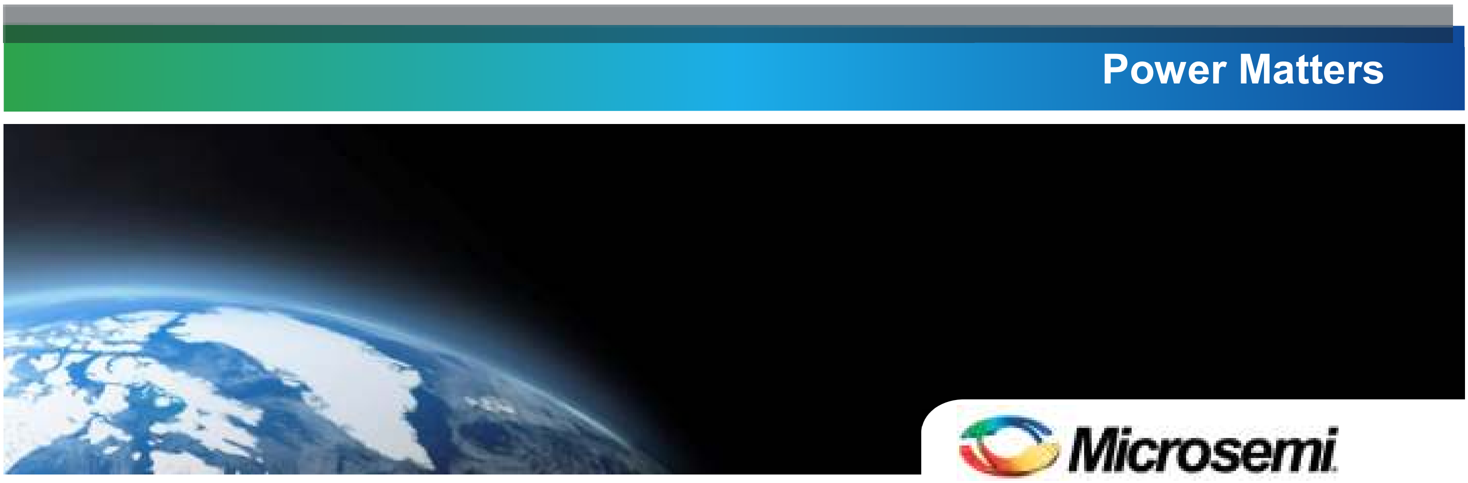

IEE802.3 4P Task Force

Derivation of:

- Pclass_PD for class 5-8.
- Updated Remedy for comment #20
  - Ppeak_PD for class 5-8
  - K for Equation 33-4 for Types 3 and 4
- Eq 33-12 for Type 3 and 4

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Rev 008

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Contents

Updated remedy for my Draft D0.4 comments.

Summary of system average, peak power and peak current parameters:

PD section

Pclass_pd(max)

(1) To update table 33-18 item 4 according to the following table.

Input average power Class	Pclass_pd(max)
5	39.94 (can be rounded to 40)
6	51.00
7	62.00

Equation 33-12 and Table 33-18 item 7

(2) To update clause 33.3.7.4 page 81 line 32 as follows:
[We have two options for Remedy and I am recommending on Option 2 (less stress on PSE at classes 7 and 8), (group to select one option)].

Option 1

(A) Replace:
"power of class 0 through class 3…"
With:
"power of class 0 through class 8…"
(B) Update Table 33-18 item 7 for class 5-8: Ppeak_PD(MAX)=1.11xPclass_PD

OR Option 2

(A) Replace:
"Peak power, *P*Peak_PD, for Class 4 is based on Equation (33–12), which approximates the ratiometric peak powers of Class 0 through Class 3. This equation may be used to calculate peak operating power for *P*Peak_PD values obtained via Data Link Layer classification or Auto class."

