# IEEE802.3at Task Force

# Vport ad hoc

# Suggested Remedy for Ipeak Issues #114, #137, #227, #79

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Yair Darshan
Microsemi Corporation

# Objectives of this presentation

- Current and Voltage numbers based on PD constant power model
- To synchronize PD and PSE text regarding average and peak current.
- Whenever possible
  - Ipeak to be presented as function of Vport(Ipeak) and/or Pport_peak
  - Idc/Irms to be presented as function of Vport(Idc) and/or Pport
- Allowing legacy 802.3af PSEs and PDs to co-exist with the new standard. (One of 5 criteria and Objectives)
- Closing the debate regarding Ipeak issues at this meeting..

# List of facts

(1) If Vpse increased Iport (average/peak) decreased (PDs negative resistance).

(2) PD max. power is known by using hardware or L2 classification ➔ PD power=Pclass

(3) PSE has to compensate for cable loss in order to supply Pclass ➔

(3.1) PSE needs to support at least (Pclass + Pcable) at the worst case unless the user has additional information regarding the actual loss on the cable

(3.1.1) From PSE point of view:

- Iport= (Pclass+Pcable) / Vpse
- Iport_peak= (Pclass_peak+Pcable_peak)/Vpse

(3.1.2) From PD point of view:

- Iport=Pclass/Vpd(Idc)
- Iport_peak=Pclass_peak/Vpd(Ipeak)

(4) Iport at the PD is defined as Pport/Vport

(5) Iport peak at the PD is defined as maximum value per Class at Vpse_min. (for legacy PD)

(6) Iport_peak for Type 2 PD is defined as (0.4/0.35)*Pport/Vport

(7) Iport peak for Class 0,3 and 4 meets the rule of Iport_peak=Icable*0.4/0.35

- Iport_peak for Class 1 and 2 is not meeting this rule. It contains some margins due to lower DC/DC efficiency at lower PD loads

- ☑ PD Section

- ■ PSE Section
- ■ Synchronizing between PSE and PD

# Analyzing Current 802.3 Draft 1.0 + resolved comments. 

| Item | Parameter | Symbol | Unit | Min | Max | PD Type | Additional Information | Comment Resolution |
|---|---|---|---|---|---|---|---|---|
| 1 | Input Voltage | Vport | V | ~~36~~37 | 57 | 1 | See 33.3.5.1 | #31,#259 |
| | | | | ~~40~~41 | 57 | 2 | | |
| 1a | Transient operating input voltage | VTran_low | V | 36 | | 2 | For time duration defined in 33.2.8.2b | #31 |
| 1b | Input voltage during overload | Voverload | V | 36 | 57 | 1 | See 33.3.5.4 | #31, #95, #259 |
| | | | | 39.7 | 57 | 2 | | |
| 2 | Input average power | Pport | W | | ~~12.95~~ | 1 | See 33.3.5.2 | #260, #32 |
| | | | | | Vport_min x Icable ~~29.5~~ | 2 | | |
| 4 | Peak operating current, Class 0,3 | Iportpk | A | | 0.4 | 1 | See 33.3.5.4 | #35 |
| | Peak operating current, Class 1 | | | | 0.12 | 1 | | |
| | Peak operating current, Class 2 | | | | 0.21 | 1 | | |
| | Peak operating current, Class 4 | | | | (400/350)x Icable | 2 | | |

Iportpk

- 33.3.5.4 Peak Operating Current
  - At any operating condition the peak current shall not exceed PPort_**max**/VPort for more than 50ms max and 5% duty cycle max. Peak current shall not exceed IPort**pk** max.

See Drawings Next Slide

# In Numbers.. ( 2 of 3)

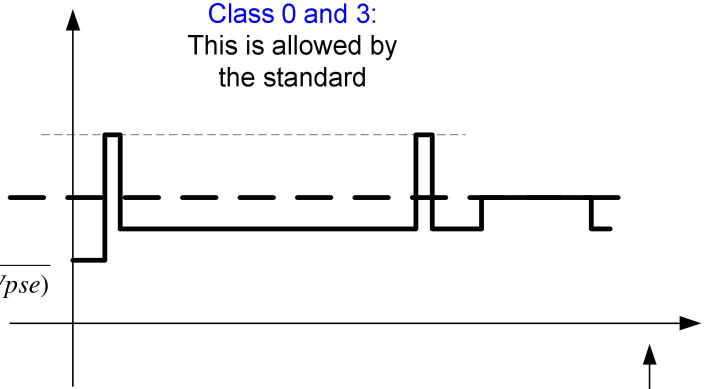
| Iport | Time duration and Duty Cycle | Iport_peak |
|---|---|---|
| Iport_avg=Iport=Pport_max/Vport=:<br>Vport is a number between 36V to 57 (Table 33-12 item 1) per equation (1) below | <50msec, 5% | 0.4A for Class 0,3<br>0.12A for Class 1<br>0.21A for Class 2 |
| | >50msec, 5% | Pport_max/Vport=<br>12.95W/37V=350mA @ Vpse=44V<br>12.95W/52V=250mA @ Vpse=57V<br>Vport is a number between 36V to 57 (Table 33-12 item 1) per equation (1) |

