IEEE802.3poep Study Group

Power feeding methods

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Objectives

- Compare between possible power feeding methods
- Generate a list of issues to be addressed
- Get info from the group of preferences, ideas, other concerns, possible benefits etc

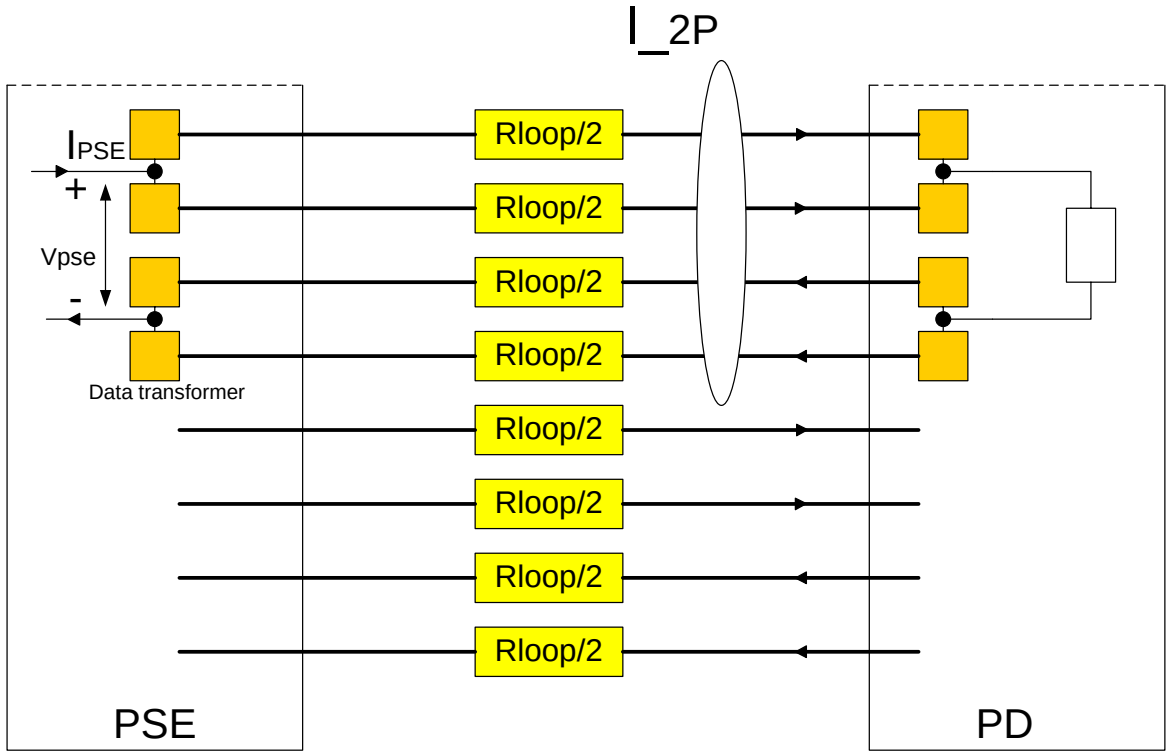
Background

- Different power feeding methods can be used, each has its advantages and disadvantages from the following point of view.
  - Economical
  - Technical
  - Effect on the cabling infrastructure performance
  - Effect on the data transformer
  - Interoperability
  - Classification resolution
  - IEEE rules?
  - Available power hence market needs coverage
  - Complexity
  - More..

Possible Power Feeding Methods

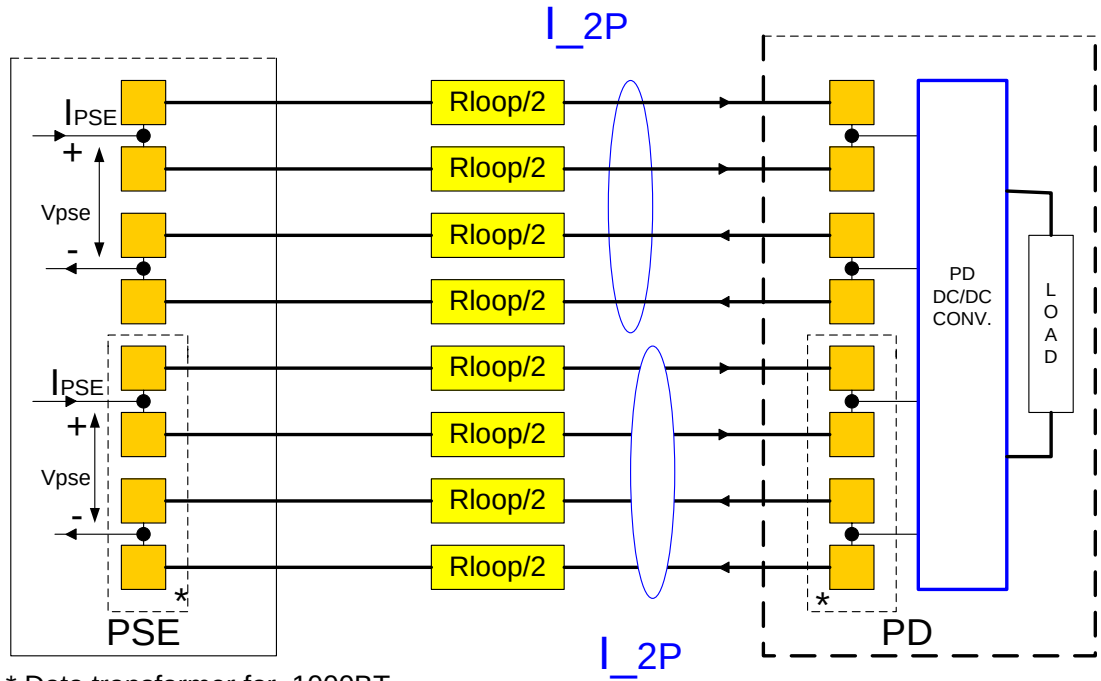
2 pairs concept (2P)

