1PPoDL system Requirements Discussion

IEEE802.3bu Task Force

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Objectives

- Discussing 1PPoDL system Requirements based on objectives, inputs from RTPGE and other resources.

Inputs from Our Objectives

(1) Specify a power distribution technique for use over a single twisted pair link segment.

(2) Allow for operation if data is not present.

(3) Support voltage and current levels for the automotive, transportation, and industrial control industries.

(4) Do not preclude compliance with standards used in automotive, transportation, and industrial control industries when applicable.

(5) Support fast-startup operation using predetermined voltage/current

(6) configurations and optional operation with run-time voltage/current configuration.

(7) Ensure compatibility with IEEE P802.3bp (e.g., EMI, channel definition, noise requirements).

This presentation will focus on objectives 1,2 and 3

Inputs From RTPGE

- There is no defined 1-pair category cable
- The automotive OEMs use all different gauge cables among themselves and for different use cases.
- Therefore, 802.3bp TF has agreed to define the parameters (IL, RL, XTALK, balance) of the link segment and not define the wire size.
- The target IL number is centered around 23 Gauge cable. One automotive connector company (Rosenberger) showed data meeting the IL limit line with a 26-gauge automotive cable.

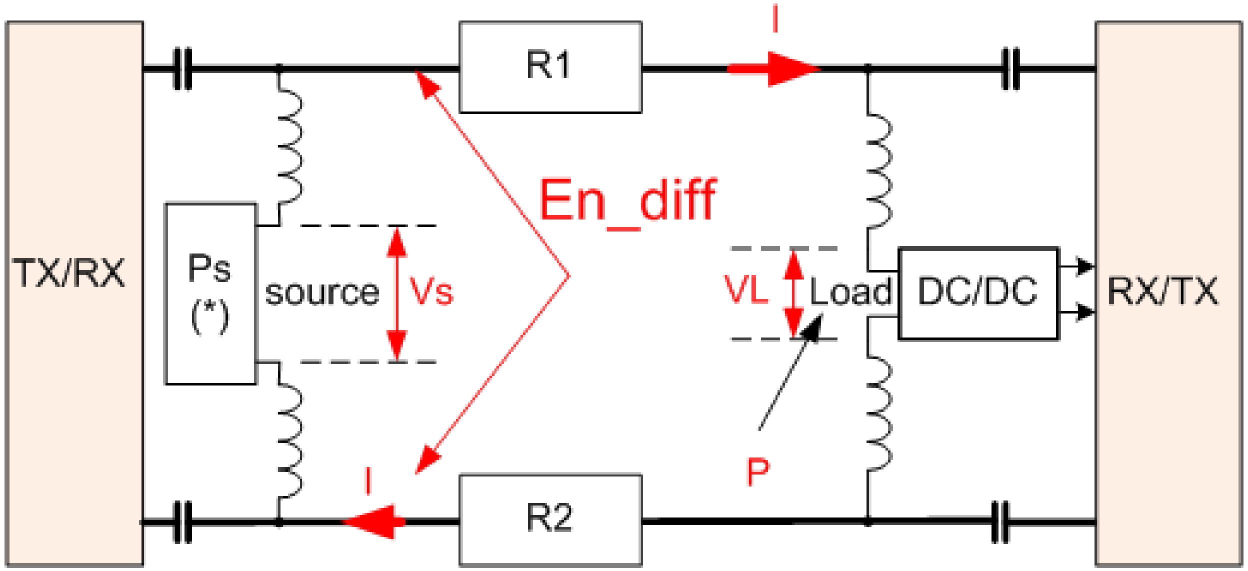
- As a result, this presentation will address the general case for any wire gauge.
- The procedure to determine the wire gauge per system requirements (Voltage/power/current) will be described.
- To discuss if to use the procedure as part of the spec to allow maximum flexibility vs. “less options=good spec,” assumption.

