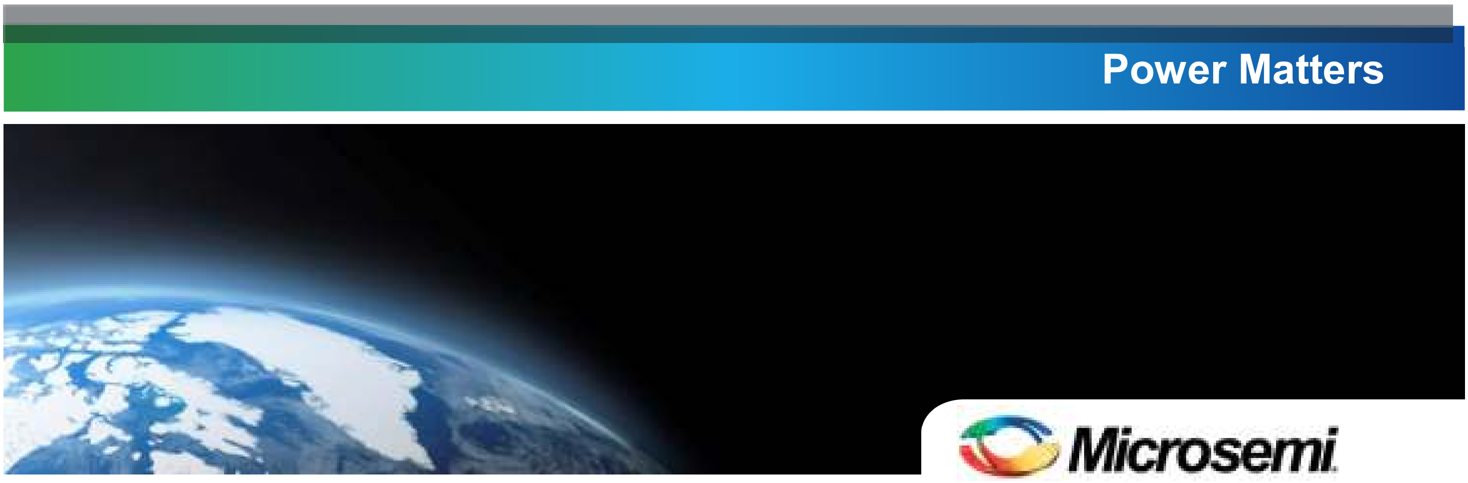

IEE802.3 4P Task Force

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

The following is the End to End Pair to Pair Resistance Unbalance (E2EP2PRUNB or "α") equation.

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

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 E2EP2PRunb 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 E2EP2PRUNB at the maximum PSE Type operating power (which is not necessarily the point of maximum pair current).

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

The results of this step will supply the equation that defines the relationship between RPSEmin and RPSEmax in terms of resistance values. e.g. if Rmin is selected by the designer, then what is the corresponding maximum allowable value of Rmax that will not exceed the E2EP2PRunb limit. (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)
$$\left(\sum R_{\max} - \sum R_{\min}\right) = \alpha \cdot \left(\sum R_{\max} + \sum R_{\min}\right)$$
$$\sum R_{\max} - \sum R_{\min} = \alpha \cdot \sum R_{\max} + \alpha \cdot \sum R_{\min}$$
$$\sum R_{\max} - \alpha \cdot \sum R_{\max} = +\alpha \cdot \sum R_{\min} + \sum R_{\min}$$
$$(1-\alpha) \cdot \sum R_{\max} = (1+\alpha) \cdot \sum R_{\min}$$
$$\frac{\sum R_{\max}}{\sum R_{\min}} = \frac{(1+\alpha)}{(1-\alpha)} = u$$

As a result from (5):

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

The E2EP2PRunb 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)
$$\left(\mathrm{U} \cdot \mathrm{R}_{\mathrm{PSEmin}} - \mathrm{R}_{\mathrm{PSEmax}}\right) + \left(\mathrm{U} \cdot \mathrm{R}_{\mathrm{CHmin}} - \mathrm{R}_{\mathrm{CHmax}}\right) + \left(\mathrm{U} \cdot \mathrm{R}_{\mathrm{PDmin}} - \mathrm{R}_{\mathrm{PDmax}}\right) =$$
$$Cont\_pse + Cont\_CH + Cont\_PD = 0$$

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

Simplifying further by combining the constants:

$\mathrm{Kpse} = Cont\_CH + Cont\_PD$

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

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

(13) $\mathrm{R}_{\mathrm{PSEmax}} \leq \mathrm{U} \cdot \mathrm{R}_{\mathrm{PSEmin}} + \mathrm{K}_{\mathrm{PSE}}$

Where:
U is a constant determined by the target balance, an
K_{pse} is a constant derived for the PSE contribution to the worst case E2ERunb.

See Example next page.

Example Usage:

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] (ie. the minimum Channel Rmax, Rmin.).

PSE: $Rpair\_max_{pse} = 0.09$ $Rpair\_min_{pse} = 0.075$

Ch + PD: $Rpair\_max_{ch+pd} = 1.253$ $Rpair\_min_{ch+pd} = 0.634$

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

$$\frac{\sum R_{max} - \sum R_{min}}{\sum R_{max} + \sum R_{min}} = E2ER_{unb} = 0.3089$$

Derive PSE Specification:

$$U = \frac{1 + E2ER_{unb}}{1 - E2ER_{unb}} = 1.894 .$$

$$Kpse = [Rpair\_min_{ch+pd} * U - Rpair\_max_{ch+pd}] = 0.634*1.894 - 1.253 = -0.052$$

Specification becomes:

$Rpair\_max_{pse} = 1.894 * Rpair\_min_{pse} - 0.052$.

Cross-Check:

Arbitrary PSE Rpair_min = 0.2

PSE Rpair_max limit Calculated with above equation: 0.326
(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 $Rpair\_max_{pse} \leq 0.326$ and $Rpair\_min_{pse} = 0.2$
With the worst case load: $Rpair\_max_{ch+pd} = 1.253$ and $Rpair\_min_{ch+pd} = 0.634$

will meet the E2ERunb Limit:
E2ERunb = [(0.326+1.253)-(0.2+0.634)] / [(.326+1.253)+(0.2+0.634)] = 0.3087