- Feeding high power through 2pairs assuming no cabling issues
- In order to achieve 30W at the PD input, the current through 2pairs=~ 0.7A
- In order to achieve 40W at the PD input, the current through 2pairs=~ 1A
- In the above examples, V_{PSE}=51V.



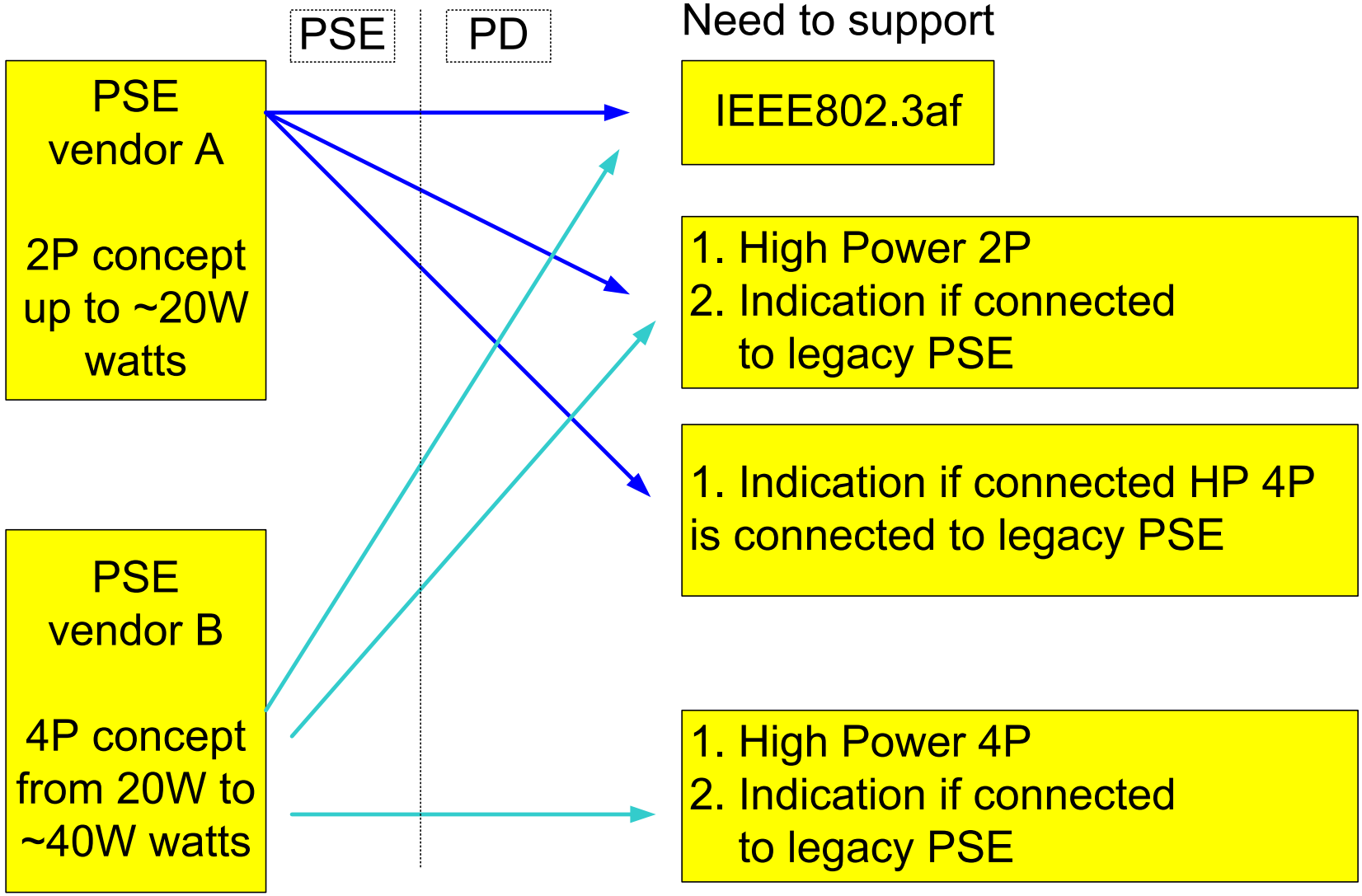
4 pairs concept (4P)

- Feeding high power through 4pairs
- In order to achieve 30W at the PD input, the current through 2pairs=~ 0.35A
- In order to achieve 40W at the PD input, the current through 2pairs=~ 0.44A
- In the above examples, V_{PSE}=51V



* Data transformer for 1000BT.

