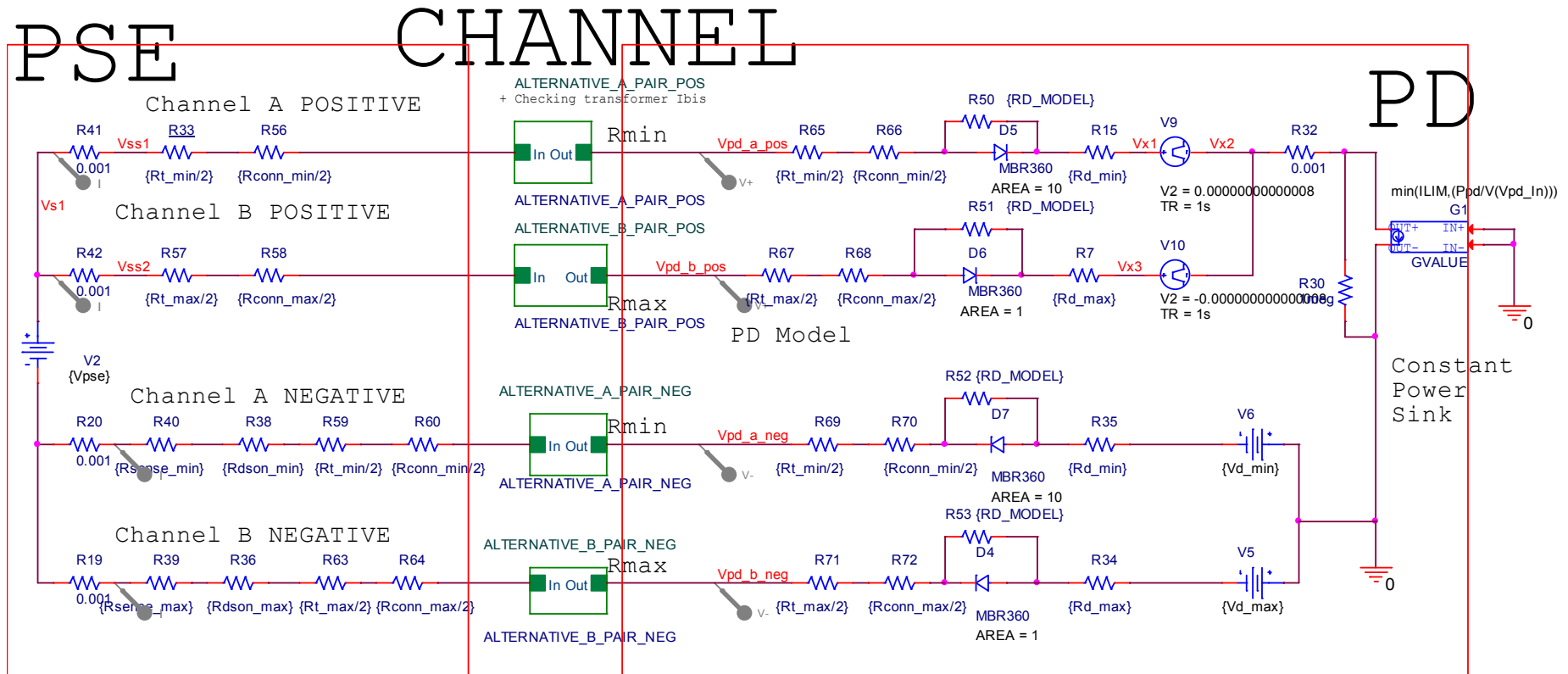
$$\Delta I = E2ECP2PRUNB_{effective} \cdot I_{p_{4P}}$$

effective = including PSE and PD Vdiff effect

$$I_{max} = 0.5 \cdot I_{p_{4P}} \cdot \left(1 + E2ECP2PRUNB_{effective} \right)$$

- We can see ΔI is not affecting total PD load current, $I_{p_{4P}}$.
- ΔI is the Pair to Pair current difference of pairs of the same polarity
- E2ECP2PRUNB=End to End Channel Pair to Pair Resistance Unbalance.
- E2ECP2PRUNB=E2ECP2PCUNB i.e. Runb=lunb by definition.
- PSE Vdif and PD Vdiff is integrated in E2ECP2PRUNB.
- Imax=The pair with maximum current due to system P2P_lunb
- P2P_lunb term is used often instead E2ECP2PRUNB and both are equivalent

Annex F1: Spice Model



- See adhoc material for PSPICE Files.

