# IEEE802.3 4P Study Group
## Temperature Rise vs. P2PCRunb

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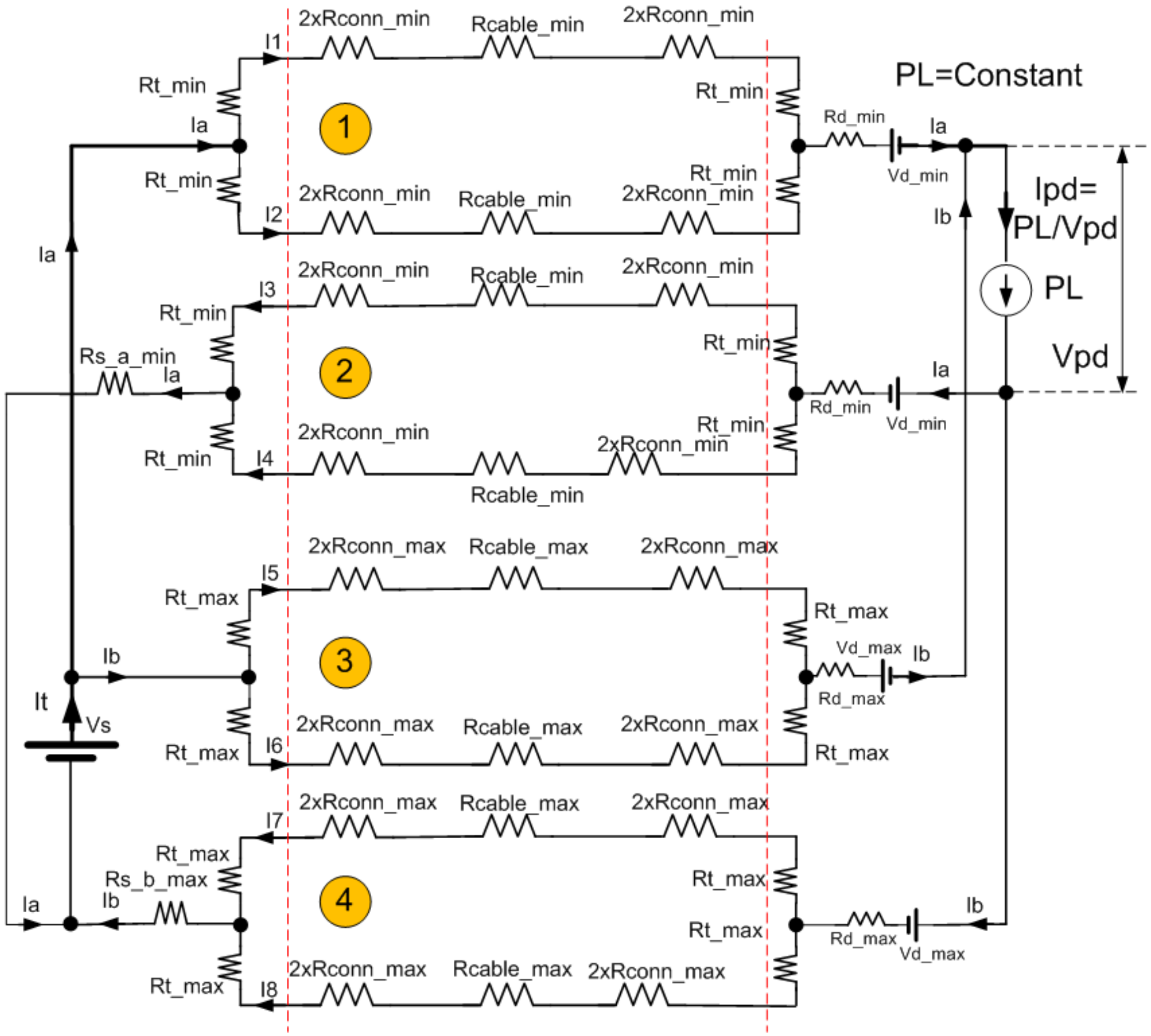
# Terminology

- P2P = Pair to Pair
- Runb=Pair Resistance Unbalance
- P2PRunb = Pair to Pair Resistance Unbalance (system level including PSE and PD output and input resistance and transformers).
- P2PCRunb = Pair to Pair Channel Resistance Unbalance (includes only 4 connector channel model components)

# Objectives

- To find the Temperature Rise as function of P2PRunb.
- To investigate the conditions in which P2PCRunb will cause a bundle of N cables to exceed Trise=10°C limit.

