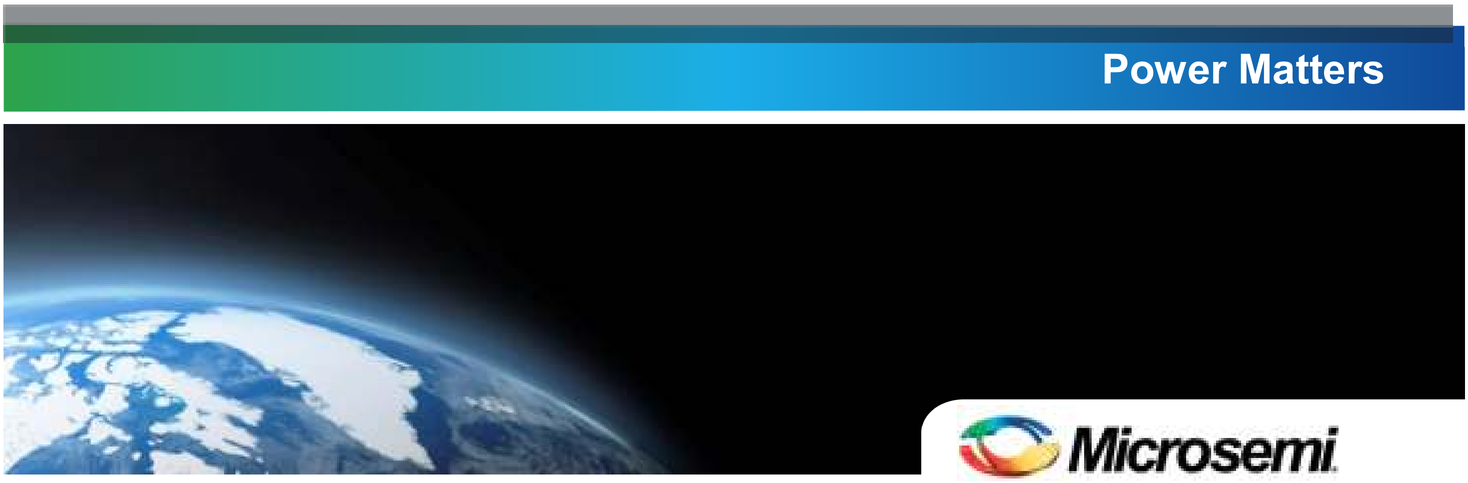

IEE802.3 4P Task Force

Derivation of PSE and PD PI Rmax, Rmin in order to meet system worst case End to End Pair To pair effective resistance unbalance

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Derivation of PSE and PD PI Requirements

Pair to pair current and resistance unbalance - Background

In a system that delivers power over all its four pairs, i.e. the power is delivered over two power channels, Alternative A pairs and Alternative B pairs. The current on Alternative A positive wires will typically be different than the current through Alternative B positive wires. The same will happen in the negative Alternative A and Alternative B wires. This is caused by the resistance difference between the wire pairs, the resistance of components in series with these wires, and different voltage drops across components such as diodes and/or different voltages between the pairs of the same polarity at the PSE power supply feeding point. See figure 1 for details.

It can be shown that the current difference between two pairs of the same polarity is a function of the resistance difference between those pairs.

The current difference between two pairs is defined as Idiff=$|I_A - I_B|$. The pair to pair current unbalance (E2E_P2PIunb) is a ratio and defined as Idiff/It were It is the total current of both pairs i.e. It=$I_A + I_B$.

As a result, $E2E\_P2PIunb = \left|\frac{I_A - I_B}{I_A + I_B}\right|$. It can be shown that $E2E\_P2PIunb$ is proportional to the pair to pair effective resistance unbalance between the two pairs of the same polarity i.e.

$$E2E\_P2PRunb = \frac{\sum R_{\max} - \sum R_{\min}}{\sum R_{\max} + \sum R_{\min}}$$

It is possible to derive simplified equations when effective resistance values are used for Rmax and Rmin because it eliminates the use of PSE Vdiff and PD Vdiff parameters in the equations.