With:
"Peak power, *P*Peak_PD, for Class 4, 5 and 6 is based on Equation (33–12). Peak power, *P*Peak_PD, for Class 7 and 8 is based on Equation 33-12a, which approximates the ratiometric peak powers of Class 0 through Class ~~3~~8. This equation may be used to calculate peak operating power for *P*Peak_PD values obtained via Data Link Layer classification or Auto class."

(B) Add after Eq 33-12, the following Eq 33-12a:
Ppeak_PD={1.07xPclass_PD}$_W$ (33-12a)

(C) Update Table 33-18 item 7 for class 5-6:
Ppeak_PD(MAX)=1.11xPclass_PD
Update Table 33-18 item 7 for class 7-8:
Ppeak_PD(MAX)=1.07xPclass_PD

PSE section

Updated comment #20 and its updated remedy

Comment #20: Clause 33.2.7.4, page 56, line 34

Comment

1. For clarity, Iport-2P, Iport-2P-unb and Ipeak need to be explained in one location which is 33.2.7.4. In addition, the relationship between them is no sufficiently clear from Table 33-11.
2. Equation 33-4 needs some updates.
3. It is needed to clarify that Ppeak_PD-2P is half of the total Ppeak PD as defined in Table 33-18 for classes 5-8 (It is half the total power).
4. K is different number for Type 3 and 4.
5. The text that explains K Is not sufficiently accurate. (K is not equal to E2EP2P_Iunb).

Suggested Remedy

(1) In clause 33.2.7.4 page 56 lines 28-30: Change text to the following:

For Type 3 and Type 4 PSEs, ICon-2P as specified in Table 33–11 shall be met when there is no end-to-end pair to pair current unbalance.

When end-to-end pair to pair current unbalance is present, the $I_{Con\text{-}2P}$ may increase up to the value of $I_{Con\text{-}2P\text{-}UNB}$ as specified by Table 33-11 item 4b.

In addition to ICon-2P as specified in Table 33–11, the PSE shall support the following AC current waveform parameters per pair-set, while within the operating voltage range of VPort_PSE-2P: IPeak-2P minimum for TCUT-2P minimum and 5 % duty cycle minimum, where

(2) In clause 33.2.7.4 page 56 line 42:

Repalce:

*“P*Peak_PD-2P is the peak power a PD may draw per pair-set for its class; see Table 33–18”

With:

*“P*Peak_PD-2P is the peak power a PD may draw per pair-set for its class; see Table 33–18. For classes 5-8, *P*Peak_PD-2P is calculated per Equation 33-4.1.”

Ppeak_PD-2P=0.5xPpeak_PD (33-4.1)

(3) In clause 33.2.7.4 page 56 line 43:

Replace:

“K is the factor due to “system end to end pair-to-pair current unbalance effect”. K=0 for two pair systems and K=TBD for four pair systems.”

With:

“K is the ratio between Ipeak-2P due to “system end to end pair-to-pair unbalance effect” and Ipeak-2P of a system with perfect “system end to end pair-to-pair balance” in Type 3 and Type 4 systems. K=0 for two pair systems (Type 1 and Type 2 systems).

The value of K for Type 3 and Type 4 that operates as four pair system are given by Equation 33-4.2.”

$$K = \min\begin{cases} 0.1882 \cdot Rchan^{-0.337},\ 0.28 & for\ type\ 3.\} \\ 0.1777 \cdot Rchan^{-0.329},\ 0.26 & for\ type\ 4.\} \end{cases} \qquad (33\text{-}4.2)$$

Detailed Analysis

Pclass_PD: Table 33-18 item 4.

Pclass_pd is specified in Table 33-18 and is calculated by Eq-1:

$$P_{CLASS\_PD} = P_{CLASS} - Rchan\_eff \cdot \left(\frac{P_{CLASS}}{Vpse_{\min}} \right)^2 \qquad \text{Eq-1}$$

Where:
Pclass_PD is the total PD power.
Pclass is the total PSE power.
$Rchan_{eff}$ is the total equivalent channel resistance were power is delivered. Rchan is defined by table 33-1 in IEEE802.3-2012 for Type 2 systems were $Rchan_{eff}$=Rchan.

