PD minimum power vs. channel current unbalance

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Introduction

- The purpose of this presentation is to update the current unbalance analysis with updated data, after the feedback received from the study group.

- The data used in this presentation come from:
  - the existing IEEE Std802.3-2012 standard
  - lab measurement and characterization of real case components.

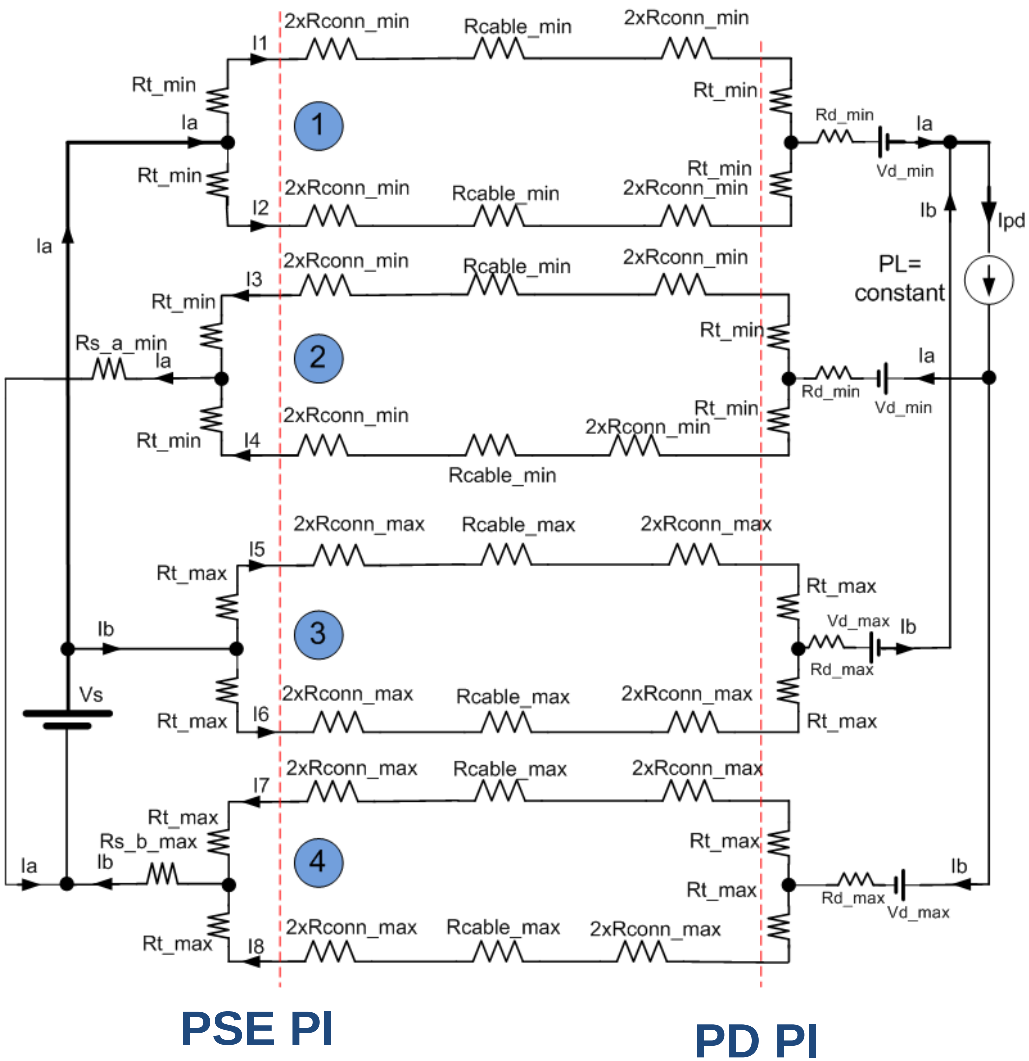
- The objective is to identify the causes of current unbalance in a real system, and their impact on power delivered to the PD and potential effect on other channel components.

- In order to provide a baseline for future improvements a worst-case approach was used.

- **Finally, a sensitivity analysis has been performed to identify the main sources of current unbalance and the key for improvements.**

Assumptions

- This presentation uses the specification of a 2-pairs Type 2 system



- Vport_PSE min = 50V – as per Table 33-11
- Icable = 0.6A (per 2P for all pairs) – as per Table 33-1
- Maximum (channel – connectors) cable loop resistance – 12.5Ω-0.8Ω=11.7Ω.
- The 4-pair PD was modeled as a constant power load that draws current from the Alt-A and Alt-B through a diode bridge. The PSE was modeled as a single voltage source with two outputs with their output resistance each.

