Power Capability vs Wire Size and Cable Length
IEEE802.3bp Task Force
Channel Definition ad-hoc

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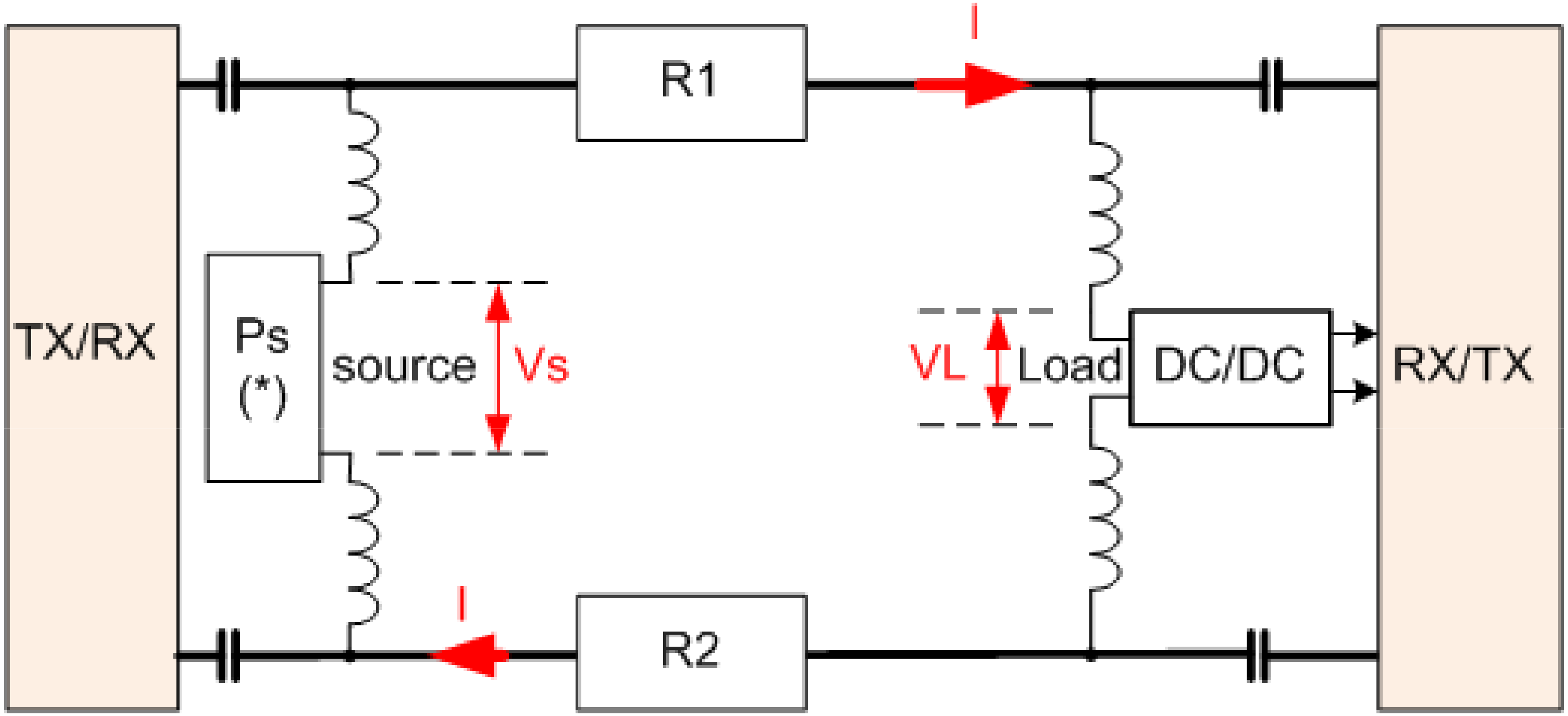
Objectives

- To supply data regarding power capability of a 1 pair channel with a lengt of L, as function of its wire resistance Ω/m and its voltage source Vpse.
- The channel model assumes:
  - Data and power may be required to be delivered over the same wires for weight and cost reduction
  - Voltage source that feeds constant power load as worst case use case through two wires (1 pair) cable.
- 0.2mm^2 wire case was demonstrated. 0.14, 0.18, 0.35, 0.5 mm^2 wires or other can be evaluated later in next meetings per ad hoc preferences
- Channels for 3m and 15m were evaluated