- For 2P operation it is $Rchan_{eff}$=Rchan =12.5Ω. For 4P operation, $Rchan_{eff}$ =0.5*Rchan=6.25Ω.

Table 1 shows the final calculation results for Pclass_PD:

							Table 33-18 item 4
Class	Pclass	Vpse	Iport_2P	Iport_4P	Rchan	$Rchan_{eff}$ [1]	Pclass_pd
4	30	50	0.6	-	12.5	12.5	25.5
5	45	50	0.45	0.9	12.5	6.25	39.94
6	60	50	0.6	1.2	12.5	6.25	51.00
7	75	52	0.72	1.44	12.5	6.25	62.00
8	90	52	0.865	1.73	12.5	6.25	71.28➔ 71.3

Table 1: Pclass PD calculations results

Note 1: In perfectly balanced system where all components have maximum loop resistance of Rmax=Rmin=R=12.5Ω which results with $Rchan_{eff}$ of 12.5Ω for 2P system or 6.25Ω for 4P system, we will get the values that we see in Pclass_PD and the current as shown in Iport_2P and Iport-4P columns. In unbalanced P2P system, due to the fact that There is unbalance in system channel components resistance i.e. Rmax>Rmin per any component along the wire from and to end, the equivalent round loop resistance will be a bit lower than 6.25 Ω for 4P system due to the fact that $Rchan_{eff}$ =Rmax*Rmin/(Rmax+Rmin) is less than Rmax/2=6.25 Ω. This will result with a bit higher PD available power than we see in Pclass_PD column OR if we keep the values of maximum power on Pclass_PD column, we will get a bit less current in Iport-2P and Iport-4P column due to a bit lower channel resistance.

Example: In perfect balanced system of Class 8, we will get:
Rchan=6.25 Ω . Iport-4P=1730.8mA which is Iport-2P= 865.4 mA.
<u>In unbalanced system we will get:</u>
Rchan<6.25 Ω (mainly lower due to 5% cable pair to pair unbalance). Iport-4P=1706.4mA (a bit lower than in the above for balanced system) and Iport-2P= 853.1=0.5* Iport-4P without the P2P_Iunb effect that will increase the current of the pair with lower resistance from 853.1mA to 931mA as can be seen below for Table 33-11 item 4a, Icont_2P_unb.

In the specification we will use the numbers in Table 1 as they are worst case with some margin.

Ppeak_PD : Table 33-18 item 7.

Ppeak_pd is specified in 33.3.7.4 and calculated per eq-33-12.

Equation 33-12 could be used for Type 3 systems due to the fact that it is 2xType 2 power level were Type 2 systems were used with Equation 33-12.

The question if it still can be used for higher power will be determined later according to Ipeak_2P maximum value with the effect of E2EP2P_Iunb in order to evaluate if the resultant Ipeak-2P is still cost effective for transformer design and other system considerations.

Ppeak_pd=1.11*Pclass_pd Eq-33-12.

Ppeak_pd calculation is presented by Table 2 based on equation 33-12 in clause 33.3.7.4:

Class	Pclass_pd From Table 1	Ppeak_pd/Pclass_pd ratio	Ppeak_pd Total Peak PD power
5	39.94	1.11	44.33
6	51	1.11	56.61
7	62	1.11	68.82
8	71.3	1.11	79.14

Table 2: Ppeak_pd calculations

Ipeak_2P PER Equation 33-4 with E2EP2P_Iunb effect.