The effective Rmax, Rmin values are the real static Rmax and Rmin values with some addition or reduction from their nominal values to account for the effect of PSE Vdiff and PD Vdiff on the pair to pair current unbalance in addition to the effect of the pair to pair resistance to the pair to pair current unbalance.

When effective resistance values are used, the following terms are identical:

$$E2E\_P2PIunb = E2E\_P2PRunb$$

The effective Rmax and Rmin are found by measuring the voltage Veff, from PSE power supply positive node (not the point of PSE voltage + Vdiff) to the other pair end. IA+ and IB+ are measured. Assuming that pair A+ is with the minimum resistance and pair B+ is with the maximum resistance then Rmax_eff=Veff /IA+ and Rmin_eff=Veff/IB+. Same is done for negative pairs. See Figure 1 for details.

Due to the fact that the measured current I is a result of all of the pair to pair unbalance sources, the effective resistance is also representing the PSE pair to pair voltage differences and the PD pair to pair voltage differences.

For a PSE designer it is useful to have specifications for the nominal component resistance values.
PSE components which cause significant differences between effective values and nominal resistance values, such as series forward biased diodes, will typically not be included in Rmax and Rmin as they reduce efficiency and will not allow the system maximum Vdiff specification to be met. For the PD designer the effective

resistance values are generally necessary due to the widespread use of diode bridges. However for testing the PD for compliance, it will be best accomplished by measuring the PD input current per pair-set of the same polarity and verifying that maximum pair current of Icont-2P_unb of Table 33-11 item 4a is not violated. When we get to the specification part, it will be shown how to derive the convenient specification.

Derivation of PD PI Requirements

The following is the End to End Pair to Pair Resistance Unbalance (E2E_P2PRunb or "α") equation for a system including PSE, PD and Channel (cables and connectors).

$$(1)\qquad \alpha = E2E\_P2PRunb = \frac{\left(\sum R_{\max}^{PSE} - \sum R_{\min}^{PSE}\right) + \left(\sum R_{\max}^{PD} - \sum R_{\min}^{PD}\right) + \left(\sum R_{\max}^{CH} - \sum R_{\min}^{CH}\right)}{\left(\sum R_{\max}^{PSE} + \sum R_{\min}^{PSE}\right) + \left(\sum R_{\max}^{PD} + \sum R_{\min}^{PD}\right) + \left(\sum R_{\min}^{CH} + \sum R_{\max}^{CH}\right)}$$

All resistance values are effective resistances, which mean that the values include the effects of non-linear components at their operating point and the effects of pair-to-pair voltage differences in both the PSE and PD.

(2) The PD PI P2PRUNB is:

$$PD\_P2PRunb = \frac{\left(\sum R_{\max}^{PD} - \sum R_{\min}^{PD}\right)}{\left(\sum R_{\max}^{PD} + \sum R_{\min}^{PD}\right)}$$

(3) The PD PI P2PRUNB contribution to the E2E_P2PRunb of the system is

$$PD\_P2PRUNB\_contribution = \frac{\left(\sum R_{\max}^{PD} - \sum R_{\min}^{PD}\right)}{\left(\sum R_{\max}^{PSE} + \sum R_{\min}^{PSE}\right) + \left(\sum R_{\max}^{PD} + \sum R_{\min}^{PD}\right) + \left(\sum R_{\min}^{CH} + \sum R_{\max}^{CH}\right)}$$

We can see that PD contribution (3) is not equal to PD PI P2PRUNB (2).

As a result we need to transform PD_P2PRUNB (2) to PD_P2PRUNB_contribution (3) in order to have the correct weight of the PD in the whole system defined by (1) i.e. to find the function Fx that satisfies the worst case E2E_P2PRunb at the maximum PD Type operating power (which is not necessarily the point of maximum pair current).

$$\frac{\left(\sum R_{\max}^{PD} - \sum R_{\min}^{PD}\right)}{\left(\sum R_{\max}^{PD} + \sum R_{\min}^{PD}\right)} \cdot Fx = \frac{\left(\sum R_{\max}^{PD} - \sum R_{\min}^{PD}\right)}{\left(\sum R_{\max}^{PSE} + \sum R_{\min}^{PSE}\right) + \left(\sum R_{\max}^{PD} + \sum R_{\min}^{PD}\right) + \left(\sum R_{\min}^{CH} + \sum R_{\max}^{CH}\right)}$$

This step will in turn provide the equation that defines the relationship between RPDmin and RPDmax in terms of effective resistance values. e.g. if Rmin is selected by the designer, then the corresponding maximum allowable value of Rmax that will not exceed the E2E_P2PRunb limit will be provided (Just specifying Rmax/Rmin ratio will not work for our objective above).