Notes:

1. 0.2 ohms is the worst case contact resistance per connector standard. So 4x0.2=0.8Ω ➔ 12.5-0.8=11.7 resulting with maximum cable loop resistance only

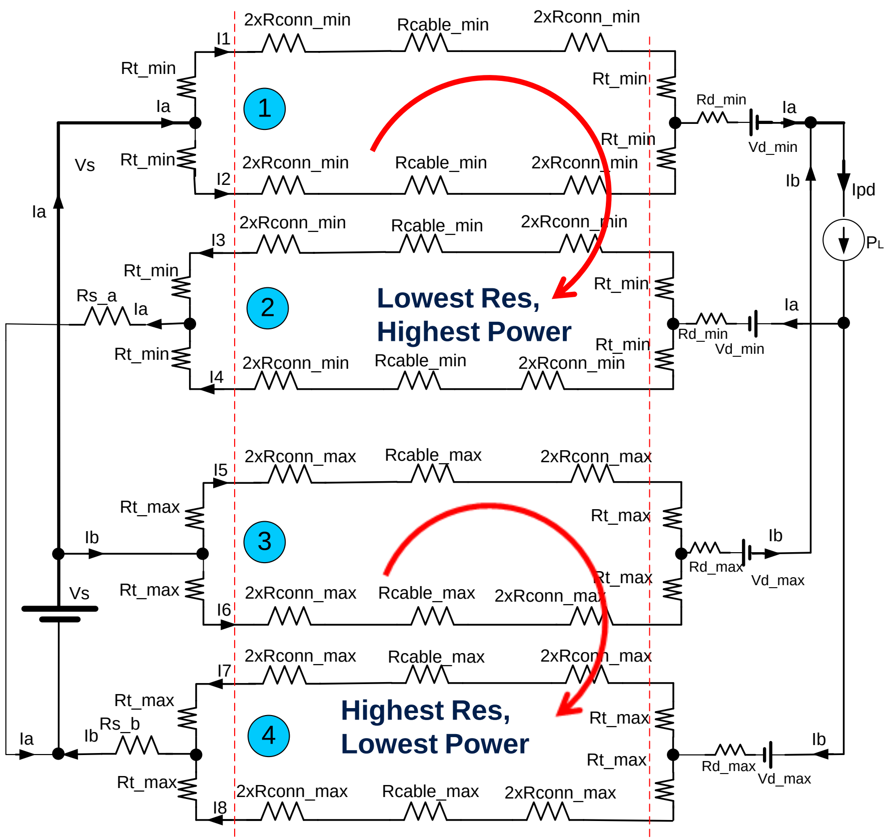
Worst case numbers set

- Two scenarios have been identified: max wire resistivity (CAT5E cables) and min wire resistivity (CAT6/A cables)

Table 1	Max Cable resistivity	Min Cable resistivity
Cable resistivity	117mOhm/m *	66mOhm/m*
Transformer winding resistance	120mOhm min, 130mOhm max	120mOhm min, 130mOhm max
Contact resistance	30mOhm min, ** 60mOhm max	30mOhm min, ** 60mOhm max
Diode bridge	0.3V+0.4Ohm*Id min; 0.4V+0.5Ohm*id max	0.3V+0.4Ohm*Id min; 0.4V+0.5Ohm*id max
PSE output resistance (e.g. Rs_a/b=Rsense+Rdson)	0.25+0.1 Ohm min 0.25+0.2 Ohm max	0.1+0.05 Ohm min 0.1+0.1 Ohm max

- *Cable pair to pair resistance max unbalance is set to 5%. See darshan_1_1113.pdf. Cable resistance within pair unbalance is max 2%. **Connector contact aging will be addressed in other work.
- All parameters are at room temperature and further study is required to address temperature variations

Defining a worst case for current unbalance



- The worst case for current unbalance happens when Alt-A loop resistance is minimum and Alt-B is maximum (or vice versa)
- The maximum current flows in the pair with minimum resistance.
- The max power delivery is reached when the current in the PSE sense resistor reaches 0.6A.

Min resistivity model results

Table 2	**Min. resistivity model**		
Cable length	*1m*	*10m*	*100m*
VportPSE AltA/B	PSE Voltage was measured at the outer legs of the transformers 50V±20mV		
I AltA Plus	612mA	604mA	598mA
I AltA Minus	600mA	600mA	600mA
I AltB Plus	349mA	399mA	502mA
I AltB Minus	361mA	403mA	500mA
Max P2P current unbalance	263mA	205mA	100mA
VportPD AltA	49.90V	49.58V	46.36V
VportPD AltB	49.94V	49.68V	46.58V
P 4P PD at ALTA + ALTB*	**47.96W**	**49.77W**	**51.12W**

- The worst case for system using Cat-6/A cables is the minimum cable length (1m, but less is worse)
- The presence of the sense resistor on return paths, results in a current balancing effect on lower legs.
- The positive current on Alt-A may exceed the 0.6A limit, since we are not monitoring it in this model.
- The presence of a sense resistor on upper legs would have a current balancing effect with no effect on power delivery.
- Simulation showed that unbalance within a pair has negligible effect on P2P unbalance.