| | | Type 1 | | | | | | Type 2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class | 0,3 | 0,3 | 2 | 2 | 1 | 1 | 4 | 4 | 4 | 4 |
| | Vpse | 44.00 | 57.00 | 44 | 57 | 44 | 57.00 | 50 | 57 | 50 | 57 |
| | Rch | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 20.00 | 12.5 | 12.5 | 12.5 | 12.5 |
| | Pclass | 12.95 | 12.95 | 6.49 | 6.49 | 3.84 | 3.84 | 29.5 | 29.5 | 20 | 20 |
| Eq-1 | Vport(PD)=(Vpse+(Vpse^2-4*Pclass*Rc)^0.5)/2 | 37.00 | 52.02 | 40.82 | 54.62 | 42.18 | 55.62 | 41.01 | 49.56 | 44.36 | 52.21 |
| | Iport=Pclass/Vport | **0.35** | **0.25** | **0.16** | **0.12** | **0.09** | **0.07** | **0.72** | **0.60** | **0.45** | **0.38** |
| | Ipeak (Table 33-12 item 4) | **0.40** | **0.40** | **0.21** | **0.21** | **0.12** | **0.12** | **0.82** | **0.68** | **0.52** | **0.44** |
| | Ipeak/Iport [%] | 1.14 | 1.61 | 1.32 | 1.77 | 1.32 | 1.74 | 1.14 | 1.14 | 1.14 | 1.14 |

# Analyzing Current 802.3 text. 3 of 3

Explicit 0.4A

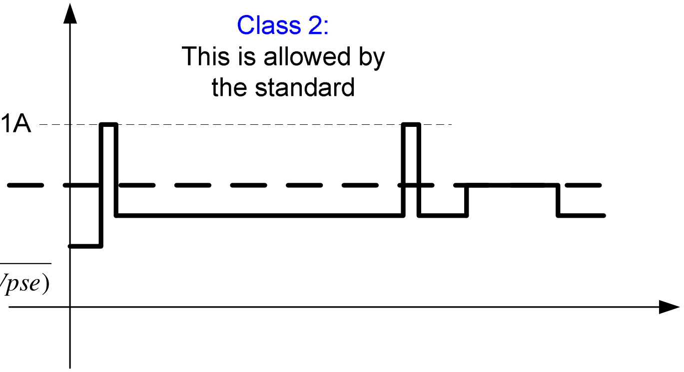
Explicit $Iport = \frac{Pport\_max}{Vport} = \frac{12.95W}{Vport(12.95W, Rchannel, Vpse)}$




## Pport, Pclass and Vport as measured at the PD

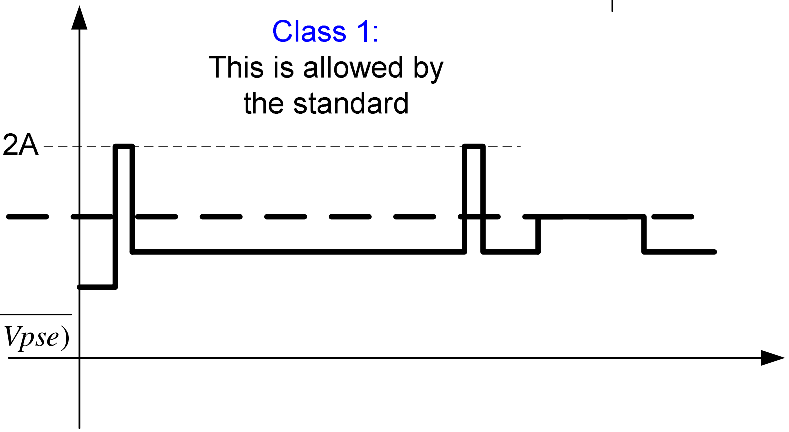
Explicit 0.21A

Implicit $Iport = \frac{Pport\_class2}{Vport} = \frac{6.49W}{Vport(6.49W, Rchannel, Vpse)}$