There are few ways to do this task. The following is a simple analytical transformation process:

Describing (1) as a system that includes all parts:

(4) $$E2E\_P2PRunb = \frac{\left(\sum R_{\max} - \sum R_{\min}\right)}{\left(\sum R_{\max} + \sum R_{\min}\right)} = \alpha$$

Opening and solving for Rmax/Rmin in terms of α.

(5)
$$\left(\sum R_{\max} - \sum R_{\min}\right) = \alpha \cdot \left(\sum R_{\max} + \sum R_{\min}\right)$$
$$\sum R_{\max} - \sum R_{\min} = \alpha \cdot \sum R_{\max} + \alpha \cdot \sum R_{\min}$$
$$\sum R_{\max} - \alpha \cdot \sum R_{\max} = +\alpha \cdot \sum R_{\min} + \sum R_{\min}$$
$$(1-\alpha) \cdot \sum R_{\max} = (1+\alpha) \cdot \sum R_{\min}$$
$$\frac{\sum R_{\max}}{\sum R_{\min}} = \frac{(1+\alpha)}{(1-\alpha)} = u$$

As a result from (5):

(6)
$$\frac{\sum R_{\max}}{\sum R_{\min}} = u$$
$$u \cdot \sum R_{\min} - \sum R_{\max} = 0$$

The E2E_P2PRunb equation from (1) or it simpler form (4) can be expressed in the following form:

(7) $U \cdot \sum R_{min} - \sum R_{max} = 0$, Where $U = \frac{1+\alpha}{1-\alpha}$

Separating the contributors PSE , PD and Channel results in:

$$(8) \quad (U \cdot R_{PSEmin} - R_{PSEmax}) + (U \cdot R_{CHmin} - R_{CHmax}) + (U \cdot R_{PDmin} - R_{PDmax}) = Cont\_PSE + Cont\_CH + Cont\_PD = 0$$

Each contributor is a constant in the worst case model:

$$Cont\_PSE + Cont\_CH + Cont\_PD = 0$$

And a contributor can be solved independently to meet an E2ERunb limit, given the worst case scenario:

(10)

$$(\mathrm{U} \cdot \mathrm{R}_{\mathrm{PSEmin}} - \mathrm{R}_{\mathrm{PSEmax}}) + (\mathrm{U} \cdot \mathrm{R}_{\mathrm{CHmin}} - \mathrm{R}_{\mathrm{CHmax}}) + (\mathrm{U} \cdot \mathrm{R}_{\mathrm{PDmin}} - \mathrm{R}_{\mathrm{PDmax}}) = Cont\_pse + Cont\_CH + Cont\_PD = 0$$

$$(11) \quad (\mathrm{U} \cdot \mathrm{R}_{\mathrm{PDmin}} - \mathrm{R}_{\mathrm{PDmax}}) + Cont\_PSE + Cont\_CH = 0$$

Simplifying further by combining the constants:

$$\mathrm{Kpd} = Cont_{PSE} + Con\_CH$$

$$(12) \quad (\mathrm{U} \cdot \mathrm{R}_{\mathrm{PDmin}} - \mathrm{R}_{\mathrm{PDmax}}) + \mathrm{K\,pd} = 0$$

Solving for Rmax expressed as a range with a worst case limit results in:

$$(13) \quad \mathrm{R}_{\mathrm{PDmax}} \le \mathrm{U} \cdot \mathrm{R}_{\mathrm{PDmin}} + \mathrm{K}_{\mathrm{PD}}$$

Where:
U is a constant determined by the target end to end pair to pair resistance/current unbalance.
K_{PD} is a constant derived for the PD and Channel contribution to the worst case E2ERunb.
R_{PDmin} and R_{PDmax} are the effective PD PI resistances.