*If we limit current on ALT A for 0.6A too, minimum available PD power will be lower.

Max resistivity model results

Table 3	Max PSE port unbalance		
Cable length	*1m*	*10m*	*100m*
VportPSE AltA	PSE Voltage was measured at the outer legs of the transformers 50V±20mV		
I AltA Plus	632mA	610mA	598mA
I AltA Minus	600mA	600mA	600mA
I AltB Plus	371mA	432mA	518mA
I AltB Minus	403mA	442mA	516mA
Max P2P current unbalance	261mA	178mA	84mA
VportPD AltA	49.87V	49.30V	43.60V
VportPD AltB	49.94V	49.44V	43.83V
P 4P PD[2]	**50.02W**	**51.41W**	**48.77W**

- 100m is the worst case for system using CAT5e
- Again, the positive current on Alt-A is exceeding 0.6A limit since it is not monitored.
- The presence of PSE RSense is not affecting the power delivered to the PD for two reasons:
  - PSE output voltage is specified at the PSE PI so the PSE voltage (before RS) must be adjusted accordingly
  - PSE RS has a current balancing effect on the monitored paths when used for each power path.
  - The P2P current balancing effect happens whenever a resistance is added to the pair, as described by P2PRunb / Runb equation[1]
  - To verify this hypothesis, some simulations with different Rs have been performed.

1. see http://www.ieee802.org/3/4PPOE/public/jul13/darshan_2_0713.pdf
2. If we limit current on ALT A for 0.6A too, minimum available PD power will be lower.

Sensitivity analysis component unbalance vs. power delivery

- Using the described scenarios, a sensitivity analysis was performed, to identify the main contributors of decrease of power delivery. Starting from a fully-balanced typical system Pmax was measured, then each contributor at a time was set to min/max and Pmin was measured.
  - $P_{\%} = \frac{Pmax - Pmin}{Pmax + Pmin} \cdot 100.$
- The diodes are the most influencing factors of power delivery in short cable, especially for low resolution cables.
  - (See proposed next action item for P2PRunb/Iunb sensitivity analysis)

Table 4

Max res scenario	Component UNB[±]	Effect on power delivery [-]		
Cable lenght		1m	10m	100m
Rt	4%	0.17%	0.10%	0.01%
Rconn	33.30%	1.02%	0.58%	0.08%
r_cable	5%	0.20%	1.13%	**1.68%**
Rdiode	11.10%	3.43%	1.96%	0.32%
Vdiode	14.30%	**5.72%**	**3.27%**	0.53%

Min res scenario	Component UNB[±]	Effect on power delivery [-]		
Cable lenght		1m	10m	100m
Rt	4%	0.18%	0.12%	0.03%
Rconn	33.30%	1.06%	0.73%	0.16%
r_cable	5%	0.12%	0.81%	**1.79%**
Rdiode	11.10%	3.56%	2.48%	0.57%
Vdiode	14.30%	**5.94%**	**4.14%**	0.96%

Summary

- P2P current unbalance increases when cable length decreases.
- P2P current unbalance increases when cable resistivity decreases i.e. CAT6A will have higher current unbalance compared to CAT5e.
- The P2P current balancing effect happens whenever a resistance is added to the pair.
- unbalance within a pair (the famous 2% pair and 3% channel) has negligible effect on P2P unbalance.
- The diodes are the most influencing factors of power delivery in short cable, especially for low resistivity cables.
- For a worst-case analysis, where PSE is limiting the current for 600mA (based on Type 2 PSE spec.) we can't meet the minimum PD objective of 49W. There are two worst cases; at 1m CAT6A and 100m CAT5e.
  - The above will be addressed in future work.

Proposed Next Action Items

- We need to define the requirements for P2PRunb and/or P2P current unbalance for the PD, Channel and PSE in order to meet our objectives.

- To analyzed the following scenarios:
  - How connector contact aging will affect the results i.e. if min/max contact resistance difference will be increased.
  - The current unbalance results as function of operating temperature range
  - To analyze the results when there is no hard limit of 600mA on the negative pair.
    - To set a worst case conditions for evaluating maximum current unbalance through transformers.
  - Consider analyzing P2P current unbalance higher category cables than CAT6A
  - To perform sensitivity analysis for P2P current and resistance unbalance.

Thank You