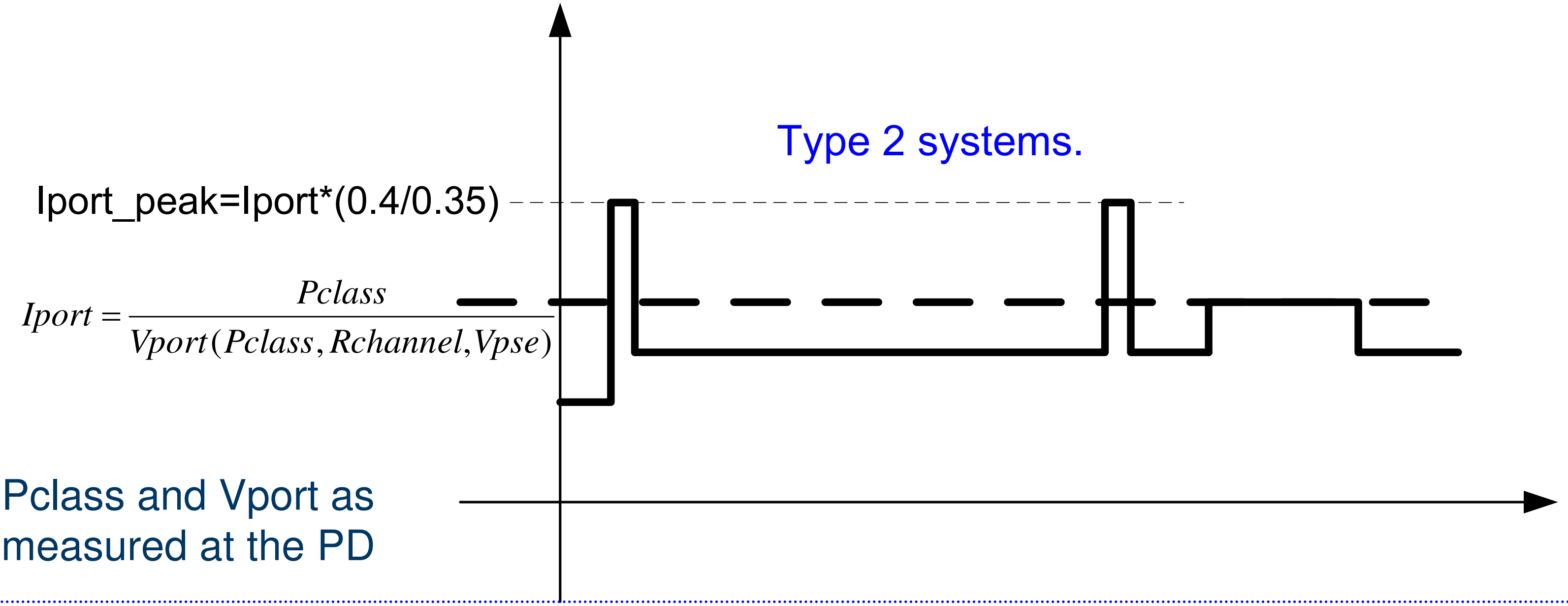



Explicit 0.12A

Implicit $Iport = \frac{Pport\_class1}{Vport} = \frac{3.84W}{Vport(3.84W, Rchannel, Vpse)}$



# Vport ad hoc objectives for Type 2 systems




☑Iport is function of Vport and Pport=Pclass

☑Iport_peak=(0.4/0.35)*Iport which is function of Vport and Pport=Pclass

☑Our objectives for Type 2 PDs and for Type 2 PDs that are using lower power then Pclass4 due to L2 results, are met as well.

# How to meet objectives for Type 1 Systems?

- ☑ Iport is function of Vport and Pport=Pclass *(Explicit for Class 0,3)*
- ☑ For Class 0,3: Iport_peak=(0.4/0.35)*Iport which is function of Vport and Pport=Pclass

- For Class 1,2:
  - Ipeak as defined in Table 33-12 item 4 **>** (0.4/0.35)*Pclass/Vport
  - We need to find a way to present Ipeak as function of Vport, Pclass etc.

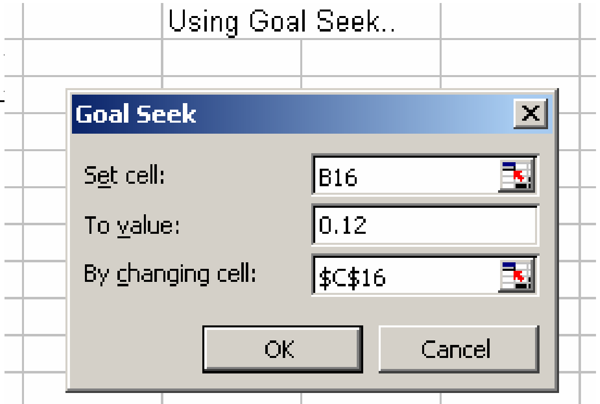
- See next slide for the methodology to get it done