See Example next page.

Example Usage for PD PI P2P_unb specifications

Assuming that the following represents a system that is considered to be a worst case system in terms of the components it uses, operation at maximum operating power, and at the practical shortest channel length[m] (i.e. the minimum Channel Rmax, Rmin.). The Rpair values below are the nominal resistances. Effective resistances, which include the Vdiff parameter effects, are determined in a simulation and are shown below as well.

1. PSE has PSE_Vdiff=2mV as specified in Table 33-11 item 1a in 802.3bt Draft D0.4 and PD Vdiff=58mV. In order to derive PSE specification components in terms of nominal Rmax and Rmin at PSE side and effective Rmax and Rmin at PD side ,the simulation was set with PSE Vdiff=0mV and PD Vdiff=60mV so total 60mV system Vdiff is maintained. This procedure will require defining PSE Vdiff, specified at no load condition.
2. PD: $Rpair\_max_{pd} = 0.09$ $Rpair\_min_{pd} = 0.075$
3. Channel : $Rpair\_max_{ch} = 0.1005$ $Rpair\_min_{ch} = 0.0909$
4. PSE: $Rpair\_max_{pse} = 0.091$ $Rpair\_min_{pse} = 0.076$
5. Channel length =2.65m , Rch_,ax=0.1Ω Rch_min=0.0857Ω
6. PD_Vdiff=60mV

PSE + CH (measured by simulations in order to find effective resistance values) :
$Rpair\_max_{pse+ch} = 0.1915$ $Rpair\_min_{pse+ch} = 0.1617$

Initial Determination of E2ERunb and Kpd using worst case simulation values of example system:

$$\frac{\sum R_{max} - \sum R_{min}}{\sum R_{max} + \sum R_{min}} = E2ER_{unb} = 0.3086$$

Derive PD Specification:

$$U = \frac{1 + E2ER_{unb}}{1 - E2ER_{unb}} = 1.8925 .$$

$Kpd = [Rpair\_min_{pse+ch} * U – Rpair\_max_{pse+ch}] = 0.1617*1.8925 – 0.1915=0.115$

Specification becomes:

$Rpair\_max_{pd} = 1.8925 * Rpair\_min_{pd} + 0.115.$

Cross-Check:

Arbitrary PD Rpair_min = 0.05

PD Rpair_max limits Calculated with above equation:
$Rpair\_max_{pd} = 1.8925 * Rpair\_min_{pd} + 0.115 = 1.8925 * 0.05 + 0.115 = 0.209$
(The above values of PD Rpairmax and Rpair min should meet the E2ERunb limit with the worst case pse+ch values represented by U and Kpd above):

Any PD that uses $Rpair_max_{pd} \leq 0.209$and $Rpair\_min_{pd} = 0.05$
with the worst case source: $Rpair\_max_{pse+ch} = 0.1915$ and $Rpair_min_{pse+ch} = 0.1617$will meet the E2ERunb Limit:
E2ERunb = [(0.209+0.1915)-(0.05 +0.1617)] /[(0.209+0.1915)+(0.05 +0.1617)] = 0.3083

Summary:

Guidelines for $Rpair\_max_{pd}$ and $Rpair\_min_{pd}$:
For Type 3: $Rpair\_max_{pd} = 1.893 * Rpair\_min_{pd} +0.115$. See derivation in the example above.
For Type 4: $Rpair\_max_{pd} = 1.893 * Rpair\_min_{pd} +0.093$. (derivation not shown.)

Meeting the above guidelines will ensure meeting the Iport-2P_unb maximum value per Table 33-11 when PD is fed with a voltage source Vport_PSE-2P_min value and with Vport_PSE_diff _max specified in Table 33-11.