Inputs from CFI

- No dynamic configuration – network topology is static
- No structured cabling or specified connector
- 12V supply vs. 50V for IEEE 802.3 PoE
- Wire size can vary with current requirements
- Additional automotive-specific conformance requirements
- Cost efficiency
- Overall costs must be lower than dedicated power lines (significant challenge, will be discussed separately)
- Possible alternate use cases
- PoDL used as a turn-on signal

As a result, this presentation will address wide range of possible automotive and industrial source voltages.

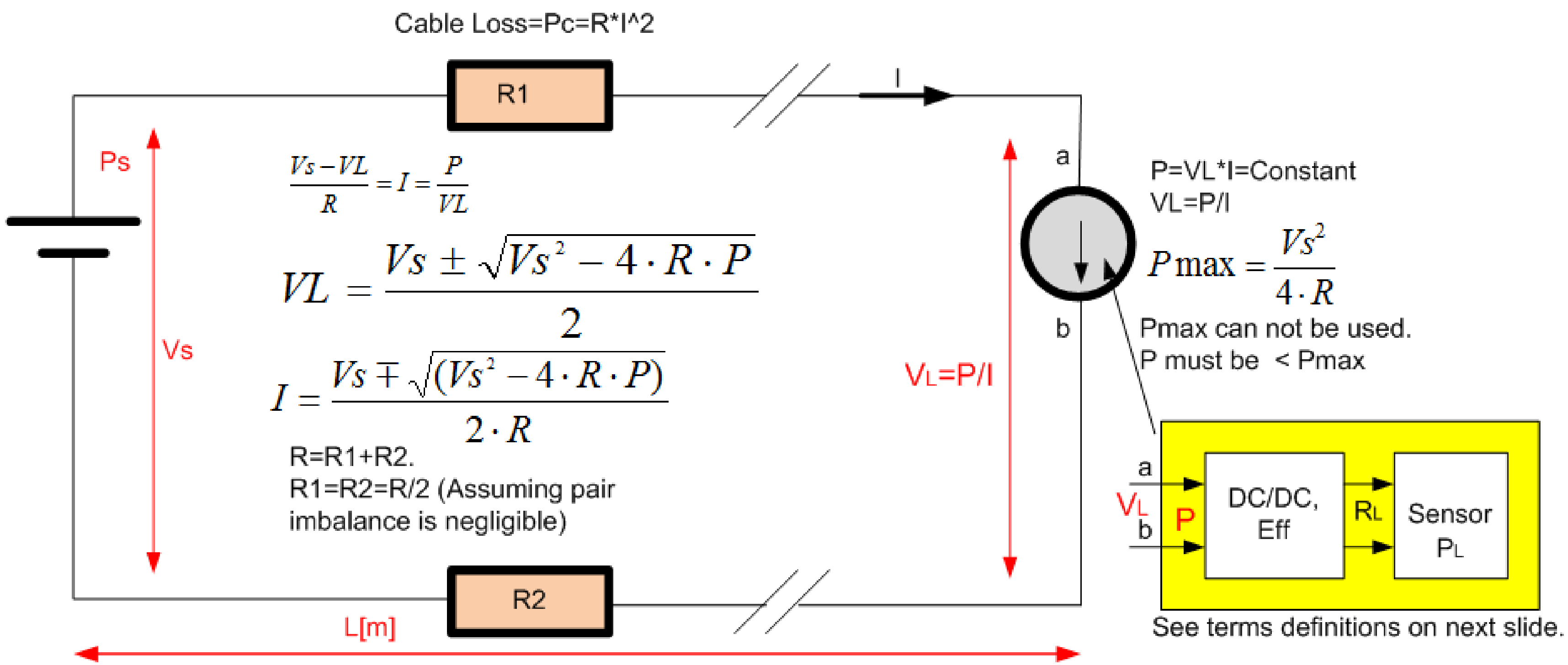
1 Pair Power Over Data Implementation **Example**.