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Annex F2: Spice parameters

RD_MODEL = 10MEG

PARAMETERS:

P2PRunb = 0.05

Pair_Runb = 0.02

Ppd = 51

ILIM = 3

Lcable = 100

Resistivity = {0.1*Cordage_Resistivity+0.9*Cable_Resistivity}

Cordage_Resistivity = 0.125

Cable_Resistivity = 0.125

Rcable_max = {Lcable*Resistivity}

N_conn = 4

Rt_max = 0.13

Rsense_max = 0.25

Rdson_max = 0.1

Rconn_max = 0.05

Rt_min = 0.12

Rsense_min = {Rsense_max*0.98}

Rdson_min = 0.07

Rconn_min = 0.03

alfa = {(1-Pair_Runb)/(1+Pair_Runb)}

beta = {(1-P2PRunb)/(1+P2PRunb)}

beta_special = 0.925

Default:

Cordage Resistivity=0.0926

Cable_Resistivity=0.074

Rcable_max is for a single wire.

Total PSE Vdiff and PD Vdiff is simulated by Diode property AREA = 10

Annex G1:Worst Case Data Base .See notes to the table in next slide

#	Parameter	Data set 1	Data set 2
1	Cordage resistivity ¹	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 when tested with maximum Iport.	7.4Ω/100m (CAT6A, AWG23) This is to give us maximum P2PRunb
3	option 2 ³	0.098Ω/m. Maximum value per TIA etc. Can't be used for worst case analysis.	
4	Unbalance parameters	<ul style="list-style-type: none"> • Cable Pair resistance unbalance: 2%. Channel pair resistance unbalance: 3% • Cable P2P Resistance Unbalance: 5%. • Channel P2P Resistance Unbalance: 0.1Ω/7.5% max which ever is greater 	
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 Pls.	
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)	Using Pspice Diode model. Vdiff max (PSE +PD)=60mV for Type 3,4 PD max power (51W, 71.3W)	
10	PSE output resistance ¹⁰	Rsense 0.25Ω±1%. RDSON_max=0.2 Ω RDSON_min=0.7*RDSON_max	Rsense 0.25Ω±1%. RDSON_max=0.1 Ω RDSON_min=0.7*RDSON_max
11	PSE Vdif	2mV maximum at NO LOAD.	

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a



Annex G2: Worst case data base- Notes

1	<p>Per standard, 0.14Ω/m is the value. It is maximum value for solid and stranded wire. The maximum value is close to -- AWG#26 wire. However it will not be used since we are looking for worst case unbalance which happens at lowest used wire resistance.</p> <p>resistance/meter including twist rate effects. See annex E1. Due to the fact that patch cords may use AWG#24 cables with stranded (for mechanical flexibility) or solid wire (for improved performance), we will use the AWG#24A for worst case analysis . Cordage with AWG#24 wire has 0.0842Ω/m for solid wire and with 10% twist rate it will be 0.09262 Ω/m.</p>
2	<p>We need both data sets (data set 1 and data set 2) to find where is the worst condition for maximum current unbalance. See Annex B curve and data showing that at short channel we get maximum P2PRUNB but it may has less concern to us since the current is lower. We need to do all use cases calculation to see where is the maximum current over the pair; at short channel or long channel. The CAT6A cable with AWG#23 has 0.066 Ω/m. Including 12% increase on cable length due to twist rate, the effective cable resistance per meter will be 1.12*6.6 Ω/100m= 0.074 Ω/m. (with 20% twist rate it will be 0.0792 Ω/m)</p>
3	<p>Standard definition per Annex E1 for maximum resistance.</p>
6	<p>PSE PI and PD PI includes: connector, transformer, resistors. PD PI includes diode bridge.</p>
8	<p>For worst case analysis we have used lowest connector resistance which is typical in the market. We didn't use the standard 60 milliohm difference since it is not representing the worst case. Wwe looked for connector Rmin and Rmax. See Annex E1-E6 for confirmation.</p>
9	<p>Using PSPICE diode model for low (0.1mA – 30mA range) and high currents >600mA range. Diode Vdiff is set by series voltage source to the diode or setting the AREA property of the diode to be e.g. AREA= 1 and the 2nd diode at the pair with the same polarity to AREA=10. This will set Vdiff=60mV. Updated March 2015 per January 2015 work.</p>
10	<p>PSE output resistance e.g. Rs_a/b=Rsense+Rdson in addition to winding resistance. See model I Annex F for reference.</p>

