PI Balance Specifications
Rev. 03

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Supporters:

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Introduction

- Two options for PI Pair-to-pair balance specifications have been proposed:
  - P2PRunb = n, R_{min}, Vdiff (embedded or as a separate spec)
  - $Reff_{max} \leq Reff_{min} * x + y$
- This presentation provides some additional information on the derivation, properties and benefits of the $Reff_{max} \leq Reff_{min} * x + y$ option
- Changes to the standard incorporating this option are proposed

P2P Unbalance Specifications

Step 1: Set a target E2E P2P unbalance

Use Models, simulations to determine an acceptable worst case

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

Step 2: Define PI Requirements such that:

Target E2E P2P Unbalance is ***never*** exceeded

Implementation independence is met:

→ No unnecessary restrictions or limits imposed

PI Specifications which meet the above requirements:

$$R_{PSEmax} \leq f(R_{PSEmin}) \qquad R_{PDmax} \leq f(R_{PDmin})$$

Need to Solve for each *f( )*

Derivation of PI Equations

The E2ERunb equation can be rearranged to the following form:

$$x \cdot \sum R_{min} - \sum R_{max} = 0, \qquad \text{Where } x = \frac{1 + E2ER_{unb}}{1 - E2ER_{unb}}$$

Separating the contributors results in:

$$(x \cdot R_{PSEmin} - R_{PSEmax}) + (x \cdot R_{CHmin} - R_{CHmax}) + (x \cdot R_{PDmin} - R_{PDmax}) = 0$$

Each contributor is a constant in the worst case model:

$$C_{PSE} + C_{CH} + C_{PD} = 0$$

And any contributor can be solved for other implementations (PSE example shown below):

$$R_{PSEmax} - x \cdot R_{PSEmin} = C_{CH} + C_{PD}$$

Solving for Rmax results in:

$$R_{PSEmax} = x \cdot R_{PSEmin} + y_{pse}$$

Where:

x is a constant determined by the target balance, and

y_{pse} is a constant determined by the other two contributors ($C_{CH} + C_{PD}$)

PI Specification Independence and Final expressions

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From the previous slide:

$$\left(x \cdot R_{PSEmin} - R_{PSEmax}\right) + \left(x \cdot R_{CHmin} - R_{CHmax}\right) + \left(x \cdot R_{PDmin} - R_{PDmax}\right) = 0$$

- Each contributor is a constant in the worst case model
- There are pairs of Rmax & Rmin that also equal that constant in each case
  - The Expressions for the other contributors are unaffected
  - The sets of Rmax & Rmin that satisfy this ***are*** the limits for PI implementations necessary to meet the target balance limit
- Contributors may have better balance without violating the target balance, so the equations may be expressed in the following form:

$$PSE_{max} \leq x \cdot (PSE_{min}) + y_{pse}$$

$$PD_{max} \leq x \cdot (PD_{min}) + y_{pd}$$

$$CH_{max} \leq x \cdot (CH_{min}) + y_{ch}$$ [1]

Where the final worst case model would provide the values for *x* and each *y*

1: Channel equation is included for discussion and is not a recommendation

Properties of the equations

- **Simple expressions, described with 2 constants**
  - Exactly fit the limits necessary to meet E2E P2P target balance
  - No unnecessary restrictions, No additional specs required
- **PI specification independence**
  - If any two contributors satisfy the equations, the third equation remains valid
- **Can be used to scale WC Resistances up or down without affecting the equations for the other contributors**
  - May be useful for test set-ups
- **If a solution is not possible, the equation will indicate it**
  - Ballast resistance (or Rmin limit) might be added to the WC model to improve target balance:
    - If low resistances in a given implementation can't provide the necessary ballast, the equation will not be solvable ($Reff_{max}$ will be ***less than*** $Reff_{min}$)