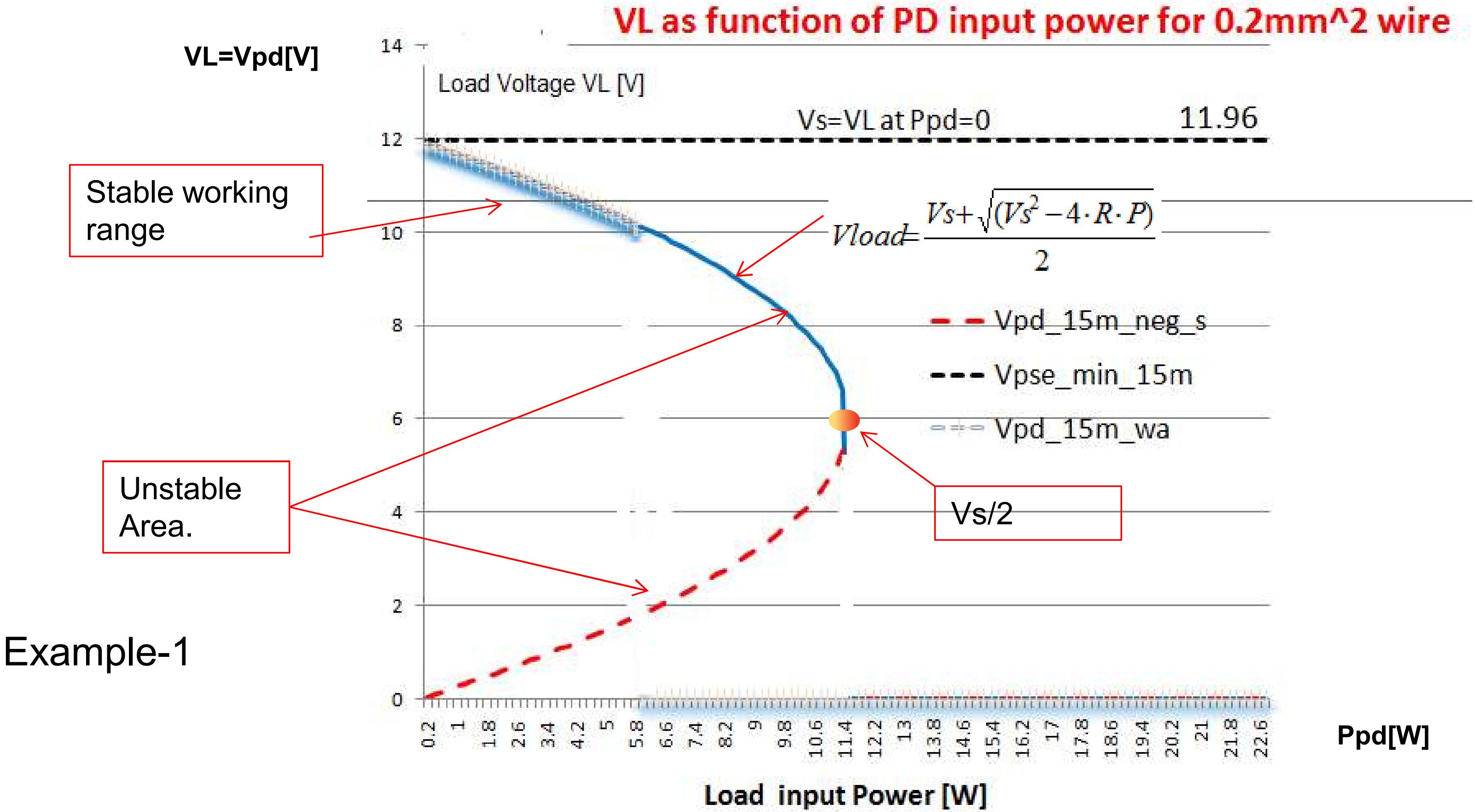
- The above power/data distribution technique and power/data interface is well known from XDSL applications and other telephony system for a long time. It works.
- Normally R1~=R2 for low CM noise
- DC Loop resistance=R=R1+R2
- *(*)Ps may be DC/DC converter fed by car battery after automotive protection circuitry block or connected to car battery w/o additional DC/DC block pending load power needs, cable loop resistance, Vs_min required to deliver max load power requirements and noise performance requirements*