Ipeak_2P maximum as function of system parameters is shown in equation 33-4 in clause 33.2.7.4 with effect of the system end to end pair to pair unbalances resistance/current effect (E2EP2P_Runb) K:

Note: K is not equal to E2EP2P_Runb.

$$I_{Peak-2P} = (1+K)\cdot\left\{\frac{V_{PSE-2P} - \sqrt{V^2{}_{PSE-2P} - 4\cdot R_{Chan}\cdot P_{Peak\_PD-2P}}}{2\cdot R_{Chan}}\right\}$$ Eq 33-4 from IEEE802.3bt Draft D0.4.

$$P_{Peak\_PD-2P} = 0.5\cdot P_{peak\_PD}$$ Eq 33-4a

$$K = \frac{Ipeak\_2P_{UNB}}{Ipeak\_2P_{BALANCED}}.$$ Specific values for K will be shown next pages.

Where

Ipeak-2P	The peak current over a pair-set which is the result of equation 33-4 and includes the system pair to pair current unbalance effect represented by K.
$Ipeak\_2P_{UNB}$	is found by SYSTEM simulation that account for all components resistance unbalance and PSE and PD Vdiff.
$Ipeak\_2P_{BALANCED}$	is found by the simulation model when all system components are set to Pair Runb=0 and P2P_Runb=0% or by calculation using equation 33-4 that represents perfect balanced system equation that has maximum loop resistance Rchan per table 1. K is found for Type 3 and Type 4 maximum Peak PD power with the same database used to simulate Icon-2P-unb in Table 33-11 item 4a (See Annex A).

Please note that K is not equal to E2EP2P_Runb or to E2EP2P_Iunb

$$\left(K = \frac{Ipeak\_2P_{UNB}}{Ipeak\_2P_{BALANCED}}\right) \neq \left(\frac{Ipeak\_2P_{UNB\_MAX} - Ipeak\_2P_{UNB\_MIN}}{Ipeak\_2P_{UNB\_MAX} + Ipeak\_2P_{UNB\_MIN}} = E2EP2P\_Iunb\right)$$

Table 3 shows the calculated Ipeak-2P for perfect E2EP2P balanced system. Table 4 will show the Ipeak-2P under E2EP2P_Iunb conditions specified by K.

Vpse	Rchan	PD Class	Pclass_pd	Ppeak_PD From Table 2	Ppeak_PD-2P	**Ipeak-2P, for P2P_Iunb=0%**
50	12.5	5	39.94	44.33	22.17	0.508
50	12.5	6	51.00	56.61	28.31	0.683
52	12.5	7	62.00	68.82	34.41	0.826
52	12.5	8	71.28	79.14	39.56	1.002

Table 3: Calculated Ipeak-2P for **P2P_Iunb=0%** i.e. at balanced theoretical system model with a PD operated as perfect constant power sink with 100% efficiency per Eq 33-4 and maximum loop resistance of Rchan over two pairs per Table 33-1 in IEEE802.3-2012.

Derivation of K for Equation 33-4.

From simulations we can see in Table 4 the following results:

Type	Class	Ppeak_PD [W]	Ipeak_2P_balanced (simulated and calculated, from Table 3) [A]	Ipeak-2P_unb(sim.) [A]	Conditions (Resistance is for a pair (two wires in parallel))	1+K
3	6	56.61	0.568	0.728	L=2meter, Rchan=0.125 Ω	1.2804
3	6	56.61	0.683	0.737	L=100meter, Rchan=12.5 Ω	1.0926
4	8	79.112	0.764	0.962	L=2meter, Rchan=0.125 Ω	1.26
4	8	79.112	1.002	1.074	L=100meter, Rchan=12.5 Ω	1.072

Table 4: Simulation results of maximum Ipeak-2P at pair to pair balanced condition and at unbalance conditions for calculating K.