# How to present Ipeak as function of PSE voltage

- Ipeak_max is obtained at Pport_peak, Rchannel_max and Vpse_min (Table 33—12 item 4)
- Ipeak is decreased when Vpse is increased for given Ppd and Rchannel
- Therefore to get Ipeak as function of Vpse, we need to convert Ipeak to PD peak power, Ppd.
- **Step 1: Convert Class 0,1,2,3,4 peak current to peak power**

$$Ipd = \frac{(Vpse - (Vpse^2 - 4 \cdot Rch \cdot Ppd)^{0.5})}{2Rch} = \frac{(44 - (44^2 - 4 \cdot 20 \cdot Ppd)^{0.5}}{20}$$

$$Solve\ Ppd\ \ for\ Ipd = 0.4A.......Ppd = (See\ Goal\ Seek\ \ \mathrm{Re}\, sults)$$




| Vpse | Rch | Ppd_peak | Ipd_peak |
|---|---|---|---|
| 44 | 20 | 14.4 | 0.4 |
| 44 | 20 | 4.992342 | 0.120009 |
| 44 | 20 | 8.361158 | 0.210089 |
| 50 | 12.5 | 32.65092 | 0.821897 |

- Class 0,3: 0.4A ➔ 14.4W (➔OK)
- Class 1: 0.12A ➔ 4.99W
- Class 2: 0.21A ➔ 8.36W
- Class 4: (0.4/0.35)*Icable ➔ Vport_min(Type 2)*Icable*(0.4/0.35)

# Summary for PD – Proposed Remedy for the PD section

| Item | Parameter | Symbol | Unit | Min | Max | PD Type | Additional Information |
|---|---|---|---|---|---|---|---|
| 4 | PSE minimum peak operating current, Class 0,3 | Iport**pk** | A | | 14.4/Voverload | 1 | See 33.3.5.4 |
| | Peak operating current, Class 1 | | | | 4.99/ Voverload | 1 | |
| | Peak operating current, Class 2 | | | | 8.36/Voverload | 1 | |
| | Peak operating current, Class 4 | | | | Vport_min*Icable*(0.4/0.35)/ Voverload | 2 | |

Add to 33.3.5.4:

Voverload in a PSE-PD system can be approximated by:

$$Voverload = \frac{Vpse + (Vpse^2 - 4 \cdot Ppd \cdot Rc)^{0.5}}{2}$$

Voverload is the PD input voltage when Ppd is the PD peak power.
If Ppd is the average power of Pclass, then Voverload=Vport.
Rc is the channel resistance for type 1 and 2 systems as defined in clause TBD.

☑PD Section

☑PSE Section

- Synchronizing between PSE and PD

# PSE section : Analyzing Current 802.3 text.

**33.2.8.4 ~~Maximum Type 1~~ PSE max output current in normal powering mode at ~~PSE~~ min output voltage**

For $V_{Port}$ > ~~44 V~~ $V_{Port}$ min, the minimum value for $I_{Port\_max}$ in Table 33–5 shall be ~~15.4 W~~ ($P_{Port}$ / $V_{Port}$). The current $I_{Port\_max}$ ensures ~~15.4 W~~ $P_{Port}$ min output power.

1

The PSE shall support the following AC current waveform parameters:

$I_{peak}$ = (400 / 350) × ($P_{Port}$ / $V_{Port}$) minimum for 50 ms minimum and 5 % duty cycle minimum.

2

~~a) $I_{peak}$ = 0.4A minimum for 50ms minimum and 5% duty cycle minimum.~~

~~b) For $V_{Port}$ > 44V, $I_{peak}$ = 17.6 W/$V_{Port}$~~

3

1. Iport average: Supports PD constant power model for type 1 and 2 PDs➔ Match PD spec. ➔ OK.
2. Iport peak: Supports only Type 2 PD.

2.1 Violates Table 33-12 item 4 for class 1 and 2.

3. Iport_peak: Item a) is good only for class 0 and 3. It is not function of Vport.

   Item b) Ipeak is 17.6W/Vport for all classes. Fully supports Table 33-12 with high margins for classes 1 and 2

3.1 The editor was not authorized do make changes 2 and 3 although some of it is good for Type 2 but not for Type 1. See comment #114 for Draft 1.0.

# Recommendations

- Part 1 of 33.2.8.4 is good. No changes are required.
- Part 3 of 33.2.8.4 should be deleted (as done in Draft 1.0)
- Part 2 deals with Ipeak.

Update 33.2.8.4 per the next slide:

**33.2.8.4 ~~Maximum~~ ~~Type 1~~ PSE max output current in normal powering mode at ~~PSE~~ min output voltage**

For $V_{Port}$ > ~~44 V~~ $V_{Port}$ min, the minimum value for $I_{Port\_max}$ in Table 33–5 shall be ~~15.4 W~~ ($P_{Port}$ / $V_{Port}$). The current $I_{Port\_max}$ ensures ~~15.4 W~~ $P_{Port}$ min output power.