“2 pairs OR 4 pairs” Concept (2Por4P)



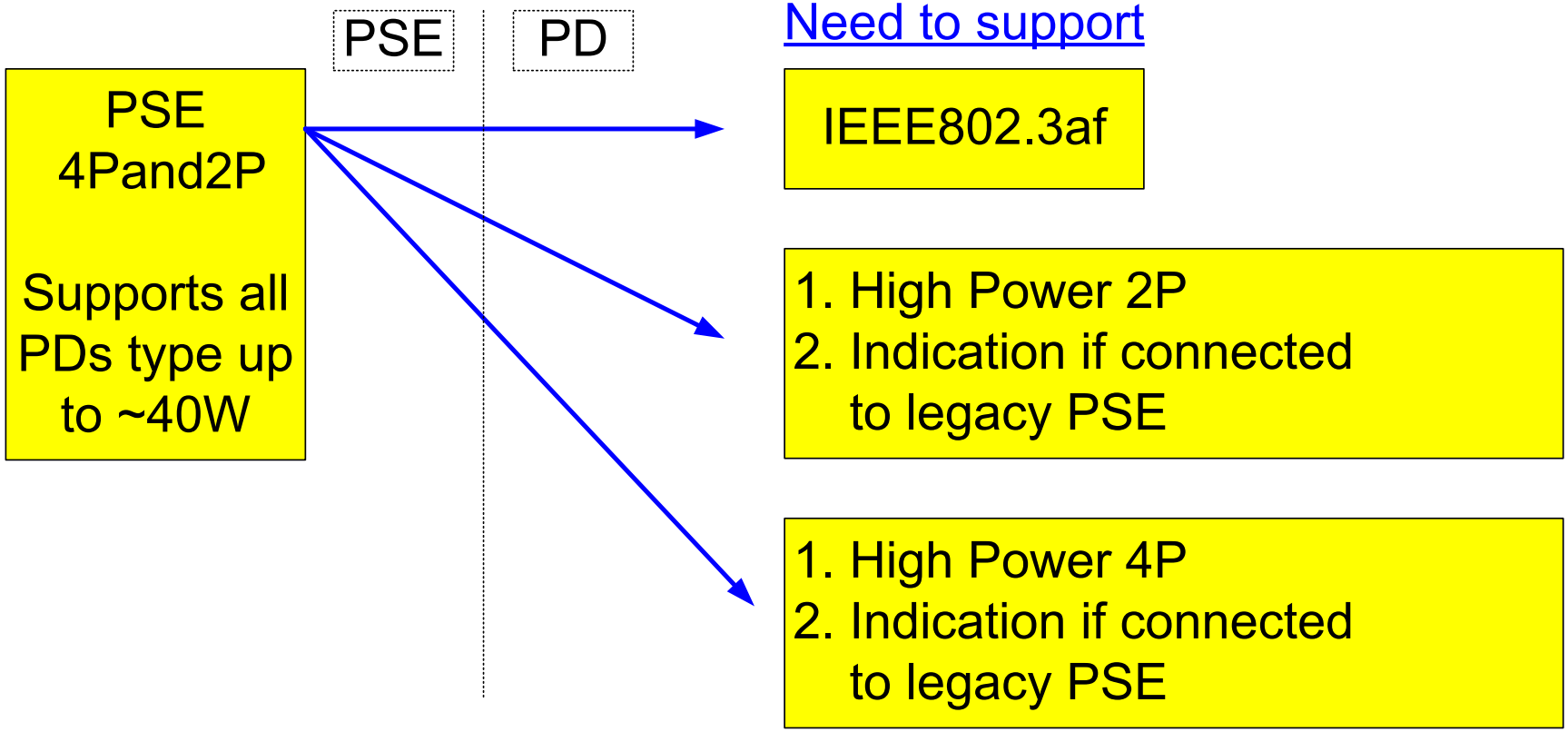
“2pairs OR 4pairs“ concept (2Por4P)

- PSE Vendor can choose to detect, classify and support power to HP 2pairs PD’s OR detect classify and support power to HP 4pairs PD’s.
- PD vendors:
- May choose their preferred alternative based on their power needs
  - Using 2 pairs for high power up to TBD1
  - Using 4 pairs for high power up to TBD2
- End result:
  - Vendor A PSE need to support IEEE802.3af and HP1 implemented by 2 pairs
  - OR
  - Vendor B PSE need to support IEEE802.3af and HP2 implemented by 4 pairs
  - **From standard point of view: Does it still considered a standard?..**

“2pairs OR 4pairs“ concept (2Por4P)…

- End user connecting PD to RJ45 and expects to get service, need to know if he gets
  - IEEE802.3af support
  - HP1 support
  - HP2 support..
- Our famous CFI promise to support PD indication
  - HP1 PD needs to support indication_10 if connected to legacy PSE
  - HP1 PD needs to support indication_12 if connected to PSE HP2
  - HP2 PD needs to support indication_21 if connected to PSE HP1
  - Complex ? Yes
- These are the results of 2 solutions for 3 problems….

2Pand4P (2pairs AND 4pairs)



2Pand4P (2pairs AND 4pairs)

- PSE vendor must support detection, classification and power to:
  - AF PD
  - High power 2 pairs PD
  - High power 4 pairs PD
- End result:
  - PSE need to detect IEEE802.3af and HP2 4 pairs and HP1 2 pairs.
  - From standard point of view: OK.
- End user need to know if he gets
  - IEEE802.3af support
  - High power support by the famous PD indication.