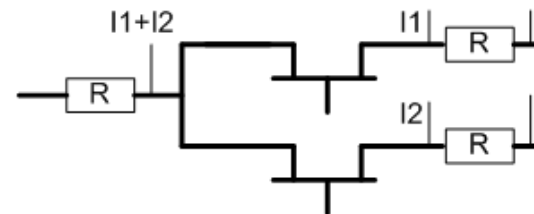
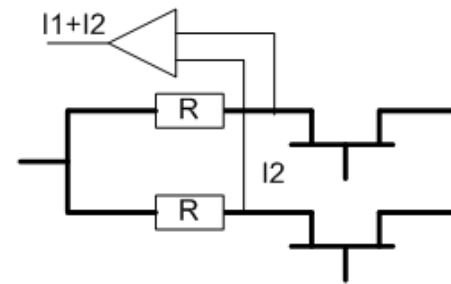
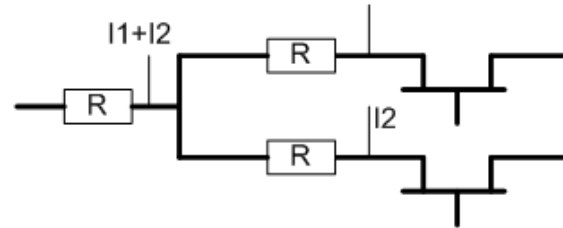
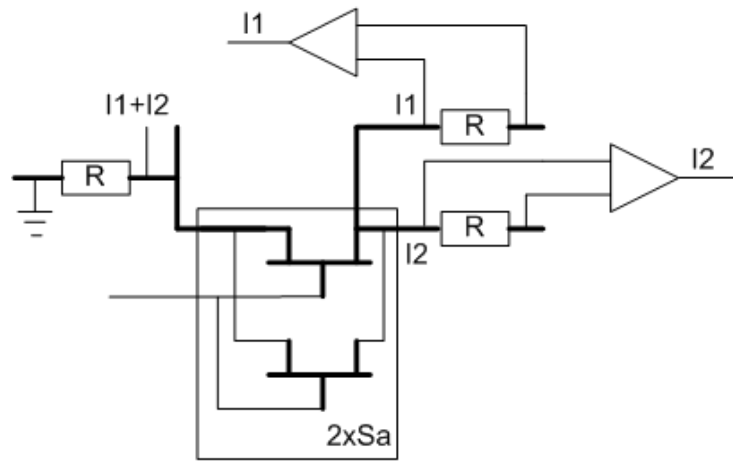
Annex G3: Worst case data base

- Rationale of cable length values
- G1 adhoc Table: we agree on 0.15m without connectors. 4m with 2 connectors etc.
- We saw that all use cases that have ≤ 0.1 ohm, are "not realistic use cases".
- As a result, 2.65m < 3 m is a possible connection with no connectors.
- 4m with one connectors represents exactly 7.5% or 0.1 ohm point per the channel spec that we agree to work until TIA will supply their spec.
- So 2.65m is < 4 m so it is reasonable to have it with zero connectors.
- And last: per TIA the minimum cable length that was used to derive the Return Loss and other RF parameters was 3m. So 2.65m < 3 m.

Annex J: When PD available power is affected by system P2P_lunb?