We can see that K is function of system Type parameters and channel resistance. The following two options are possible to specify K. (a) K is worst case constant. K is function of Rchan as currently in Eq 33-4.

a) K is fixed worst case number:
   We will see in Annex B that if K is specified as worst case single number, then Ipeak-2P may be over specified or underspecified due to the fact that Ipeak-2P maximum under E2EP2P_Iunb condition may happen at short or long channel lengths pending system type 3 or 4 and its E2EP2P_Iunb curves. We need to make sure that Ipeak-2P is cost effective value due to the fact that we are using it to specify ILIM_MIN and also it is a requirement for transformer design pending system worst case conditions

b) K is function of Rchan.
   Eq-33-4 is function of Rchan. As a result, Ipeak can be different value for different Rchan value. The worst case Ipeak-2P under balanced conditions is obtained when Rchan=12.5Ω / pair.
   In an unbalanced P2P system conditions, K is also a function of Rchan.
   As a result, the entire equation 33-4 including the term K can be specified as function of Rchan which allow minimum use of margins that are mainly required at short channel lengths but less required at long channel lengths.

   As a result, the end user has the freedom to decide the value of Ipeak-2P of his system per the knowledge he have on its system parameters per Eq 33-4.
   For example, PD vendor that don have AC current per equation 33-4, can use transformers that can work with lower current. PSE vendor can control the PSE effect on the entire E2EP2P-Iunb and also use lower ILIM_MIN and transformers that stand lower maximum current etc.

   Choosing option (b) for updating the specifications.

It is important to understand that the total 4P Ipeak i.e. the total current sum of pairs with the same polarity is not 2xIpeak-2P. It will be less than 2xIpeak-2P . Moreover it will be less than Total Ipeak current that would be achieved in perfect P2P balanced system due to the fact that the channel resistance is in P2P unbalanced conditions are lower than in perfect balanced conditions. As a result total Ipeak current over pairs with the same polarity will be not affected by K.

$$I_{Peak-2P} = 2 \cdot \left\{ \frac{V_{PSE-2P} - \sqrt{V^2{}_{PSE-2P} - 4 \cdot R_{Chan} \cdot P_{Peak\_PD-2P}}}{2 \cdot R_{Chan}} \right\}$$

Rchan_unb is the effective pair common mode resistance when Rmax≠Rmin which will be resulted with Rchan_unb<Rchan.

Finding K as function of Rchan[Ω]

In order to find K as function of Rchan, simulations were run to find Imax, Imin (current values of the pairs with the same polarity) vs. Rchan for PD peak power, per Type 3 above which results with K as function of Rchan and converting the curve to equation as described in Annex B.

$$K = \min \begin{cases} 0.1882 \cdot Rchan^{-0.337},\ 0.28 \quad for\ type\ 3. \\ 0.1777 \cdot Rchan^{-0.329},\ 0.26 \quad for\ type\ 4. \end{cases}$$

We can see that as predicted in previous work, system P2P_Iunb is lower at higher power which resulted with lower K ratio for Type 4.

$$\frac{Ktype\_3}{Ktype\_4} = \frac{0.1882 \cdot Rchan^{-0.337}}{0.1777 \cdot Rchan^{-0.329}} == \frac{0.1882 \cdot Rchan^{(0.329-0.337)}}{0.1777} =$$

$$= 1.059 \cdot Rchan^{-0.008} = \frac{1.059}{Rchan^{0.008}}$$

The ratio is the highest at lowest Rchan and resulted with ~7% max at Rchan=0.25Ω (the actual 4P channel resistance is Rchan_eff which is half of it due to 4P operation) and the ratio will be lowest at Rchan=12.5Ω. This analysis can help later if we want to use K equation of Type 4, for Type 3 or vise versa for simplifying the specification however at this point of time, I prefer to optimize requirement to prevent situations of under or over specifications.

Addressing Equation 33-12

So far the analysis was assume that we keep using the existing ratio used in Equation 33-12 i.e. Ppeak_pd/Pclass_pd=1.11 for type 4 as well.

The existing ratio of 1.11 when used with Type 4, generates AC current peak level of (100%*(Ipeak-Icont)/Icont-1) 15.8%.

The motivation to reduce Ppeak_pd/Pclass_pd ratio is to reduce Ipeak-2P in 4P systems due to the additional current increase of one of the pairs (the one with lowest resistance) due to system P2P_Iunb.