- PD vendors
- May choose their preferred alternative based on their power needs

More details on each concept

- 2P, 4P: Power Capability if infrastructure is not the limiting factor
- 2P, 4P: Power Capability if temperature rise is the limiting factor
- Cost at the PSE side
- Cost at the PD side
- Cabling and connector issues
- Data transformer
- Mandatory requirements on current limit per port per class
- Unique distinction and classification resolution levels
- Single solution to a Single problem
- Project time table estimation
- Summary and conclusions
- Annexes

Analysis method

- Due too the fact that we don’t have all the information at this point
  - We will use “separation of variables” method
  - Example: If we want to analyze the effect on power dissipation over cable at high current through the cable WE ASSUME that the cable can handle it with out degradation in data performance.
  - Later we address this assumption by establishing other assumptions or facts etc.
- This method allow us to get some predictions and use it to get better picture of possible coarse of action

Power Capability – What-if analysis: 40W at PD input example

Parameter ($V_{PSE=51V}$)	2pairs	4pairs
P_{PD} = Available power to PD	40W[1]	40W
I_2P	**1.059A**[1,2,3]	**0.44A**[2]
Equivalent R_{LOOP}	12.5Ω	6.25Ω
P_{CABLE}	**14W**	**4.8W**
P_{PSE}	**54.4W**	**44.8W**
Port to Port Efficiency	**74%**	**89%**
Additional PSE PS cost / Size	**+20%**	**Ref**

Note 1: Assuming cables and connectors can handle this current without degradation in RF performance due too temperature rise.

Note 2: Assuming Data Transformers can handle the current without saturating.

Note 3: Ignoring FCC current capacity limitations on AWG24 wires which is 394mA at 60C per 2 wires when all conductors are working i.e. 4pairs.

For 2pairs, with optimistic interpretation of FCC, 788mA for 2 wires when the other 2pairs are not working.

Power Capability – Temperature rise is the limiting factor

Parameter ($V_{PSE=51V}$)	2pairs	4pairs
P_{PD} = Available power to PD	24.5W[1]±TBD	36.3W[2]±TBD
I_2P	**0.557A**[3]	**0.394**[2]
Equivalent R_{LOOP}	12.5Ω	6.25Ω
P_{CABLE}	3.87W	3.87W
P_{PSE}	NA	NA
Port to Port Efficiency	**86%**	**90.3%**
Additional PS cost / Size	NA	NA
P_{PD} = Available power to PD [%]	ref	**+48%**

Note 1: Temperature rise is the limiting factor. 24.5W is derived by equating 4pairs power dissipation to 2pairs power dissipation and finding the max current permitted in 2pairs assuming the same thermal resistance in both concept. Actual thermal resistance need to be verified by testing. See annex A.

■**Note 2:** 36.3W is the power achieved at the PD port by using FCC current capacity limit per conductor at 60C (394mA) when all conductors are working e.g. 4pair.

■**Note 3**: Assuming data transformer can handle this current.

Cost – PSE: 2P, 4P, 2Pand4P, 2Por4P concepts

- Assuming integrating hardware in chips
- The PSE port driver controller consist of:
  - Control & logic
  - Output switch + driver
- Control and Logic for 2P or 4P cost difference is negligible
- 2P needs single switch
- 4P needs double switch.
- Long term cost difference of PSE chip/port: 2P=1, 4P=~1.1-1.3
  - Relative to product cost : negligible (<7%)
- 2Pand4P concept shows the same results as 4P concept
- 2Por4P concept:
  - 2P HP1 is lower by 5% from 2P
  - 4P HP2 is similar to 4P

Cost – PD: 2P, 4P, 2Pand4P, 2Por4P concepts

- Assuming integrating hardware in chips
- The PD port interface controller consist of:
  - Control & logic
  - Signature, Classification, Isolating switch + current sharing for each 2pairs, in 4pairs concept.
- Control and Logic for 4P to 2P cost difference is < +5%
- Signature, Classification, Isolating switch + current sharing < +20%
- Long term cost difference of PD chip/port: 2P=1, 4P=~1.2-1.5
  - Relative to product cost : negligible (<5%)
- 2Pand4P, 2Por4P
  - HP1 2P (+PD indications) is similar to 2P
  - HP2 4P similar to 4P

Cabling and Connector issues

- 4P: Working with ~350mA (394mA) in all 4 pairs feasible according to FCC, ISO and other related standards.
  - More?
- Working with higher than ~350mA (2P, 2Pand4P, 2Por4P) requires
  - Testing: Long term reliability effects
  - Testing: RF performance vs temperature rise in different cables, connectors etc.
  - In particular to check 1G/10G due to their sensitivity compared to 10/100BT
  - Need to check effects on Patch Panel Midspan
  - Investigating other standard
  - Determine the worst case installation
  - Connector behavior under voltage and current transients during connection and disconnection
  - Traces on PCB, the effect on the impedance of the transmission line, density near RJ45 connectors etc
  - More ??