# P2P **Channel R**esistance Unbalance[1] Model




1. I1, I2, I3 and I4 may not be equal however in this presentation I1=I2=I3=I4=Imax and I5=I6=I7=I8=Imin by setting resistance and voltages to min and max respectively.

2. rs_a=Rs_b=0 for simplifying analysis.

Figure 1

# Finding Trise as function of P2PCRunb. -1

- The objective is to find the channel P2P Resistance Unbalance that will keep the temperature rise of 100 cables bundle, when each cable pair is caring current in all its 4 pairs and the current between pairs is not balanced as was assumed in 802.3at work.
- Two pair were set to having maximum current and the other two pairs were set to minimum current to reflects worst case current imbalance in a single cable.
- Per figure 1, Wires of pairs 1 and 2 were set to Rmin and wires of pair 2 and 3 were set to Rmax.
- As a result Pairs 1 and 2 are set to max current and pairs 3 and 4 are set to min current resulting with the following:

$$P2PCRunb \equiv \frac{\frac{R\max}{4} - \frac{R\min}{4}}{\frac{R\max}{4} + \frac{R\min}{4}} = \frac{R\max - R\min}{R\max + R\min}$$

$$Iunb = Ia - Ib = It \cdot P2PCRunb$$

Ia=It/2+Iunb/2
Ib=It/2-Iunb/2

# Finding Trise as function of P2PCRunb. -2

- Setting our base line per 802.3at project limitations:
  - The temperature rise of 100 cables, all caring current of 0.6A per pair at all pairs (total current It=1.2A), when all pairs are balanced i.e. all have the same loop resistance is:

$$N \cdot P \cdot \theta_{(N)} = Trise$$

$$N \cdot (R_{loop} \cdot I^2 + R_{loop} \cdot I^2) \cdot \theta_{(N)} = Trise$$

$$N \cdot (12.5\Omega \cdot 0.6^2 + 12.5\Omega \cdot 0.6^2) \cdot \theta_{(N)} = 10°C$$

$$\theta_{(N=100)} = 0.0111°C/W$$

The equivalent 100 cable bundle temperature thermal resistance is $0.0111°C/W$.

# Finding Trise as function of P2PCRunb. -3

- Finding Trise as function of P2PCRunb:
- N=Number of cables in a bundle
- $\theta$(N)=The thermal coefficient for a bundle with N cables.

$$Trise = N \cdot (Pa + Pb) \cdot \theta_{(N)}$$

$$Trise = N \cdot (R_{loop\_min} \cdot \mathrm{Im}aax^2 + R_{loop\_max} \cdot \mathrm{Im}in^2) \cdot \theta_{(N)}$$

$$\mathrm{Im}ax = 0.5 \cdot It + 0.5 \cdot P2PCRunb \cdot It = 0.5 \cdot It \cdot (1 + P2PCRunb)$$

$$\mathrm{Im}in = 0.5 \cdot It - 0.5 \cdot P2PCRunb \cdot It = 0.5 \cdot It \cdot (1 - P2PCRunb)$$

$$Trise = N \cdot 0.25 \cdot It^2 \cdot [R_{loop\_min} \cdot (1 + P2PCRunb)^2 + R_{loop\_max} \cdot (1 - P2PCRunb)^2] \cdot \theta_{(N)}$$

$$R_{loop\_min} = R_{loop\_max} \cdot \left( \frac{1 - P2PCRunb}{1 + P2PCRunb} \right)$$

$$= N \cdot 0.25 \cdot It^2 \cdot R_{loop\_max} \left[ \left( \frac{1 - P2PCRunb}{1 + P2PCRunb} \right) \cdot (1 + P2PCRunb)^2 + (1 - P2PCRunb)^2 \right] \cdot \theta_{(N)}$$

$$Trise = N \cdot 0.5 \cdot It^2 \cdot R_{loop\_max} \left[ 1 - P2PCRunb \right] \cdot \theta_{(N)}$$