General Power Channel Model

- Load is typically constant power sink. Its power, P[W]=Constant=VL*I
- Power source is normally current limited (Fuse or electronic device)
- **L**= channel length [m], with a resistance r [Ω/m]. R=Loop resistance=2xL*r
- Round Trip Wire Length=2L with a total resistance of R.
- **Pmax**: is the maximum theoretical available output power



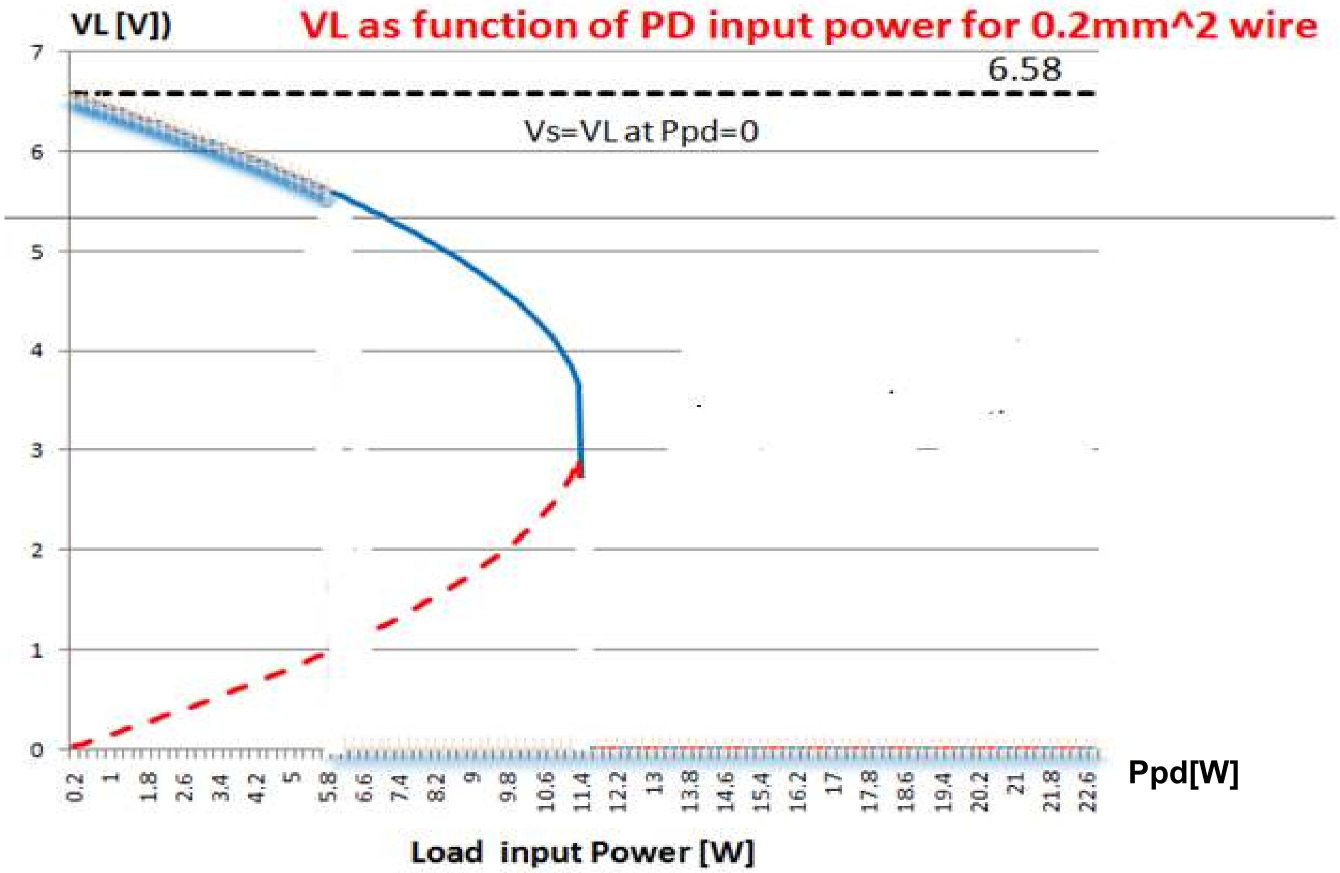
Example for: Vs=12V, 15m cable.
Wire: AWG24 (d=0.511mm, 0.205mm^2, 0.082Ω/m).