Derivation of PSE PI Requirements

The following is the End to End Pair to Pair Resistance Unbalance (E2E_P2PRunb or "α") equation for a system including PSE, PD and Channel (cables and connectors).

$$(1)\quad \alpha = E2E\_P2PRunb = \frac{\left(\sum_{R_{\max}}^{PSE} - \sum_{R_{\min}}^{PSE}\right) + \left(\sum_{R_{\max}}^{PD} - \sum_{R_{\min}}^{PD}\right) + \left(\sum_{R_{\max}}^{CH} - \sum_{R_{\min}}^{CH}\right)}{\left(\sum_{R_{\max}}^{PSE} + \sum_{R_{\min}}^{PSE}\right) + \left(\sum_{R_{\max}}^{PD} + \sum_{R_{\min}}^{PD}\right) + \left(\sum_{R_{\min}}^{CH} + \sum_{R_{\max}}^{CH}\right)}$$

All resistance values are effective resistances which mean that the values include the effects of non-linear components at their operating point and the effects of Pair to pair voltage differences both in the PSE and PD.

(2) The PSE PI P2PRUNB is: $$PSE\_P2PRunb = \frac{\left(\sum_{R_{\max}}^{PSE} - \sum_{R_{\min}}^{PSE}\right)}{\left(\sum_{R_{\max}}^{PSE} + \sum_{R_{\min}}^{PSE}\right)}$$

(3) The PSE PI P2PRUNB contribution to the E2E_P2PRunb of the system is

$$PSE\_P2PRUNB\_contribution = \frac{\left(\sum_{R_{\max}}^{PSE} - \sum_{R_{\min}}^{PSE}\right)}{\left(\sum_{R_{\max}}^{PSE} + \sum_{R_{\min}}^{PSE}\right) + \left(\sum_{R_{\max}}^{PD} + \sum_{R_{\min}}^{PD}\right) + \left(\sum_{R_{\min}}^{CH} + \sum_{R_{\max}}^{CH}\right)}$$

We can see that PSE contribution (3) is not equal to PSE PI P2PRUNB (2).

As a result we need to transform PSE_P2PRUNB (2) to PSE_P2PRUNB_contribution (3) in order to have the correct weight of the PSE in the whole system defined by (1) i.e. to find the function Fx that satisfies the worst case E2E_P2PRunb at the maximum PSE Type operating power (which is not necessarily the point of maximum pair current).

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

This step will in turn provide the equation that defines the relationship between RPSEmin and RPSEmax in terms of effective resistance values. e.g. if Rmin is selected by the designer, then the corresponding maximum allowable value of Rmax that will not exceed the E2E_P2PRunb limit will be provided (Just specifying Rmax/Rmin ratio will not work for our objective above).

There are few ways to do this task. The following is a simple analytical transformation process:

Describing (1) as a system that includes all parts:

(4) $$E2EP2PRunb = \frac{\left(\sum R_{\max} - \sum R_{\min}\right)}{\left(\sum R_{\max} + \sum R_{\min}\right)} = \alpha$$

Opening and solving for Rmax/Rmin in terms of α.

(5) $$\begin{aligned}
&\left(\sum R_{\max} - \sum R_{\min}\right) = \alpha \cdot \left(\sum R_{\max} + \sum R_{\min}\right) \\
&\sum R_{\max} - \sum R_{\min} = \alpha \cdot \sum R_{\max} + \alpha \cdot \sum R_{\min} \\
&\sum R_{\max} - \alpha \cdot \sum R_{\max} = +\alpha \cdot \sum R_{\min} + \sum R_{\min} \\
&(1-\alpha) \cdot \sum R_{\max} = (1+\alpha) \cdot \sum R_{\min} \\
&\frac{\sum R_{\max}}{\sum R_{\min}} = \frac{(1+\alpha)}{(1-\alpha)} = u
\end{aligned}$$

As a result from (5):

(6) $$\begin{aligned}
&\frac{\sum R_{\max}}{\sum R_{\min}} = u \\
&u \cdot \sum R_{\min} - \sum R_{\max} = 0
\end{aligned}$$

The E2E_P2PRunb equation from (1) or it simpler form (4) can be expressed in the following form:

(7) $U \cdot \sum R_{min} - \sum R_{max} = 0$,   Where $U = \frac{1+\alpha}{1-\alpha}$