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



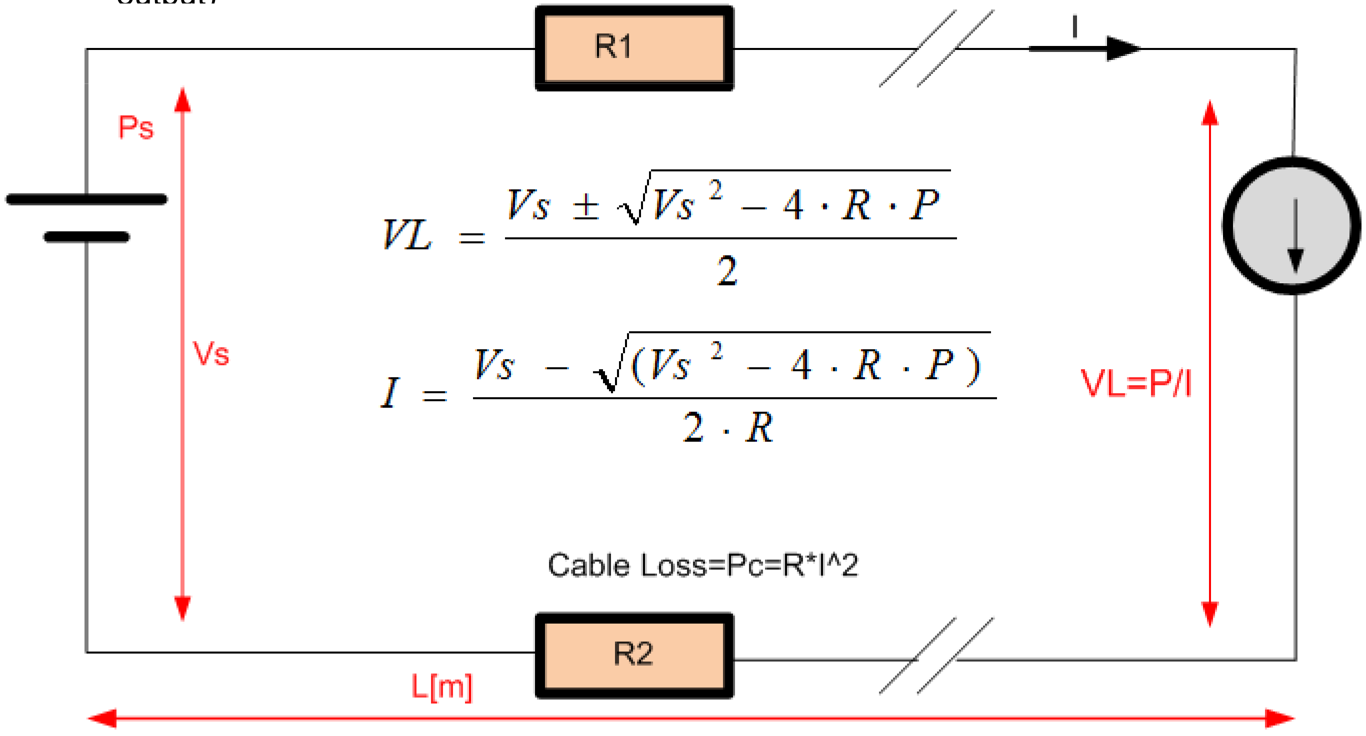
- Normally R1~=R2 for low CM noise
- Loop DC resistance=R=R1+R2
- *(*)Ps may be DC/DC converter fed by car battery after automotive protection circutry block or connected to car battery w/o additional DC/DC block pendig load power needs, cable loop resistance and Vs_min required to deliver max load power requirements*

Channel Power Model and its Equation:

$$\frac{Vs-VL}{R}=I=\frac{P}{VL}$$

R=R1+R2

- Load is typically constant power sink. Its power, P[W]=Constant=VL*I
- Power source is normally current limited
- 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 output power
- Channel Efficiency: P/Ps (The ratio between the load input power and the power source) output)



$$VL=\frac{Vs\pm\sqrt{Vs^2-4\cdot R\cdot P}}{2}$$

$$I=\frac{Vs-\sqrt{(Vs^2-4\cdot R\cdot P)}}{2\cdot R}$$

Cable Loss=Pc=R*I^2

P=VL*I=Constant
VL=P/I

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

Pmax can not be used.
P must be < Pmax

Calculation Procedure – General case

- R=Total Round Loop cable resistance including Vs output resistance
- K=0.8 is realistic channel efficiency number that ensures that load resistance at maximum power, is higher than total channel resistance so power loss over cable is cobtrolled to have channel efficiency>=k and ensure system stability due to operating point of VL>Vs/2
- Therfore for a given load power P, it is possible to compute the channel total power loss. 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=VL*I ➔ VL_min=P/I
- The minum source voltage can be calculated :Vs_min=VL_min+I*R