Proposed Text

PSE PI Table 33-11 New Content for Types 3, 4

<table>
<tr><td rowspan="3">20</td><td rowspan="3">Current Unbalance</td><td rowspan="2">Iunb</td><td rowspan="2">A</td><td></td><td>3% x Icable</td><td>1</td><td rowspan="2">See 33.2.7.11, 33.4.8. Note- For practical implementations, it is recommended that Type 1 PSEs support Type 2,3,4 Iunb requirements</td></tr>
<tr><td></td><td>3% x Ipeak</td><td>2,3,4</td></tr>
<tr><td>Iunb_ptp</td><td>A</td><td></td><td>TBD% x Ipeak</td><td>3,4</td><td>See 33.2.7.x. Iunb_ptp is the current difference between two pairs of the same polarity</td></tr>
</table>

PSE Subsection Content

33.2.7.x Pair-to-Pair Current Unbalance

Iunb_ptp shall be met at >85% of maximum PSE port capacity with the unbalanced resistive loads defined in 33-$\#_2$

$$\text{Rpair\_max} = \text{TBD}, \quad \text{Rpair\_min} = \text{TBD} \qquad 33\text{-}\#_2$$

Where the pair resistances are common mode resistances in the wire pairs of the same polarity, as shown in figure 33-$\#_3$

Iunb_ptp may be met with PSE PI effective resistances between pairs of the same polarity by conforming to equation 33-$\#_4$:

$$R\mathit{eff}_{\mathbf{max}} < R\mathit{eff}_{\mathbf{min}} * \mathit{TBD}_{\boldsymbol{x}} + \mathit{TBD}_{\boldsymbol{Ypse}} \qquad 33\text{-}\#_4$$

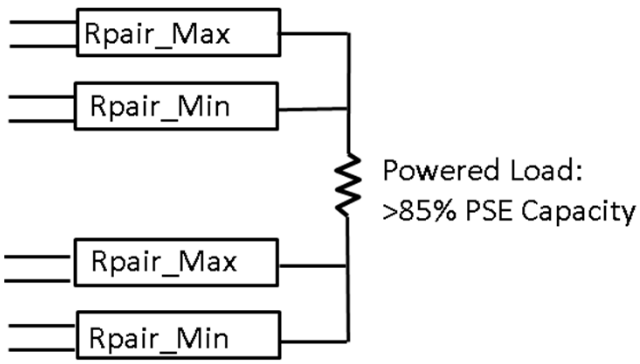

FIG. 33-$\#_3$

where $R\mathit{eff}_{max}$ and $R\mathit{eff}_{min}$ are maximum and minimum effective resistances determined at >85% of maximum port capacity.
Each of the R*eff* parameters is the common mode effective resistance in the path of a twisted wire pair, including all PSE elements that are exclusively in the path of that wire pair.

**** Rpair values and Equation 33-#4 are derived from worst case system models***

(Actual test procedures may be included in an informative Annex)

Questions and Comments

Thank You

Annex:

PD PI Specification

R*eff* Test Method

PD Table 33-18 New Content for Types 3, 4

##	Current Unbalance	Iunb_ptp	A		TBD% x Ipeak	3,4	See 33.3.7.x. Iunb_ptp is the current difference between two pairs of the same polarity

PD Subsection Content

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33.3.7.x Pair-to-Pair Current Unbalance

Iunb_ptp shall be met at >85% of maximum PD port operating Current Sourced through the unbalanced resistances defined in 33-$\#_5$

$$\text{Rpair\_max} = \text{TBD}, \quad \text{Rpair\_min} = \text{TBD} \qquad \text{33-}\#_5$$

Where the pair resistances are common mode resistances in the wire pairs of the same polarity, as shown in figure 33-$\#_6$

Iunb_ptp may be met with PD PI effective resistances between pairs of the same polarity by conforming to equation 33-$\#_7$:

$$\mathrm{R}\mathit{eff}_{\mathbf{max}} < \mathrm{R}\mathit{eff}_{\mathbf{min}} * \mathit{TBD}_{\boldsymbol{x}} + \mathit{TBD}_{\boldsymbol{Ypd}} \qquad \text{33-}\#_7$$