Separating the contributors PSE, PD and Channel results in:

(8) $$\left(U \cdot R_{PSEmin} - R_{PSEmax}\right) + \left(U \cdot R_{CHmin} - R_{CHmax}\right) + \left(U \cdot R_{PDmin} - R_{PDmax}\right) = Cont\_PSE + Cont\_CH + Cont\_PD = 0$$

Each contributor is a constant in the worst case model:

$$Cont\_PSE + Cont\_CH + Cont\_PD = 0$$

And a contributor can be solved independently to meet an E2ERunb limit, given the worst case scenario:

(10)

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

$$Cont\_pse + Cont\_CH + Cont\_PD = 0$$

(11) $$\left(U \cdot R_{PSEmin} - R_{PSEmax}\right) + Cont\_CH + Cont\_PD = 0$$

Simplifying further by combining the constants:

$$Kpse = Cont\_CH + Cont\_PD$$

(12) $$\left(U \cdot R_{PSEmin} - R_{PSEmax}\right) + K\,pse = 0$$

Solving for Rmax expressed as a range with a worst case limit results in:

(13) $$R_{PSEmax} \leq U \cdot R_{PSEmin} + K_{PSE}$$

Where:
U is a constant determined by the target end to end pair to pair resistance/current unbalance.
K_{PSE} is a constant derived for the PD and Channel contribution to the worst case E2ERunb.
R_{PSEmin} and R_{PSEmax} are the effective PSE PI resistances.

In order to simplify PSE PI specification and make it practical for the design phase, it is possible to specify RPSEmin and RPSEmax in terms of nominal component resistance values and specifying PSE pair to pair voltage difference as two separate parameters which is equivalent to specifying the effective values of RPSEmin, RPSEmax as currently presented by Equation 13. (KPSE is specified with PD diode pair to pair voltage differences so it stays with effective resistance value) Due to the fact that PSE_Vdiff is very small (2mV currently in the specification), the effective values of RPSEmin and RPSEmax are similar to the nominal components values of RPSEmin and RPSEmax with some negligible error.

See Example next page.

Example Usage for PSE PI P2P_unb specifications

Assuming that the following represents a system that is considered to be a worst case system in terms of the components it uses, operation at maximum operating power, and at the practical shortest channel length[m] (i.e. the minimum Channel Rmax, Rmin.). The Rpair values below are the nominal resistances. Effective resistances, which include the Vdiff parameter effects, are determined in a simulation.

1. PSE has PSE_Vdiff=2mV as specified in Table 33-11 item 1a in 802.3bt Draft D0.4 and PD Vdiff=58mV. In order to derive PSE specification components in terms of nominal Rmax and Rmin at PSE side and effective Rmax and Rmin at PD side ,the simulation was set with PSE Vdiff=0mV and PD Vdiff=60mV so total 60mV system Vdiff is maintained. This procedure will require defining PSE Vdiff, specified at no load condition.
2. PD: $Rpair\_max_{pd} = 0.09$ $Rpair\_min_{pd} = 0.075$
3. Channel : $Rpair\_max_{ch} = 0.1005$ $Rpair\_min_{ch} = 0.0909$
4. PSE: $Rpair\_max_{pse} = 0.091$ $Rpair\_min_{pse} = 0.076$
5. Channel length =2.65m , Rch_,ax=0.1Ω Rch_min=0.0857Ω
6. PD_Vdiff=60mV

The Ch + PD effective resistance:

$Rpair\_max_{ch+pd} = 1.249$ $Rpair\_min_{ch+pd} = 0.6324$

Initial Determination of E2ERunb and Kpse using worst case values of example system:

$$\frac{\sum R_{max} - \sum R_{min}}{\sum R_{max} + \sum R_{min}} = E2ER_{unb} = 0.3086$$

Derive PSE Specification:

$$U = \frac{1 + E2ER_{unb}}{1 - E2ER_{unb}} = 1.893.$$

Kpse = $[Rpair\_min_{ch+pd} * U - Rpair\_max_{ch+pd}] = 0.6324*1.893 - 1.249 = -0.053$