Further reduction of Ipeak-2P in Type 4 systems is possible if the AC current peak level (100%*(Ipeak-Icont)/Icont-1) will be reduced from 15.8% peak (In Type 4) to ~10% peak and we can still be able to utilize the full DC and RMS power/current capability that AC CURRENT in the current allow us. (The use of AC current as specified in 33.2.7.4 and 33.3.7.4 allow us to utilize the full DC power capability. Without AC current definitions, the PD would have to limit its peak power to Pclass_PD which practically mean that PD maximum average power will be less than Pclass_PD due to existing practical AC current variations at PD and PD application components accuracy.)

As a result, reducing Ppeak_pd/Pclass_pd ratio at perfect balance conditions to from 1.11to 1.07 will results with reducing Ipeak-2P by ~5.4%.

It is recommended to discuss this possibility during the next meeting.

Specified Ppeak_PD=1.07xPclass_PD for Type 4 only will not change the requirements for K due to negligible effect and the existing margins we have as worse-case analysis concept that we have used so far.

Annex A: Simulation Data Base

For Type 3 use: Vpse=50.3V, Ppd=56.61W, L=2.65M, N=0.0001.

<u>Type 4 simulations data.</u>

For Type 3 use: Vpse=52.31V, Ppd=79.112W, L=100m, N=4.

Vpse = 52.31

RD_MODEL1 = 10MEG

Ideal_Diode_Bridge_Rdson = 10MEG

PARAMETERS:
P2PRunb = 0.05
Pair_Runb = 0.02
ILIM = 3
Resistivity = {0.1*Cordage_Resistivity+0.9*Cable_Resistivity}

alfa = {(1-Pair_Runb)/(1+Pair_Runb)}
beta = {(1-P2PRunb)/(1+P2PRunb)}
beta_special = 0.925