Data transformer

- Working with 4 pairs will not affect data transformer

- 2P, 2Pand4P and 2Por4P concepts with current >~350mA affect the following parameters:
  - Increased size: to prevent saturation due too current imbalance
    - May be solved by using spare pairs however still problem in 1G/10G
    - May be solved by adding balance resistor/impedance and split center tap, affect power dissipation, more components. Need to be investigated.
  - Temperature rise
  - Need to check how it will affect high density designs such as integrated RJ45 PoE and RJ45 connectors with data transformer
  - Increase size probably will have negligible effect on the direct costs of the data transformer however the indirect cost need to be verified too.

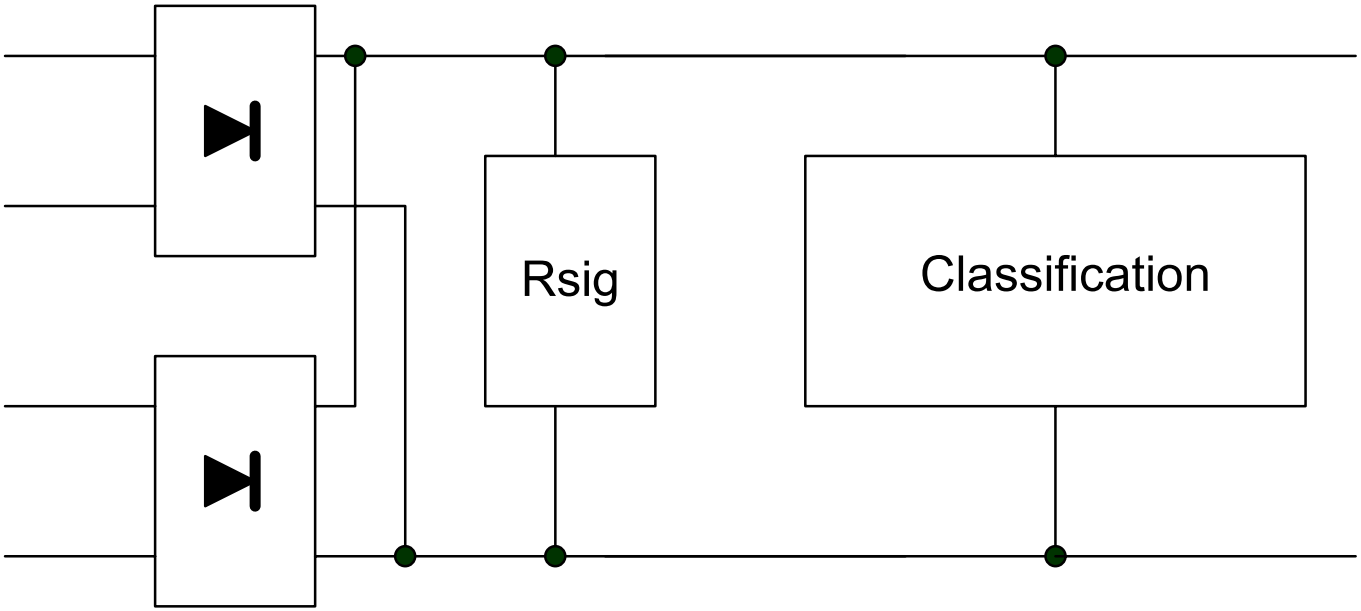
Mandatory requirement for Current limit per port, per class

- Working with 4 pairs at ~350mA will keep the current limit protection per port and per class similar to IEEE802.3af

- Allowing 2P, 4Por2P concepts will require protection of the infrastructure and PSE hardware per the detected PD class
  - If IEEE802.3af PD is connected to 2P high power PSE and the PD have OVLD condition with I>350mA than PSE or cable may be damaged, therefore overload protection per class may required which increase PSE port driver cost.