# Finding Trise as function of P2PCRunb. -4

$$Trise = N \cdot 0.5 \cdot It^2 \cdot R_{loop\_max} \left[1 - P2PCRunb\right] \cdot \theta_{(N)}$$

- We see that Trise is going low if P2PCRunb is >0.
- This was expected results up to some value of P2PCRunb however the surprise is that it keep behaving like this for any P2PCRunb from ZERO to 1. Possible explanation for it is that we assumed constant $\theta_{(N)}$ regardless of non-uniform current distribution for P2PCRunb>0.
- However, I am not sure that it is the case for different (non Uniform=not symmetrical current distribution) i.e. cooling surface is not fully utilized which results with higher thermal coefficient as P2PCRunb is increased.
- As a result, as a worst–case working assumption (in addition to others..☺ ), It is proposed to use thermal coefficient which start to increase above $\theta_{(N=100)}$ at P2PCRunb=0.4 by a factor of TBD.
- As a result, without waiting for lab results to confirm the equation prediction, it is proposed to recommend that up to P2PCRunb=40% which is more than we need (we need <30%), we will not have thermal issues.

# Finding Trise as function of P2PCRunb. - 5

- There is additional factor that works for us.
- The fact that our load is constant power sink helps to reduce the current It when Pair A resistance is reduced due to P2PCRunb>0. As a result, the equivalent 4P loop resistance is reduced which cause Vpd to increase and reducing It which reduces power loss on the cable. Ppd=51W, E=50V, Rmax=12.5Ω, N=100, θ(N)=0.01111.

$$Vpd = \frac{E + \sqrt{E^2 - 4 \cdot Req \cdot Ppd}}{2}$$

$$Req = \frac{R\max \cdot R\min}{R\max + R\min}$$

$$R\min = R\max\left(\frac{1 - P2PCRunb}{1 + P2PCRunb}\right)$$

$$Req = 0.5 \cdot R\max(1 - P2PCRunb)$$

$$It = \frac{E - Vpd}{Req} = \frac{E + \sqrt{E^2 - 4 \cdot Req \cdot Ppd}}{2Req}$$

$$It = \frac{E - \sqrt{E^2 - 4 \cdot Req \cdot Ppd}}{2Req}$$

Once we have It, we continue per previous slides and find Ia, Ib, Iunb and power loss.

- The results of Trise vs P2PCRunb are slightly better then using fixed 1.2A all the way.

$$Trise = N \cdot 0.5 \cdot It^2 \cdot R_{loop\_\max}\left[1 - P2PCRunb\right] \cdot \theta_{(N)}$$