Ppd = 79.112

Lcable = 100

Cordage_Resistivity = 0.125

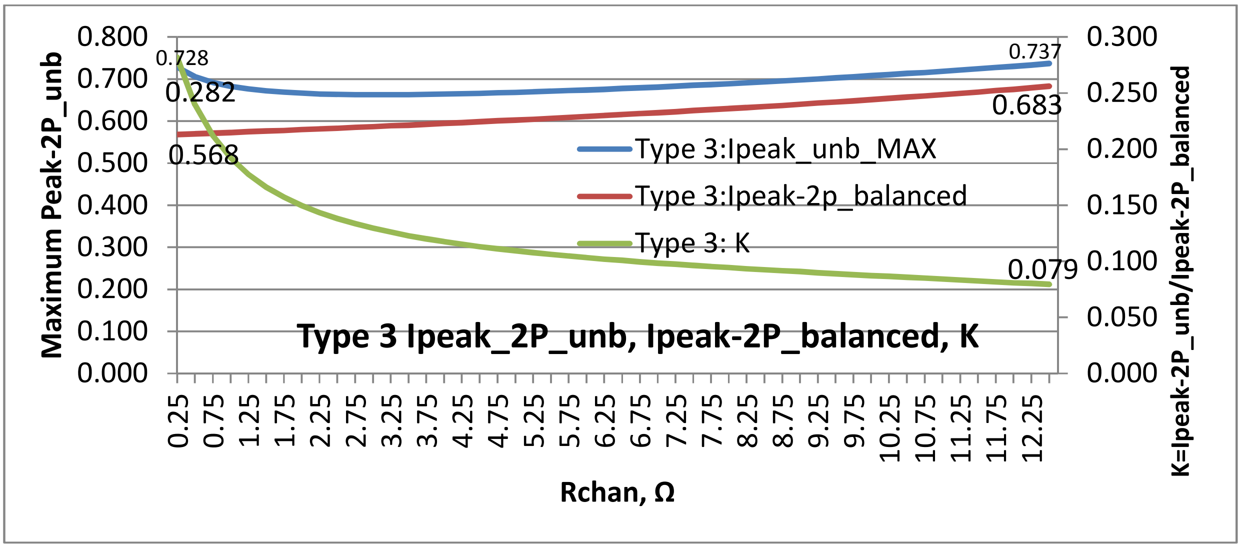
Cable_Resistivity = 0.125

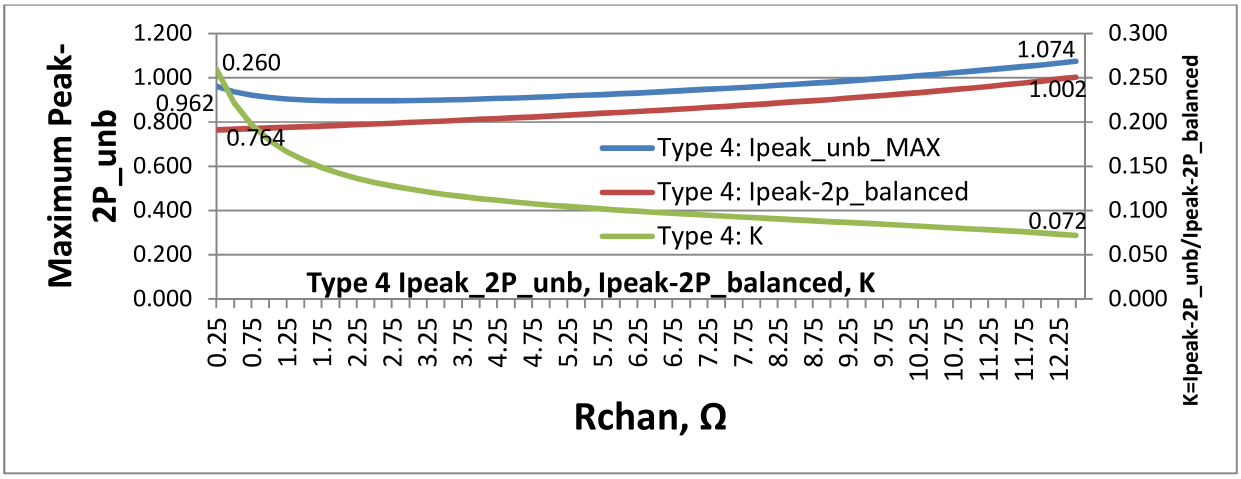
N_conn = 4

Rcable_max = {Lcable*Resistivity}

Rt_max = 0.13	Rt_min = 0.12
Rsense_max = 0.25	Rsense_min = {Rsense_max*0.98}
Rdson_max = 0.1	Rdson_min = 0.07
Rconn_max = 0.05	Rconn_min = 0.03
Vd_max = 0.001	Vd_min = 0.00001
Rd_max = 0.001	Rd_min = 0.001

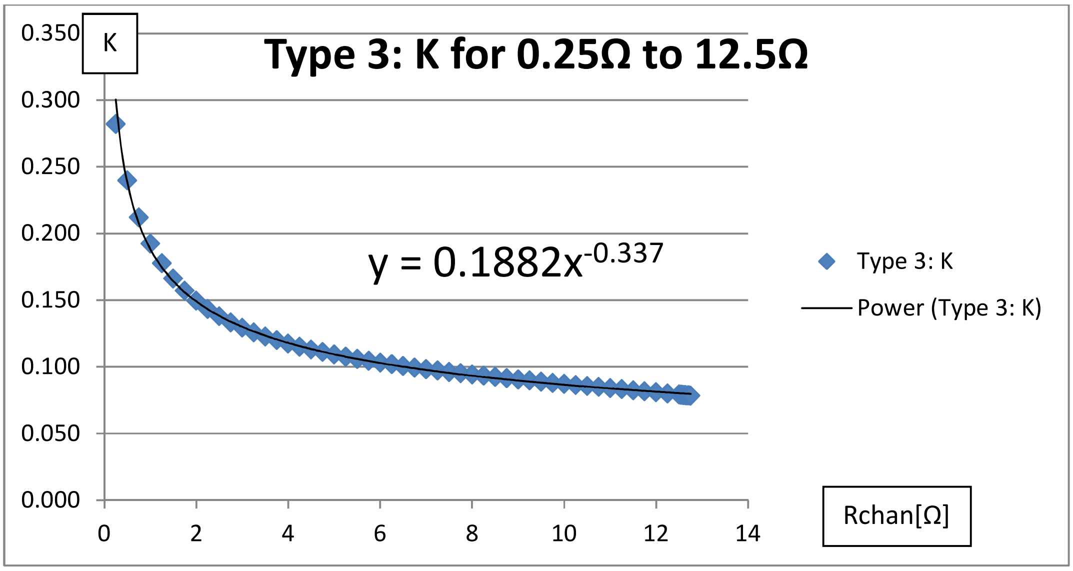
Annex B: Ipeak-2P and K vs. Rchan[Ω] derivation