- Plot of real system: load voltage vs. load power for 12V source (with 0.4Ω output DC resistance) for supporting 5-6W load

Example for: Vs=7V, 3m cable.
Wire: AWG24 (d=0.511mm, 0.205mm^2, 0.082Ω/m).

- *Source voltage now, can be lower for supplying the same load requirements*

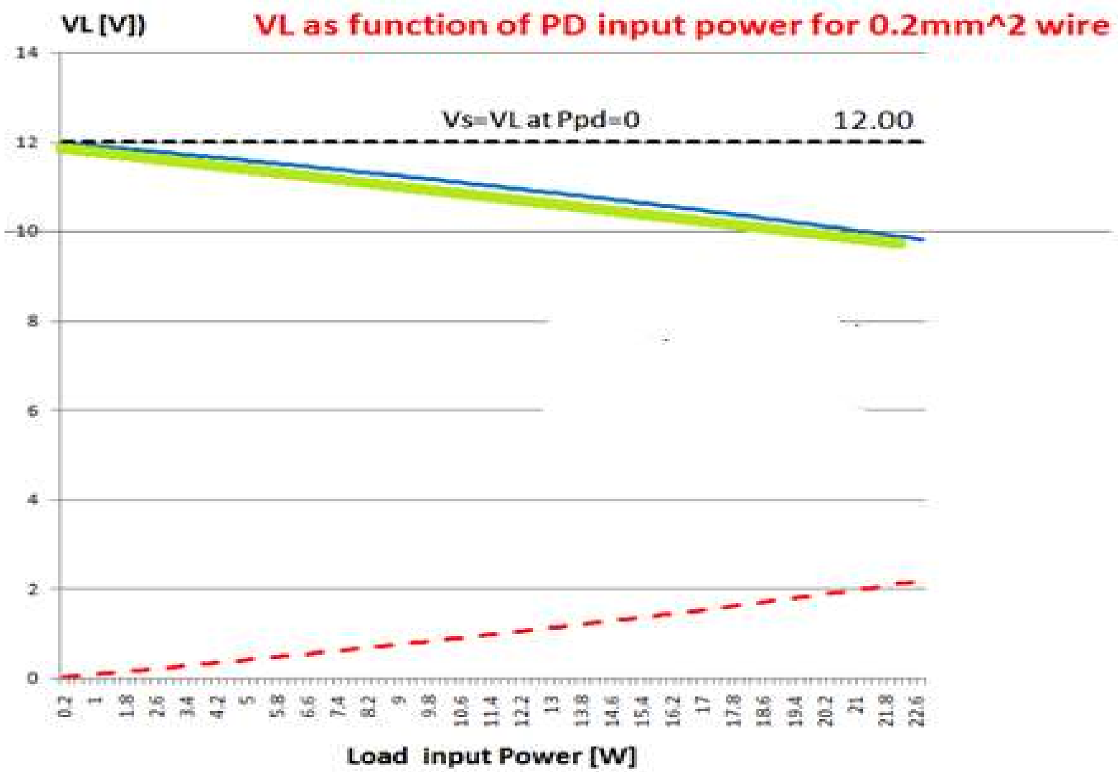


Example-2

Notes:
VL=Vpd[V]

Example for: Vs=12V, 3m cable.
Wire: AWG24 (d=0.511mm, 0.205mm^2, 0.082Ω/m).