- Design margins and temperature effects are not included above. To adress it, it is required to set R at maximum system operating temperature and add additional design margin to the resultant Vs_min.

Calculation Procedure Example for 15m, 0.2mm^2 wire, 5.9W load, Channel Efficiency=0.8, Vs output resistance 0.4Ω.

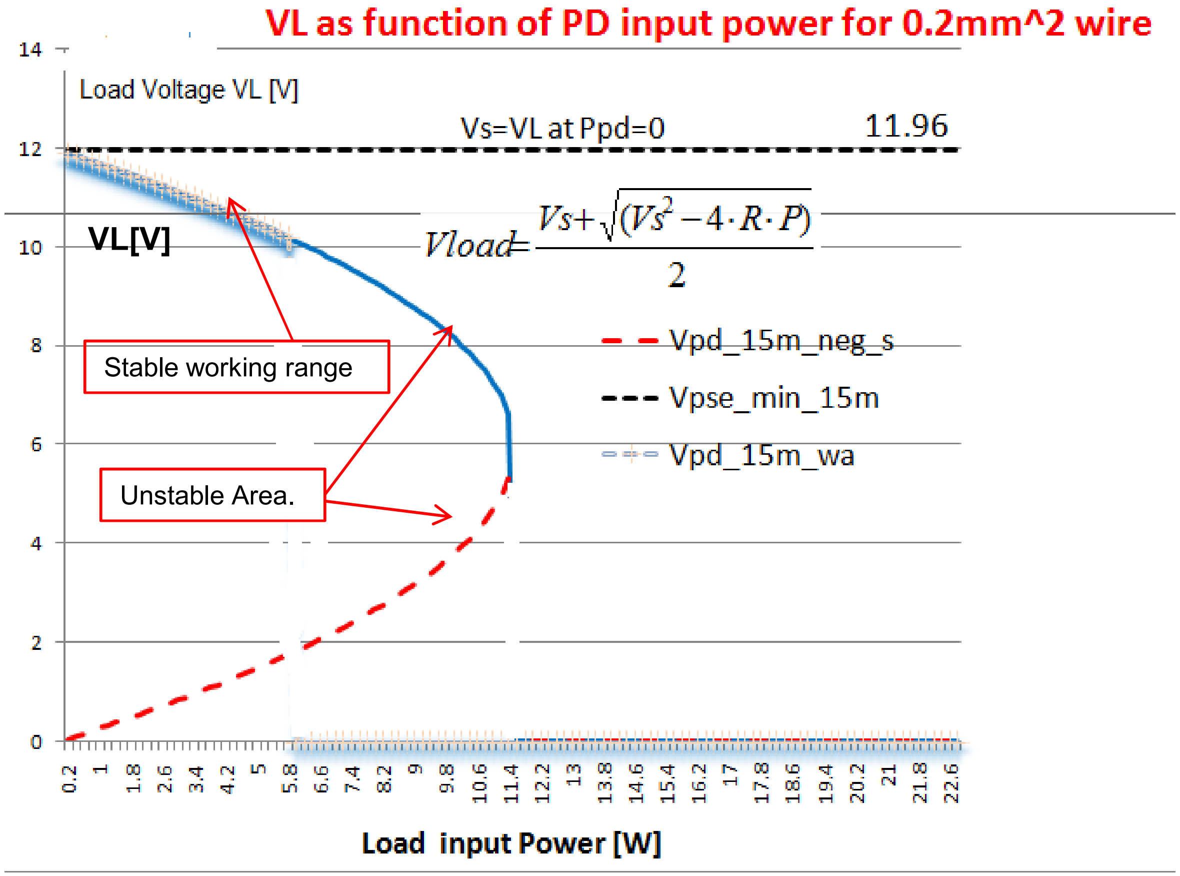
Step	1	2	3	4
Load input power	Pc=Cable Loss= P*(1/k-1). k=0.8	I_max =(Pc/R)^0.5	VL_min =P/I	Vs_min =VL_min+I*R
1	0.18	0.21	4.88	5.74
2	0.35	0.29	6.90	8.12
3	0.53	0.36	8.45	9.94
4	0.71	0.41	9.76	11.48
5	0.88	0.46	10.91	12.83
6	1.06	0.50	11.95	14.06
7	1.24	0.54	12.91	15.18
8	1.41	0.58	13.80	16.23
9	1.59	0.62	14.63	17.22
10	1.76	0.65	15.42	18.15
11	1.94	0.68	16.18	19.03
12	2.12	0.71	16.90	19.88
13	2.29	0.74	17.59	20.69