Specification becomes:

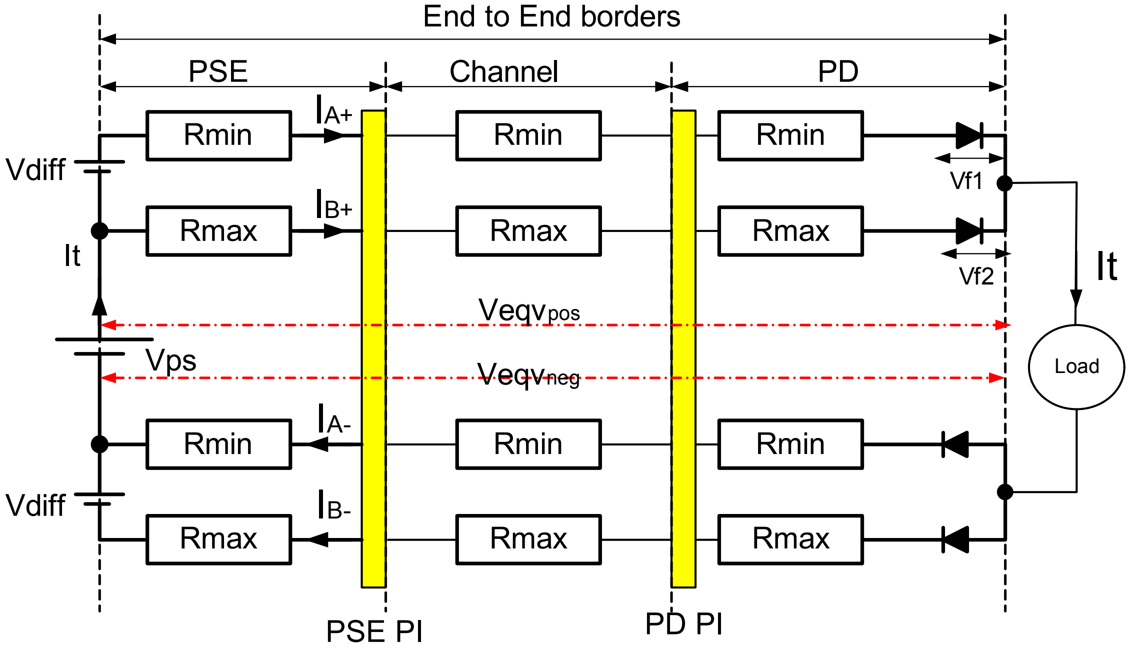
$Rpair\_max_{pse} = 1.893 * Rpair\_min_{pse} - 0.053.$

Cross-Check:

Arbitrary PSE Rpair_min = 0.2

PSE Rpair_max limit Calculated with above equation: $Rpair\_max_{pse} = 1.893 * 0.2 - 0.053 = 0.3256$
(The above values of PSE Rpairmax and Rpair min should meet the E2ERunb limit with the worst case ch+pd values represented by U and Kpse above):
Any PSE that uses $Rpair\_max_{pse} \leq 0.325$ and $Rpair\_min_{pse} = 0.2$
With the worst case load: $Rpair_max_{ch+pd} = 1.249$and $Rpair\_min_{ch+pd} = 0.6324$,
will meet the E2ERunb Limit:
E2ERunb =(Rmax-Rmin)/(Rmax+Rmin)=
[(0.3256+1.249)-(0.2+0.6324)] / [(0.3157+1.257) + (0.2+0.630)] = 0.3089

Figure 1



$$E2EP2P\_Iunb = \frac{IA^+ - IA^-}{IA^+ + IA^-} = \frac{\left(\frac{Veqv\_pos}{IA^+}\right) - \left(\frac{Veqv\_pos}{IA^-}\right)}{\left(\frac{Veqv\_pos}{IA^+}\right) + \left(\frac{Veqv\_pos}{IA^-}\right)} = \frac{\sum R\min\_eqv - \sum R\max\_eqv}{\sum R\min\_eqv + \sum R\max\_eqv} = E2EP2P\_Runb$$

- This is a worst case model. All contributors of voltage and resistance are set to maximize the current on Pair A+ and minimize the current on pair B+. Same applies for the negative pairs. Example: Vf1<Vf2. Vdiff at positive side is in positive polarity in relation to Vps positive feeding point.
    - The same equation applies for the negative pairs.
    - PD Vdiff is Vf1-Vf2 in this example.
    - PSE Vdiff is the pair to pair voltage difference measured at the PSE PI at no load conditions.
    - If Vdiff=0 and Vf1=Vf2, then components nominal static value are equal to their effective value.