Unique Distinction - Background

- IEEE802.3af PD

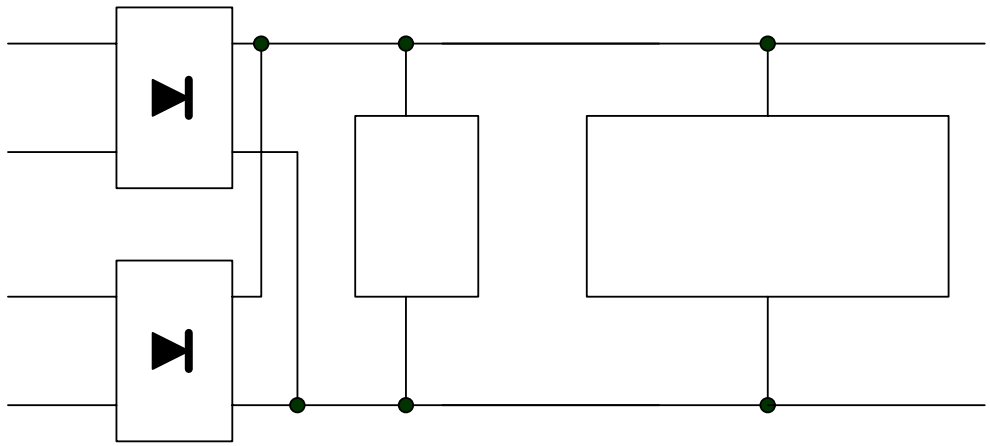


Rsig=25K

Class 1-3, 4 for future use

Unique Distinction – Proposal for 2P concept

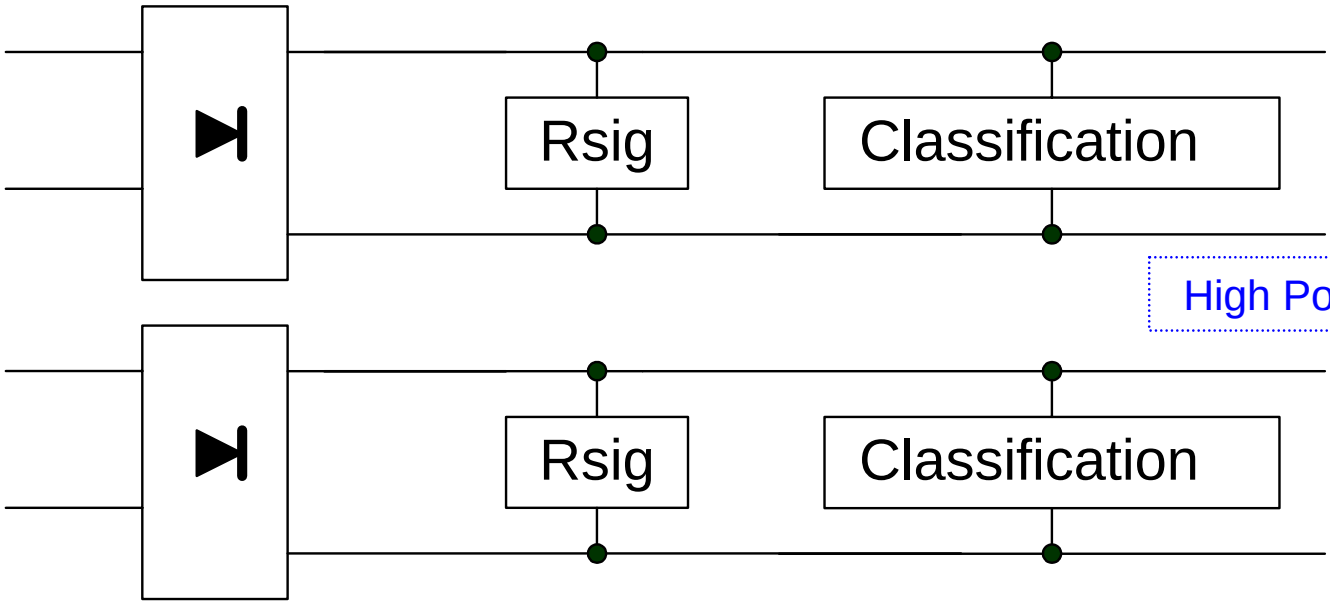
- Changing Rsig allows using Classes 1-4 and optionally class 5 for 5 levels of HP resolution
- If Rsig stays 25K then we will have max 1-2 HP levels due to classification current limitation on PD chip



Rsig=10K

High Power 2P PD

Unique Distinction – Proposal for 4P concept



High Power 4P PD

Rsig=25K

Class 1-3, Use class 4 and optional class 5

PSE detects and classifies each channel and decides according to the logic table in next slide, if it is Legacy DTE, Legacy PD or HP PD.

4P concept: Getting high resolution classification

- Classes 1-4 generates:
  - 20 HP levels
  - 5 AF levels
- If ch-1 and ch-2 are designated to the pair type (data or spare or pin numbers).
- More levels can be generate if class 5 is added

Meaning	Reading	ch-2 Pins 4,5,7,8	ch-1 Pins 1,2,3,6
AF, NO CLASS, 15.4W	**AF CLASS 0**	**0**	**0**
coding of different combinations of HP	HP CLASS 1	1	0
coding of different combinations of HP	HP CLASS 2	2	0
coding of different combinations of HP	HP CLASS 3	3	0
coding of different combinations of HP	HP CLASS 4	4	0
coding of different combinations of HP	HP CLASS 1	0	1
AF, CLASS 1, 4W	**AF CLASS 1**	**1**	**1**
coding of different combinations of HP	HP CLASS 5	2	1
coding of different combinations of HP	HP CLASS 6	3	1
coding of different combinations of HP	HP CLASS 7	4	1
coding of different combinations of HP	HP CLASS 2	0	2
coding of different combinations of HP	HP CLASS 5	1	2
AF, CLASS 2, 7W	**AF CLASS 2**	**2**	**2**
coding of different combinations of HP	HP CLASS 8	3	2
coding of different combinations of HP	HP CLASS 9	4	2
coding of different combinations of HP	HP CLASS 3	0	3
coding of different combinations of HP	HP CLASS 6	1	3
coding of different combinations of HP	HP CLASS 8	2	3
AF, CLASS 3, 15.4W	**AF CLASS 3**	**3**	**3**
coding of different combinations of HP	HP CLASS 10	4	3
coding of different combinations of HP	HP CLASS 4	0	4
coding of different combinations of HP	HP CLASS 7	1	4
coding of different combinations of HP	HP CLASS 9	2	4
coding of different combinations of HP	HP CLASS 10	3	4
AF, CLASS 4, Reserved or HP	**AF/HP CLASS 4**	**4**	**4**

4P concept: Reading coded table - Example

- After successful Detection…
- If Class 4 is being red from ch-2 and

  Class 1 is being red from ch-1

  than

  It is HP class 7 (=PD needs TBD watts)