- Vs=12V>> Vs_min required for 3m, 6W load.
- ***Source voltage higher than required allows larger stable operating range as known when much lower resistance cable is used and simple ohms law can be applied…..However this is not the optimized case copper/cost wise.***
- The voltage drop is almost straight linear line as in resistive load case



Example-3

The unstable working area is Far here

Typical Q&A

- **What is the maximum theoretical available load power?**

It happens when Vpd=Vs/2 as in all power transmission links when R=RL

$$P\max = \frac{Vs^2}{4 \cdot R}$$

- **Can we use Pmax?**

No when constant power load is involved. It has negative impedance therefore not stable. Usable Ppd<Pmax by a factor(s) that controls power loss on the cable, and how far we are from Vs/2 which is the instability point.

- **Why we cant use Pmax?**

Each load power value has two load voltage solutions, Vpd1 and Vpd2.
Only the highest curve allows stability if we stay above Vs/2 at all system operating conditions.

- **Why I never had problems of stability etc.?**

You may have used:

a) Very large copper diameter (low R) or
b) P<<Pmax
c) Or both a and b which resulted with $Vs^2 >> 4 \cdot R \cdot P \Rightarrow Vs \cong VL >> Vs/2$

In such conditions VL=Vs-R*I as usual…☺

Summary

- Typical Power Channel Model was shown for automotive applications.
- Available stable power at load is function of minimum source voltage, cable length, wire resistance and maximum operating temperature.

Minimum source voltage for k=0.85, Rs=0.5, 15m channel with different wire sizes at 20°C		
Vs_min =VL_min+I*R [VDC]	Stable PD input power[W]	
	Wire: AWG27, d=0.361mm, 0.102mm^2 (0.01689Ω/m)	AWG24: Wire d=0.511mm, 0.205mm^2 (0.08422Ω/m)
3.0	0.28	0.50
5.0	0.77	1.40
9.0	2.51	4.53
12.0	4.46	8.05
14.0	6.07	10.96
18.0	10.04	18.12
24.0	17.85	32.21
36.0	40.16	72.48

- Simple Calculation procedure is presented in Annex A**. More data on Annex B and C**

Proposed Specification Text

- To support the input parameters below, minimum wire size according to Equation TBD1 is required (See Annex A).
  - Input parameter:
    - maximum load power at application input PI.
    - Cable length from power source PI to application input PI.
    - Operating temperature and other design margins are implementation specific/TBD.
  - Maximum current shall be limited per Equation TBD2.
  - PSE source voltage operating range is defined in Table TBD.
  - PSE shall supply minimum voltage according to Equation TBD3
  - PSE maximum voltage TBD.
  - Maximum load power range: See Table TBD.

The output of the above should be inserted in Table – TBD (see example in previous presentation)

The above allows design flexibility for the automotive vendors regarding wire size and PSE output voltage.

The above need to be discussed with the group regarding how flexible our standard need to be and if it supports high quantities low cost when single voltage source can cover all use cases.

Proposed topics for Discussion

- Topics
  - Flexible standard: How much flexible?
    - Any wire size
    - Fixed Source voltage or implementation specific?
  - Mandate DC/DC between Battery to Vpse?
  - Cost/Flexibility/ Automotive needs trade off's
  - Other?

Thank You

Annex A: Calculation Procedure – General case

- **Vs**=Source voltage
- **V$_L$**=Load Voltage measure at the application (PD) input voltage.
- **R**=Total Round Loop cable resistance including Vs output resistance
- **PL**=The application load after its PD DC/DC output.
- **Eff**= the application (PD) DC/DC efficiency.
- **P**=Load input power P=PL/eff. We care about P only in the model. PL and eff are implementation specifics.
- **Pc**=Cable and connectors power loss
- **K**=P/Ps=Channel Efficiency (It is not DC/DC efficiency, **Eff**). It is the ratio between the load input power **P**, and the power source Ps. It actually sets the power loss on the channel components, Pc, e.g. cables and connectors. K=0.8 to 0.85 is a realistic number and normally required. Pc, ensures that load resistance at maximum load power and operating temperature, is higher than total channel resistance so most source power Ps, is delivered to the load and ensure system stability due to the need for operating point of VL>Vs/2 for stable operation (See curves next slides).
- Therefore, for a given load power P, it is possible to compute the channel total power loss for a given P and K values: k=P/Ps. k=P/(P+Pc). ➔ Pc=P*(1/k-1)
- R and Pc are known hence maximum channel DC current can be computed: Pc=R*I^2 ➔ I_max=(Pc/R)^0.5
- Minimum load voltage can be calculated since P=V$_L$*I ➔ V$_L$_min=P/I
- The minimum source voltage can be calculated :Vs_min=VL_min+I*R
- **Design margins and temperature effects are not included above. To address it, it is required to set R at maximum system operating temperature and add additional design margin to the resultant Vs_min.**