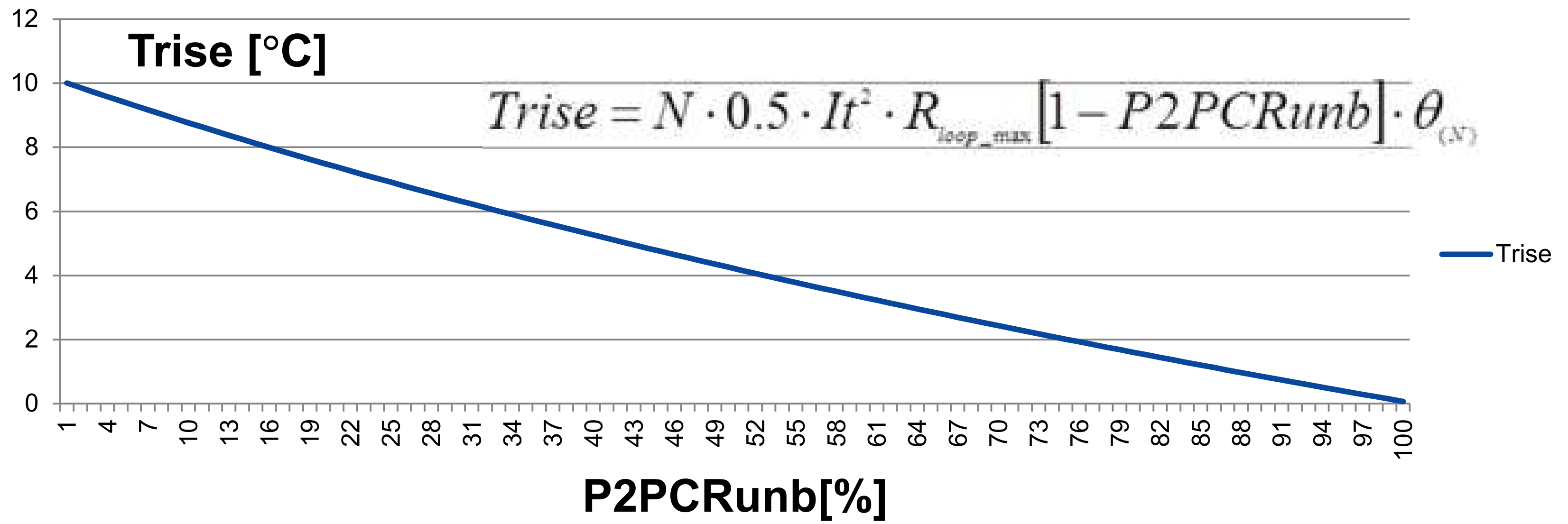
# Conclusions

- Temperature rise for 100 cables in a bundle for Type 2 current levels on all 4 pairs when P2PCRunb>0 is not an issue.
- Moreover: Trise is decreased when P2PCRunb is increased.

- Rational (see detailed mathematical analysis in the annex):
- Rmax (the lower two pairs) is 12.5Ω max. It is not function of P2PCRunb.
- Rmin (the upper two pairs) is 12.5Ω at P2PCRunb=0 and reduced when P2PCRunb is increased.
- As a result more current is flowing through Rmin and lower current through Rmax.
- Therefore
  - The power loss on lower pairs (Rmax) is reduced due to lower current.
  - The power loss on the upper pairs (Rmin) is a function higher current and lower loop resistance.
    - The factor in which current^2 is increased is: f1=(1+P2PCRunb)^2.
      f1= (1+2*P2PCRunb+P2PCRunb^2)
    - The factor in which resistance is decreased is: f2=(1-P2PCRunb)/(1+P2PCRunb)=
      (1-P2PCRunb^2)/(1+P2PCRunb)^2= (1-P2PCRunb^2)/(1+2*P2PCRunb+P2PCRunb^2)
      f1= (1+2*P2PCRunb+P2PCRunb^2)
      f2=(1-P2PCRunb^2)/(1+2*P2PCRunb+P2PCRunb^2)
      f1xf2= 1-P2PCRunb^2 i.e. power loss on Rmin is decrased by a factor of 1-P2PCRunb^2 .
    - In both pairs power is reduced when P2PCRunb is reduced.
- Resulting with lower total power dissipation on the cable as P2PRCRunb is increased.
- In addition, the fact that we have constant power sink load, help to further reduce Trise when P2PCRunb is increased. (lower resistance➔ Higher Vps➔ Lower Ipd➔ Lower loss➔lower Trise)

# Summary

- For our P2PCRunb<30%, Trise will stay below 10°C .
- Further more, Trise will reduced as P2PCRun is increase to 1 (theoretically, ignoring non uniform current distribution).
- Thermal coefficient as function of P2PCRunb is not known and may affect Trise however not at our P2PCHRunb<30% working range.
- Equation valid for future case were N<100, It=1.9A for 95W system.



# Sources

- Sorted per latest dates
- **Reserved room for worst case P2PRunb for the channel**
- http://www.ieee802.org/3/4PPOE/public/nov13/darshan_01_1113.pdf
- http://www.ieee802.org/3/4PPOE/public/nov13/beia_01_1113.pdf
- http://www.ieee802.org/3/4PPOE/public/jul13/beia_1_0713.pdf
- http://www.ieee802.org/3/4PPOE/public/jul13/darshan_2_0713.pdf

# Thank You