- If Class N is being red from ch-2 and

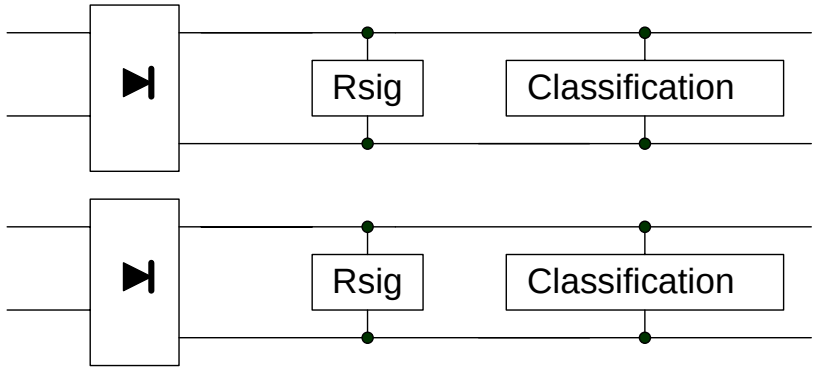
  Class N is being red from ch-1

  than

  it is IEEE802.3af class N.

- Etc..
- There are additional outputs of the operating flow chart of this concept however they are not important for this discussion.

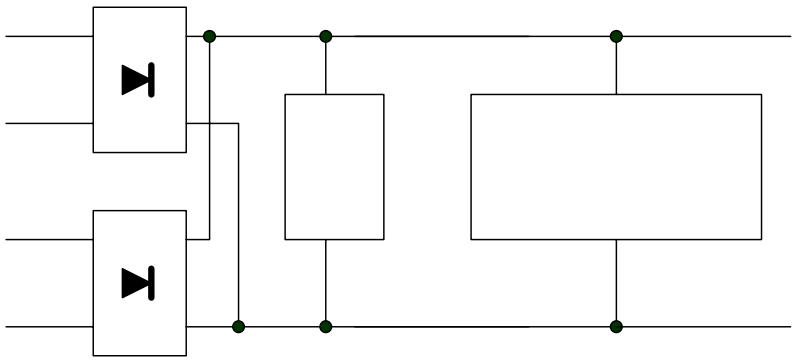
Unique Distinction – Proposal for 2Por4P concept



Rsig=5K

Class 1-3. Use class 4 and optional class 5 for better class resolution

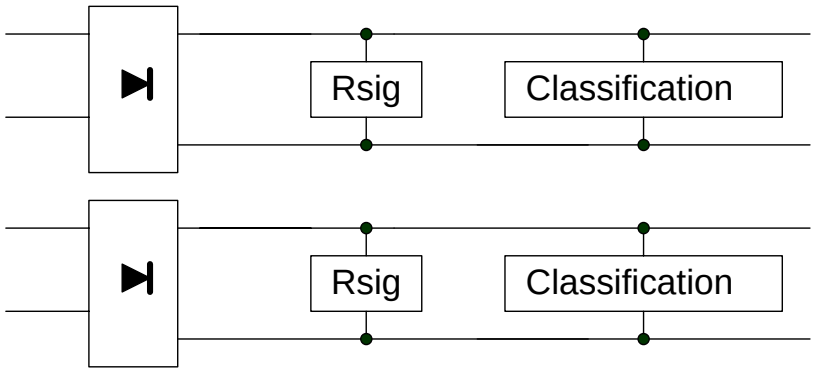
High Power 4P PD



Rsig=10K

High Power 2P PD

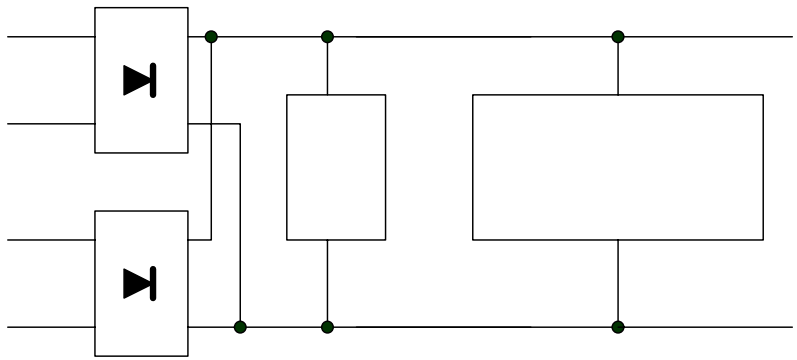
Unique Distinction – Proposal for 2Pand4P concept



Rsig=5K

Class 1-3. Use class 4 and optional class 5 for better class resolution

High Power 4P PD



Rsig=10K

High Power 2P PD

Unique distinction and classification-Summary

- HP 4pirs:
- For HP 4pairs concept unique distinction is achievable without changing signature value (25K)

- HP 2pairs
- Concept will have low classification resolution issue which need to be solved if we wish to maintain passive classification concept as we did in IEEE802.3af.
  - Possible solution is to change Rsig to lower value such 10K.
  - The Study Group need to discuss if we want to go through this adventure again..