1

The PSE shall support the following AC current waveform parameters:

$I_{peak}$ = (400 / 350) × ($P_{Port}$ / $V_{Port}$) minimum for 50 ms minimum and 5 % duty cycle minimum.

2

~~a) $I_{peak}$ = 0.4A minimum for 50ms minimum and 5% duty cycle minimum.~~

~~b) For $V_{Port}$ > 44V, $I_{peak}$ = 17.6 W/$V_{Port}$.~~

3

# Updated part 2 of 33.2.8.4

| Table 33-2a (TBD) | | | |
|---|---|---|---|
| Class | Minimum peak power at PSE port [W] | Minimum Peak Current at PSE port [A] | Additional Information |
| 0,3 and 4 | (400/350)xPport | (400/350)xPport / Vport | 1) Vport is specified in Table 33-5 item 1.<br>2) Pport is specified in Table 33-3.<br>3) PSE peak power=PD peak power + Channel power loss at PD peak current. |
| 1 | 5.28 | 5.28/Vport. | |
| 2 | 9.24 | 9.24/Vport | |

**<u>Change from:</u>**

The PSE shall support the following AC current waveform parameters:

Ipeak = (400 / 350) × (PPort / VPort) minimum for 50 ms minimum and 5 % duty cycle minimum.

**<u>To:</u>**

The PSE shall support the peak current values as defined in Table 33-2b for 50 ms minimum and 5 % duty cycle minimum.

The PSE may support lower peak current values if the actual peak power is lower then specified in Table 33-2a due to system additional information.

The derivation of system additional information is out of scope of this standard

# Sanity Check- Text Synchronization Test

| Class | Iport | Iport_peak | Iport | Iport_peak |
|---|---|---|---|---|
| 0,3 | 15.4/Vport | 17.6/Vport | 12.95/Vport[1] | 14.4/Vport[2] |
| 1 | 4/Vport | 5.28/Vport | 3.84/Vport[1] | 4.99/Vport[2] |
| 2 | 7/Vport | 9.24/Vport | 6.49/Vport[1] | 8.36/Vport[2] |
| 4 | $\frac{Icable\_max \cdot Vport\_min}{Vport}$ | $\frac{0.4}{0.35} \cdot Iport$ | $\frac{Icable\_max \cdot Vport\_min^{1}}{Vport^{1}}$ | $\frac{0.4}{0.35} \cdot Iport$ |

- Text or numbers already in the baseline or calculated from it
- Calculated from PD specifications (Table 33-12 item 4) and system constants
- (1) PD input voltage is calculated by Vport=0.5*((Vpse+(Vpse^2-4*Pport*Rc)^0.5)
- (2) PD input voltage is calculated by Voverload=0.5*((Vpse+(Vpse^2-4*Pport_peak*Rc)^0.5)