Annex B: Calculation Procedure Example for 15m, Ta=125°C.
Wire: AWG24 (d=0.511mm, 0.205mm^2, 0.082Ω/m).
Channel Efficiency k=0.85, Vs output resistance 0.5Ω.

Step	1	2	3	4
Load input power, P[W]	Pc=Cable Loss= P*(1/k-1). k=0.85	I_max =(Pc/R)^0.5	VL_min =P/I	Vs_min =VL_min+I*R
1	0.176	0.204	4.901	5.766
2	0.353	0.289	6.931	8.154
3	0.529	0.353	8.489	9.987
4	0.706	0.408	9.802	11.532
5	0.882	0.456	10.959	12.893
6	1.059	0.500	12.005	14.123
7	1.235	0.540	12.967	15.255
8	1.412	0.577	13.862	16.308
9	1.588	0.612	14.703	17.298
10	1.765	0.645	15.498	18.233
11	1.941	0.677	16.255	19.123
12	2.118	0.707	16.977	19.973
13	2.294	0.736	17.671	20.789

- Calculations at 125°C. For higher temperatures R is increased per copper thermal coefficient resulting with higher Vs_min.
- This procedure optimize Vs_min and keep power channel efficiency (Excluding PSE DC/DC converter if used and excluding PD DC/DC converter) as required e.g.

Annex C: Vpse_min vs PD input power P [W] and cable length. k=0.85, Ta=125°C, PSE Rs=0.5Ω, wire Ω/m=0.082 at 20 °C

Vpse_min [V] for given PD input power P[W] at Amb. Temp.=									125	degC	
	L[m]										
P[W]	2	3.3	4	5	6	8	10	12	14	15	40
1	2.50	2.88	3.06	3.30	3.53	3.95	4.32	4.67	4.99	5.15	8.09
2	3.53	4.07	4.33	4.67	4.99	5.58	6.12	6.61	7.06	7.28	11.44
3	4.33	4.98	5.30	5.72	6.12	6.84	7.49	8.09	8.65	8.91	14.01
4	5.00	5.75	6.12	6.61	7.06	7.90	8.65	9.34	9.99	10.29	16.18
5	5.59	6.43	6.84	7.39	7.90	8.83	9.67	10.44	11.17	11.51	18.09
6	6.12	7.04	7.49	8.09	8.65	9.67	10.59	11.44	12.23	12.61	19.81
7	6.61	7.61	8.09	8.74	9.34	10.45	11.44	12.36	13.21	13.62	21.40
8	7.07	8.13	8.65	9.34	9.99	11.17	12.23	13.21	14.12	14.56	22.88
9	7.49	8.63	9.18	9.91	10.59	11.84	12.97	14.01	14.98	15.44	24.27
10	7.90	9.09	9.67	10.45	11.17	12.48	13.68	14.77	15.79	16.28	25.58
11	8.29	9.54	10.14	10.96	11.71	13.09	14.34	15.49	16.56	17.07	26.83
12	8.65	9.96	10.60	11.44	12.23	13.68	14.98	16.18	17.30	17.83	28.02
13	9.01	10.37	11.03	11.91	12.73	14.24	15.59	16.84	18.00	18.56	29.17

- Yellow area: Can work with battery voltages range up to 5m cable for entire power range for the implementation conditions (k, Ta, Rs, wire size).