- 2Por4P concept and 2Pand4P concept
- Rsig is probably need to be changed to achieve unique distinction and good enough resolution for PD classes. For these two concepts the following Rsig are proposed:
  - IEEE802.3af =25K
  - HP 2P up to TBD1 Watts = 10K
  - HP 4P up to TBD2 Watts = 5K

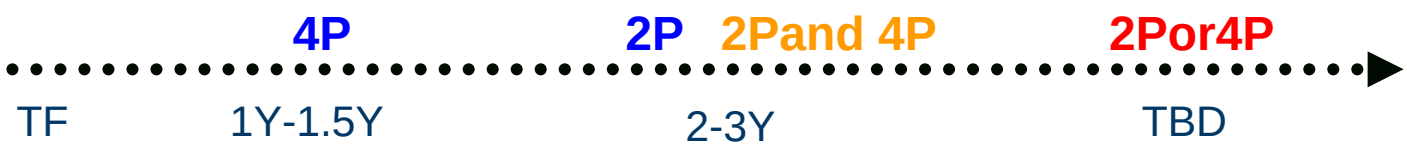
Single solution to a Single problem

- Are multiple solutions for a single problem still considered a good standard ?
  - No, or potentially a bad standard.
  - 2Por4P concept is within this category.

- 2P, 4P and 2Pand4P concepts are a single solution to a single problem.
  - Potentially a good standard category

Project time table estimation

- 4P – the shortest
- 2P – Longer than 4P (cabling issues, Data transformer and classification resolution)
- 2Pand4P – shorter than 2Por4p, longer than 4P (cabling issues, Data transformer, unique distinction issue).
- 2Por4P – longest. (cabling issues, Data transformer, classification resolution, unique distinction issue and PD indication if connected to legacy PSE– complex)



Summary

- We should look for the concept that will meets the following requirements:
  - Maximum benefits for the long term.
  - Works within the current infrastructure limitations
  - Unique distinction
  - Sufficient resolution of power classification
  - Reasonable time table
  - Enables future growth: More applications, higher power
- Due to the fact that economical feasibly shows that both 2P and 4P concepts are cost effective in average compared to the alternative, we should concentrate on the other benefits

Conclusions

- 4pairs concept appears as the best alternative
- 2Pand4P is the 2nd best alternative.
- 2P or 2Por4P are the worst alternatives
- Results are based on the preliminary comparison table presented in Annex B, which need to be updated due too test results and additional parameters and issues that may raised by the study group.

Annexes

Annex A: Power Capability – Temperature rise is the limiting factor

- 197mA per wire in 8 AWG24 wires cable is permitted by FCC, ISO and other spec.

$$tr = Ploss \cdot \Theta r$$

$$tr\_4p = Ploss\_4p \cdot \Theta r\_4p = 0.394A^2 \cdot 12.5\Omega \cdot 2 \cdot \Theta r\_4p = 3.88W \cdot \Theta r\_4p$$

$$tr\_4p = 3.88W \cdot \Theta r\_4p$$

$$tr\_2p = Ploss\_2p \cdot \Theta r\_2p = I^2 \cdot 12.5\Omega \cdot \Theta r\_2p$$

$$tr\_2p = I^2 \cdot 12.5\Omega \cdot \Theta r\_2p$$

$$tr\_2p = tr\_4p$$

$$I^2 \cdot 12.5\Omega \cdot \Theta r\_2p = 3.88W \cdot \Theta r\_4p$$

$$I^2 = \frac{3.88W \cdot \Theta r\_4p}{12.5\Omega \cdot \Theta r\_2p} = \frac{0.3104 \cdot \Theta r\_4p}{\Theta r\_2p}$$

$$I = \sqrt{\frac{0.3104 \cdot \Theta r\_4p}{\Theta r\_2p}} = 0.557A \cdot \sqrt{\frac{\Theta r\_4p}{\Theta r\_2p}}$$

Annex A: Power Capability – Temperature rise is the limiting factor..

- If, and only if, $\Theta r\_2p = \Theta r\_4p$ than I_2P=0.557A ==> PD input power=24.5W.
- However, (need to be verified by tests) $\Theta r\_2p > \Theta r\_4p$
- Therefore I_2P<0.557A ==> PD input power < 24.5W…

Annex B: Preliminary, proposed Power Feeding Methods Comparison

(high number is better than low number)

#	Parameter	2p	4p	2Por4P	2Pand4P
1	Highest power	6	10	10	10
2	Lowest cost - Relative to 4P concept.	10	7	9	7
3	Lowest cost - Relative to product cost è negligible at high quantities	10	10	10	10
4	Lowest cost / size of PSE PS	8	10	8	8
5	Cost optimization according to power needs in the PD	10	8	10	10
6	Cost optimization according to power needs in the PSE	10	8	10	8
7	No cabling issues	5	10	8	8
8	No connector issues (arc, voltage , current)	5	10	8	8
9	No issues with PCB traces	5	10	8	8
10	No issue with data transformer (size, temp rise, cost)	1	10	1	1
11	Low sensitivity to 1G, 10G RF performance due to temp rise	5	10	8	8
12	No issues with patch panel Midspan	5	10	8	10
13	Simple circuitry in PSE	10	8	8	8
14	Simple circuitry in PD	10	8	8	8
15	No mandatory requirement for Current limit per port, per class.	5	10	5	5
16	Unique distinction between AF and HP alternatives	10	10	1	10
17	Single solution to a single problem – good or bad standard?	10	10	1	10
18	Classification resolution potential with passive classification.	1	10	1	10
19	Project time table	6	10	3	5
20	Modular extension per needs from IEEE802.3af to PoEp	1	10	6	6
21	**Summary**	**133**	**189**	**131**	**158**