# Detailed Calculations

**Class 0,3**

$$Ppd = 12.95,\ \ Iport = 0.35A \quad (IEEE802.3)$$

$$Ppd\_peak = \frac{0.4}{0.35} \cdot 12.95W = 14.4W \quad (IEEE802.3)$$

$$Pcable = 0.35^2 \cdot 20 = 2.45W \quad (IEEE802.3)$$

$$Pcable\_peak = 0.45^2 \cdot 20 = 3.2W \quad (IEEE802.3)$$

$$Ppse = Ppd + Pcable = 12.95 + 2.45 = 15.4W \quad (IEEE802.3)$$

$$Ppse\_peak = Ppd\_peak + Pcable\_peak =$$

$$14.4 + 3.2 = 17.6W \quad (IEEE802.3)$$

**Class 2**

$$Ppd = 6.49,\ \ Iport = 0.159A \quad (IEEE802.3)$$

$$Ppd\_peak = 0.21 \cdot Vpd(0.21A) = 8.36W \quad (IEEE802.3)$$

$$Pcable = 0.159^2 \cdot 20 = 0.506W \quad (IEEE802.3)$$

$$Pcable\_peak = 0.21^2 \cdot 20 = 0.883W$$

$$Ppse = Ppd + Pcable = 6.49 + 0.506 = 7W \quad (IEEE802.3)$$

$$Ppse\_peak = Ppd\_peak + Pcable\_peak =$$

$$8.36 + 0.883 = 9.244W$$

**Class 1**

$$Ppd = 3.84,\ \ Iport = 0.091A \quad (IEEE802.3)$$

$$Ppd\_peak = 0.12 \cdot Vpd(0.12A) = 4.99W \quad (IEEE802.3)$$

$$Pcable = 0.091^2 \cdot 20 = 0.166W \quad (IEEE802.3)$$

$$Pcable\_peak = 0.12^2 \cdot 20 = 0.288W$$

$$Ppse = Ppd + Pcable = 3.84 + 0.166 = 4W \quad (IEEE802.3)$$

$$Ppse\_peak = Ppd\_peak + Pcable\_peak =$$

$$4.99 + 0.288 = 5.28W$$

**Class 4**

$$Ppd = 29.52,\ \ Iport = 0.72A \quad (IEEE802.3at)$$

$$Ppd\_peak = \frac{0.4}{0.35} 0.72 \cdot Vpd(\frac{0.4}{0.35} 0.72) = 32.68W \quad (IEEE802.3at)$$

$$Pcable = 0.72^2 \cdot 12.5 = 6.48W \quad (IEEE802.3at)$$

$$Pcable\_peak = 0.823^2 \cdot 12.5 = 8.467W \quad (IEEE802.3at)$$

$$Ppse = Ppd + Pcable = 29.52 + 6.48 = 36W \quad (IEEE802.3at)$$

$$Ppse\_peak = Ppd\_peak + Pcable\_peak =$$

$$32.68 + 8.467 = 41.15W \quad (IEEE802.3at)$$

# Discussion

# Reference Material

*Cl* **33** *SC* **2.8.4** *P* **42** *L* **38** *#* 114, *Comment Type* **TR**

Comment

1. The editor was not authorized to make the changes in this clause due to the fact that the remedy suggested by the ad-hoc was not concluded and adopted.

2. In addition, the new text makes legacy PSE non compliant due to the fact that the peak power for type PSE is not function of (Pport/Vport)*(0.4/0.35) for class 1 and 2. It is correct only for class 0,3.

3. The peak current is already defined in Table 33-12 item 12 (Ed note: Item 4) and we don't need to define it again for the PSE due to the simple physical fact the PSE output current is equal to the PD input current..

*SuggestedRemedy*

Option 1: (Not recommended) Restore the old text.

Option 2: (Recommended) Change the text in line 38 from:

"The PSE shall support the following AC current waveform parameters:

Ipeak = (400 / 350) ª (PPort / VPort) minimum for 50 ms minimum and 5 % duty cycle minimum."

To: "The PSE shall support the following the maximum peak current as defined by Table 33-12 item 4 for 50 ms minimum and 5 % duty cycle minimum."

Note to the group:

1. The peak current already defined in table 33-12 item 4. No need to repeat it again.
2. The peak current numbers should be defined in one place i.e. in the PD side due to the fact that it is defined by the load and the PSE has only to support it.
3. The peak current with option b remedy is function of (0.4/0.35)*Port/Vport only for Type 2 PD due to the fact that we don't have to take in account previous legacy definitions. For type 1 class 1 and 2 PDs, the constant power model contains some margin from reasons that was explained in my presentation (that was not presented yet) which is located at the web site of the October 2007 meeting).
3. For class 0,3 the peak current is a constant and not a function of Vport. (The average current was described as a function of Pport/Vport.)

Taking all this data in account, leads to the suggested remedy of option b.

- Old Material for reference

# IEEE802.3 Draft D1.0 Status

Eq-2 is just Informative..

$$(Eq-2)\ \ Kp_{class} = \frac{Ki_{class} \cdot (Vpse - Ki_{class} \cdot Iport\_avg \cdot Rc)}{(Vpse - Iport\_avg \cdot Rc)}$$

| Source | Table 33-10 | | Table 33-12 | Table 33-12 | Table 33-12 | Table 33-12 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Name | Ppd_Class | Ppd_Class | Vpd | Vpd | Iport | Iport | Ppeak/Pavg | Ipeak/Iavg | Rc | Vpse |
| Units | W (DC/RMS) | W peak | avg | at Ipeak | peak | avg | **Kp** | **Ki** | OHMS | Vdc |
| Class1 | 3.84 | 4.992 | 42.179 | 41.600 | 0.12 | 0.091 | 1.300 | 1.318 | 20 | 44 |
| Class 2 | 6.49 | 8.358 | 40.820 | 39.800 | 0.21 | 0.159 | 1.288 | 1.321 | 20 | 44 |
| Class 0,3 | 12.95 | 14.400 | 37 | 36.000 | 0.4 | 0.350 | 1.112 | 1.143 | 20 | 44 |
| Class 4 | 29.52 | 32.683 | 41.000 | 39.713 | 0.823 | 0.720 | 1.107 | 1.143 | 12.5 | 50 |

$$(Eq-3)\ \ Iport\_peak = Ki_{class} \cdot Iport\_avg$$

$$(Eq-1)\ \ Iport\_avg = \frac{Vpse - (Vpse^2 - 4 \cdot Ppd \cdot Rc)^{0.5}}{2 \cdot Rc}$$