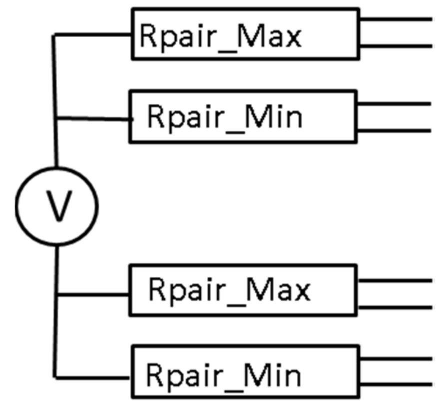
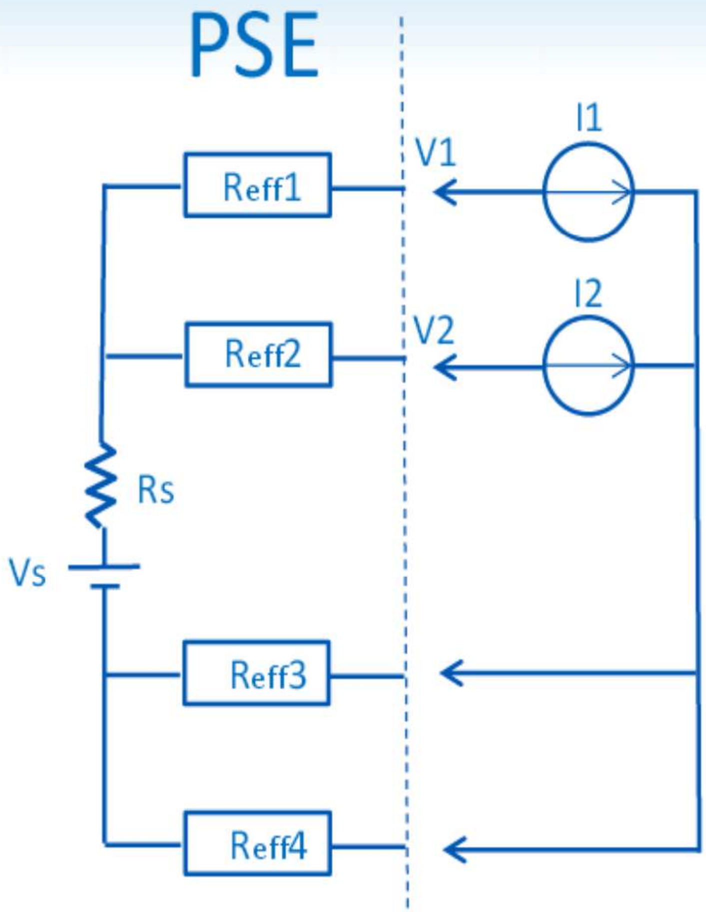


FIG. 33-$\#_6$

where $\mathrm{R}\mathit{eff}_{\mathbf{max}}$ and $\mathrm{R}\mathit{eff}_{\mathbf{min}}$ are maximum and minimum effective resistances determined at >85% of maximum port capacity.
Each of the R*eff* parameters is the common mode effective resistance in the path of a twisted wire pair, including all PD elements that are exclusively in the path of that wire pair.

**** Rpair values and Equation 33-#7 are derived from worst case system models***



Test 1 – Effective Resistance:

1. Determine $R_{eff}1$
   $I1 = I_a$, $I2 = I_c$, Measure V1, V2
   $I1 = I_b$, $I2 = I_c$, Measure V1', V2'
   $R_{eff}1 = |[(V1-V1')-(V2-V2')]/(I_a - I_b)|$
2. Determine $R_{eff}2$
   $I2 = I_a$, $I1 = I_c$, Measure V1, V2
   $I2 = I_b$, $I1 = I_c$, Measure V1', V2'
   $R_{eff}2 = |[(V2-V2')-(V1-V1')] / (I_a - I_b)|$
3. Determine R_{eff} Compliance
   $R_{eff}max \leq X * R_{eff}min + Y$
   (X, Y are Constants derived from the final worst case
4. Repeat steps 1-3 for the negative pairs