Annex A – Additional Research conclusions.

Effective resistance:

The effective resistance of a pair from end to end (see figure 1) is function of the actual pair to pair current unbalance.

The pair to pair current unbalance is a function the component's pair to pair resistance differences and the pair to pair voltage differences in the PSE and voltage drop differences at the PD.

As such effective resistance is a dependent variable unlike the resistance of a resistive element that is a fixed value and is independent variable.

The effective resistance is measured by using Veq_xxx divided by the pair current. Veq_xxx includes all unbalance sources and is described by Figure 1.

Kpse and Kpd

For compliance tests of PSE or PD, the test setup has to include fixed values of the components of Kpse and Kpd. The components of Kpse and Kpd are described by the specification derivation calculation examples in this document.

Worst case analysis

The specification equations were derived based on the positive pairs because they are subject to a higher worst case E2EP2P_Iunb and/or maximum pair current than the negative pairs. This is due to a lower total resistance in the PSE positive pairs and the fact that the additional PSE PI resistance on the negative pairs (Rsense and RDSON) improves E2EP2P_Iunb.

Components values are based on ad-hoc database. See reference 5.

PSE Vdiff vs PD Vdiff

1. Total budget for PSE Vdiff and PD Vdif is 60mV. This number was derived in reference 8.
2. The PD vdiff gets most of the Vdiff budget in order to allow low cost diode bridges in the PD.
3. Typical 4P PSE is using common power supply and only resistive elements in the PSE PI that results with very low Vdiff <1mV when common power supply practice design rules are used in order to reduce PCB trace resistance or connecting wires whenever high current is flowing through it.
4. Currently in IEEE802.3bt Draft 0.4, the PSE Vdiff is set to 2mV max. As a result, PD Vdiff=58mV.
5. It is important to emphasis that moving 60mV total Vdiff to PSE and having Zero Vdiff at PD will result with lower E2EP2PRunb (~22% in Type 3) than if 60mV will be in the PD and 0mV at the PSE (~30% in Type 3). This is due to the nonlinear nature of the diodes that the diode forward voltage difference affects the current unbalance and the value of the current affect the effective resistance. At low voltage difference at PSE i.e. PSE Vdiff=2mV and PD Vdiff=58mV, if PSE Vdiff=0mV and PD Vdiff=60mV, almost the same E2EP2P_Iunb results will be obtained. This fact, help us during simulation, to set PSE Vdiff=2mV and PD Vdiff=60mV to get specification numbers for PSE side in nominal component values and at PD side with effective values.
6. Increase of PSE Vdiff from 0 to 2mV (PD Vdiff=60mV) increases pair maximum current by ~2mA and E2EP2P_Iunb by 0.62%.

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	Table G1 pages 34,35 at: http://www.ieee802.org/3/bt/public/mar15/darshan_02_0315.pdf
	System Unbalance Calculations	
	Cordage Resistivity (wire)	
	Cable Resistivity (wire)	
	Number of connector	
	Connector resistance, Rconn.	
	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/mar15/darshan_03_0315.pdf
9	PD Load power	http://www.ieee802.org/3/bt/public/mar15/darshan_01_0315.pdf
10	System Unbalance simulations	http://www.ieee802.org/3/bt/public/may14/beia_1_0514.pdf http://www.ieee802.org/3/bt/public/mar15/darshan_02_0315.pdf
11	System Unbalance calculations	http://www.ieee802.org/3/bt/public/sep14/index.html by Ken Bennett
12	PSE PI requirements	http://www.ieee802.org/3/bt/public/mar15/darshan_08_0315.pdf