Shown in the specification or derived directly from it

Calculated values based on PD constant power equations

Rc=Channel Resistance

Vpse=PSE voltage

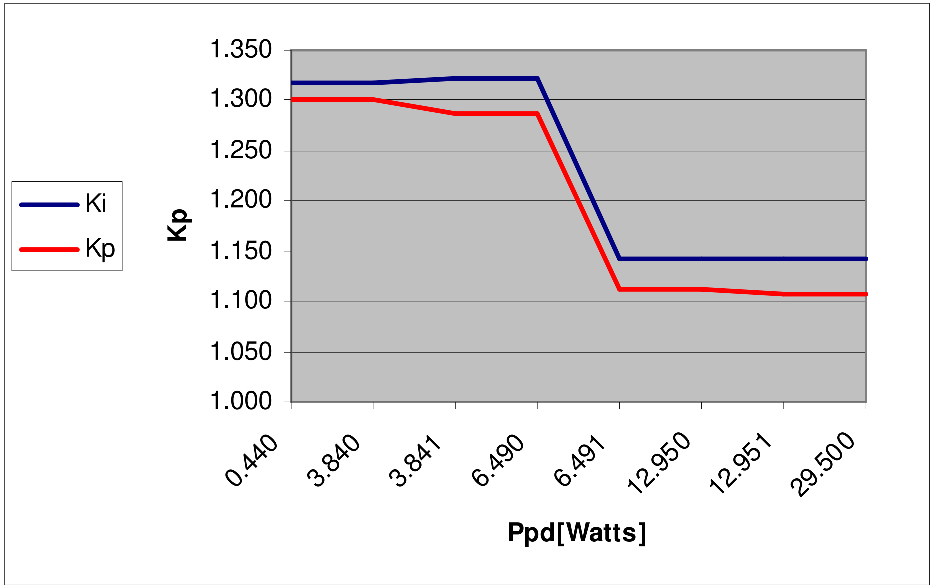
Ppd=PD average power

# Key inputs

- **Ki_class=Ipeak/Iavg. ➔ Ki_class determines Ipeak, Ppeak.**
- Kp_class is a function of Ki_class, Vpse and Iport_avg. It is not a constant actually it is a complex variable.
  - Kp transforms current to power in the PD constant power equations.
- **Using only Ki as proposed in the Table below allows meeting all our objectives**

| Class | Ppd | Kp | Ki |
|---|---|---|---|
| 1 | 0.440 | 1.300 | 1.318 |
| 1 | 3.840 | 1.300 | 1.318 |
| 2 | 3.841 | 1.288 | 1.321 |
| 2 | 6.490 | 1.288 | 1.321 |
| 0,3 | 6.491 | 1.112 | 1.143 |
| 0,3 | 12.950 | 1.112 | 1.143 |
| 4 | 12.951 | 1.107 | 1.143 |
| 4 | 29.500 | 1.107 | 1.143 |

Table TBD-1



# Additional Information

- Ipeak used in Table 33-12 item 4 contains margins for class 1 and 2 i.e. Ki>0.4/0.35. Hence the equation as proposed to be used needs some modifications to present Ipeak as function of Ki_class.
  - The actual PD constant power model is not pure constant power model since efficiency is not 100%. This is the reason for the margin taken for Class 1,2 at Iport_eak per table 33-12 item 4.

- Ipeak numbers per table 33-12 item 4 can not be changed due to the above rational and to keep legacy PDs compliant.

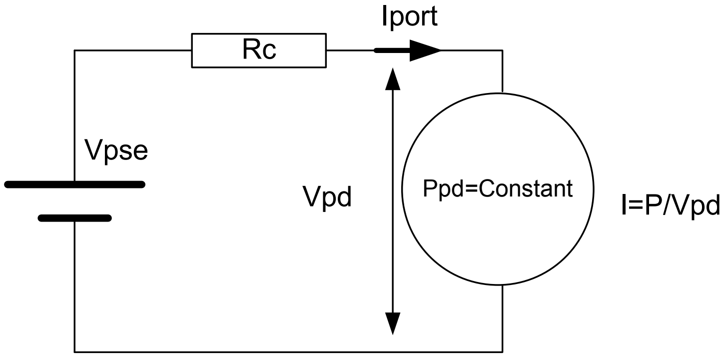
# Simplified PD constant Power Model[1]