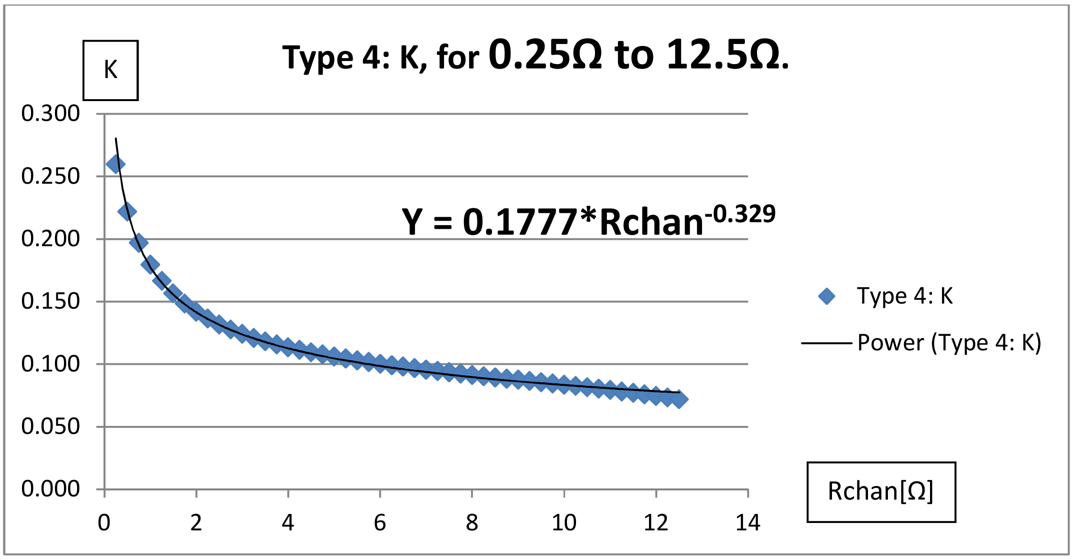




We can see that if we use constant worst case K, Ipeak-2P will be much higher than it will really be in reality due to the fact that Eq-33-4 is function of Rchan and K will be fixed, so the margin between Ipeak-2P at P2P unbalanced conditions and Ipeak-2P at perfect balanced condition will be high with no real need which is overdesigned specifications. When K as function of Rchan is used ,PD and PSE vendor can optimize its Ipeak-2P that is needed to be supported per the system parameters in Eq-33-4.

This is a different case where during the work for P2P_Runb for cables and channels we looked for constant worst case number due to the fact that the end user has no control on the channel installation being used and he will need to design for the worst case and not to specific channel and cable parameters.


K
Type 3: K for 0.25Ω to 12.5Ω
y = 0.1882x^-0.337
Type 3: K
Power (Type 3: K)
Rchan[Ω]
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0 2 4 6 8 10 12 14


K
Type 4: K, for 0.25Ω to 12.5Ω.
Y = 0.1777*Rchan^-0.329
Type 4: K
Power (Type 4: K)
Rchan[Ω]
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0 2 4 6 8 10 12 14