- In the objectives, we set Type 3 PD maximum power available to 49W due to the worst case initial assumption that pair current will not exceed 600mA when 4P system has $|P2P_Runb/lunb| = \alpha > 0$. As a result, the pair with low resistance will be limit to 600mA and the 2nd pair will be 600mA-Idiff. Idiff= $\alpha * I_t$. It is the total sum of both pair-sets current=Total load current. As a result, the total load current will be 1200mA-Idiff which results with lower PD power than 51W (49W) at 100m for 12.5Ω pair-set resistance.
- The above was meant to get consensus for the objective until we study the subject.
- If we are not limiting Type 3 pair current to 600mA or in general to $0.5 * P_{type} / V_{pse_min}$ then the PD will get the full total load current I_t resulting with maximum available power.
- $I_t = I_{max} + I_{min} = (0.5 * (P_{type} / V_{pse_min}) + Idiff/2) + (0.5 * (P_{type} / V_{pse_min}) - Idiff/2) = I_t = 1200mA$ for Type 3.
- The same is applied for Type 4 power.

Annex K: Current sensing options



- $S_a =$ is the silicon area required to support $2P$ current.

Type 3 and 4 Worst Case results for system P2P_lunb, Pair maximum current and PD available power . Yair Darshan , March 2015 Rev 006a

Annex L: Terms

Parameter	Definition
Channel Length [m]	The cable and cordage total length as defined by the Channel Model in TIA specifications
Common mode resistance	The resistance value of the two wires in a pair connected in parallel
Resistance Unbalance (Runb)	$(R_{max}-R_{min})/(R_{max}+R_{min})$. R_{max} and R_{min} are the resistance of wire 1 and wire 2 of the same pair.
Pair to Pair Resistance Unbalance (P2PRUnb)	$(R_{max}-R_{min})/(R_{max}+R_{min})$. R_{max} and R_{min} are the common mode resistance of pair 1 and pair 2 of the same polarity.
Cable Runb	The Cable Runb.
Cable P2PRUNB	The cable P2PRunb
Channel P2PRUNB	The cables and up to 4 connectors P2PRunb
Current Unbalance	$(I_{max}-I_{min})/(I_{max}+I_{min})$. I_{max} and I_{min} are the current of wire 1 and the current of wire 2 of the same pair.
P2P Current Unbalance	$(I_{max}-I_{min})/(I_{max}+I_{min})$. I_{max} and I_{min} are the total current of pair 1 and pair 2 of the same polarity.
PSE Vdiff	The PSE Pair to pair Voltage difference of the same polarity that will cause additional P2P Current unbalance
PD Vdiff	The PD pair to pair voltage difference that will cause additional P2P Current Unbalance
End to End Pair to Pair Runb (E2EP2PRunb)	The P2PRunb of the whole system including: PSE PI and PD PI circuitry and channel
P2P Resistance Unbalance and Pair to Pair Current Unbalance results with the same ratio when PSE and PD Vdiff are addressed in the P2PRunb calculations.	

References

Reference #	Subject	Link/Source
1	Channel Length, L.	ANSI/TIA-568-C.2
	Cable Runb	
	Number of connector	
	Connector resistance, Rconn_max	
2	Cable P2PRUNB	http://www.ieee802.org/3/4PPOE/public/nov13/darshan_01_1113.pdf
3	Channel P2PRUNB	802.3bt D0.2. annex 33A.3
4		http://www.ieee802.org/3/bt/public/sep14/darshan_05_0914_rev_7a.pdf
5	System Unbalance Adhoc material	darshan_04_0315.pdf Table G1.
	System Unbalance Calculations	
	Cordage Resistivity (wire)	
	Cable Resistivity (wire)	
	Number of connector	
	Connector resistance, Rconn.	
6	Sense Resistor	
6	Rdson	http://www.ieee802.org/3/bt/public/jan15/darshan_01_0115.pdf
7	PSE Vdiff	http://www.ieee802.org/3/bt/public/jan15/darshan_03_0115.pdf
8	PD Vdiff	http://www.ieee802.org/3/bt/public/jan15/darshan_02_0115.pdf
9	PD Load power	Darshan_01_0315.pdf
10	System Unbalance simulations	http://www.ieee802.org/3/bt/public/may14/beia_1_0514.pdf
11	System Unbalance calculations	http://www.ieee802.org/3/bt/public/sep14/index.html by Ken Bennett

Revision History

- Rev 006a: Annex G1 item 9: Adding text that V_{diff} max was defined for limiting maximum pair current at Type 3 and 4 PD maximum power per previous adhoc conclusions. The value of V_{diff} was derived from ref 8.