$Assuming\ efficiency\ of\ PD\ is\ 100\%$

$$\frac{Vpse - Vpd}{Rc} = \frac{Ppd}{Vpd}$$

$$Vpd = \frac{Vpse + (Vpse^2 - 4 \cdot Ppd \cdot Rc)^{0.5}}{2}$$

$$Iport = \frac{Vpse - Vpd}{Rc} = \frac{Vpse - (Vpse^2 - 4 \cdot Ppd \cdot Rc)^{0.5}}{2 \cdot Rc}$$




$$Ki = \frac{Iport\_peak}{Iport\_avg}$$

$$Iport\_peak = Ki \cdot Iport\_avg$$

$$Vpd\_peak = (Vpse - Iport\_peak \cdot Rc)$$

$$Vpd\_avg = (Vpse - Iport\_avg \cdot Rc)$$

$$Kp = \frac{Ppd\_peak}{Ppd\_avg} = \frac{Vpd\_peak \cdot Iport\_peak}{Vpad\_avg \cdot Iport\_avg} =$$

$$Kp = \frac{Ki \cdot (Vpse - Ki \cdot Iport\_avg \cdot Rc)}{(Vpse - Iport\_avg \cdot Rc)}$$

Pport_peak

$$Iport\_peak = \frac{Vpse - (Vpse^2 - 4 \cdot Ppd\_avg \cdot Kp_{class} \cdot Rc)^{0.5}}{2 \cdot Rc}$$

$or$

$$Iport\_peak = Ki_{class} \left[ \frac{Vpse - (Vpse^2 - 4 \cdot Ppd\_avg \cdot Rc)^{0.5}}{2 \cdot Rc} \right]$$

# Actual PD constant power model

*Assuming efficiency of PD is a variable, eff :*

$$eff = \frac{Pout}{Ppd} = \frac{Pout}{Pout + Ploss}$$

$$Ploss = \frac{Pout \cdot (1 - eff)}{eff}$$

$$Reff = \frac{Pout \cdot (1 - eff)}{eff \cdot Iport^2}$$

$$Vpse - Ipd \cdot Rc - Ipd \cdot Reff = V$$

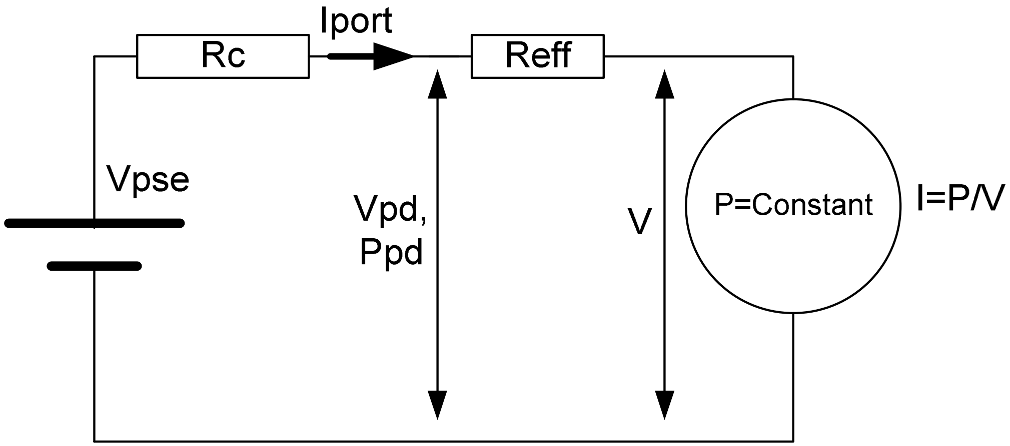
$$Ipd = \frac{P}{V}$$

$$V^2 - V \cdot Vpse + P(Rc + Reff) = 0$$

$$V = \frac{Vpse - (Vpse^2 - 4 \cdot P \cdot (Rc + Reff))^{0.5}}{2}$$

$$Ipd = \frac{Vpse - V}{Rc + Reff}$$

$$Vpd = V + Reff \cdot Ipd$$




$$Ipeak = \frac{Vpse - (Vpse^2 - 4 \cdot P \cdot Kp\_class \cdot (Rc + Reff))^{0.5}}{2 \cdot (Rc + Reff)}$$

*or*

$$Ipeak = Ki_{class} \left[ \frac{Vpse - (Vpse^2 - 4 \cdot P \cdot (Rc + Reff))^{0.5}}{2 \cdot (Rc + Reff)} \right]$$

For each Ppd we need to find its Reff, P numbers on order to get Vpd and Ppd. Next we have to use Ki, Kp techniques as in the simplified model

# Efficiency v.s. Power

- In conventional DC/DC converters efficiency is optimized near max. power.
- If output power is decreased, efficiency is decreased due to the growing effect of constant losses that are not function of the load power (housekeeping etc.)
- As a result, the simplified model is good enough at max. power range. At lower power range additional design margin is required. Hence Table 33-12 item 4 is using higher peak current than Ki=0.4/0.35 for class 1 and 2.