- Calculations at 25degC. For higher temperatures R is increased per copper thermal coeficient resulting with increase Vs_min.
- This procedure optimize Vs_min and keep channel power efficiency as required.(k=0.8)

  (Total System Efficiency = Eff1*k*Eff2 (source DC/DC, cable, load DC/DC whenever applicable))

System Behaviour Example for 15m cable with a wire of 0.2mm^2

- Complete Equation has two solutions (VL_P,VL_N)
- Only positive (VL_P) range solution can be used due to stability considerations
- Plot of real system: load voltage vs. load power for 14V source (with 0.4Ω output DC resistance) for supporting 5-6W load



VL as function of PD input power for 0.2mm^2 wire

$$Vload = \frac{Vs + \sqrt{(Vs^2 - 4 \cdot R \cdot P)}}{2}$$

Stable working range

Unstable Area.

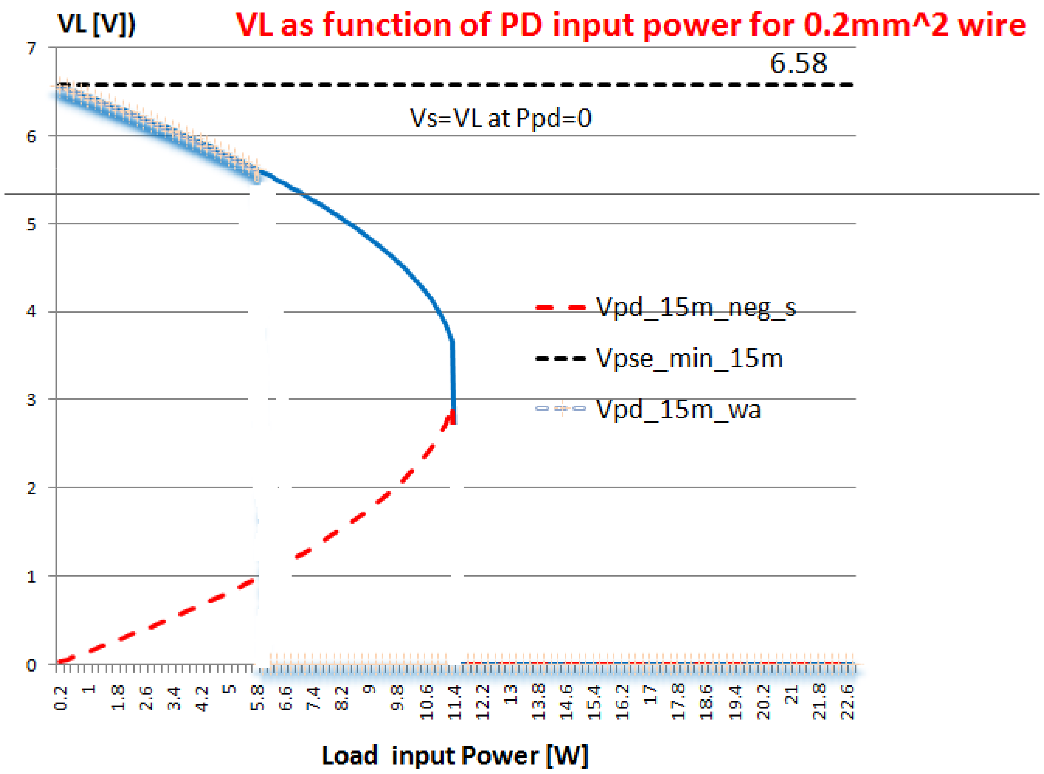
Ex.-1

P[W]

2.38W

System Behaviour Example for 3m cable with a wire of 0.2mm^2

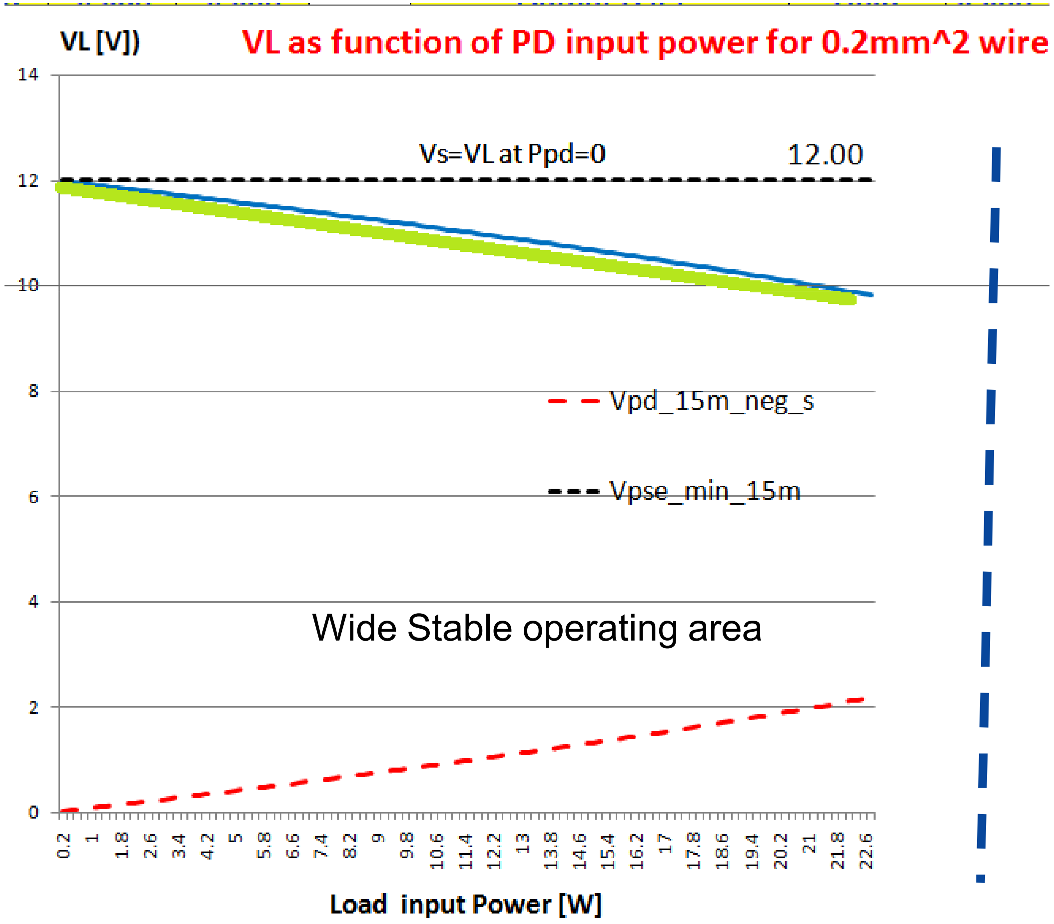
- Same system with 3m Cable with 0.2mm^2
- *Source voltage now can be lower for supplying the same load requirements*



Ex.-2

System Behavior Example for 3m cable with a wire of 0.2mm^2 and same Vs value as in 15m Ex-1 shown previously

- Vs=12V>> Vs_min required for 3m, 6W load and 0.2mm^2 wire.
- ***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 streight linear line as in resistive load case



Wide Stable operating area

Ex.-3

The unstable working area is Far here

Summary

- Typical Power Channel Model was shown when the load is a constant power sink (DC/DC supply of the end application)
- When wire size (resistance per meter, copper area mm^2 etc.) is selected along with the other cable parameters, the wire size need to be evaluated for its power capabilities per the 15m channel objective.
- It was shown that for 15m channel the minimum source voltage with 0.4Ω o/p resistance required for 0.2mm^2 wire at 25degC is:

Load input power	Vs_min =VL_min+IR
1	5.74
2	8.12
5	12.83
10	18.15
13	20.69

- Simple Calculation procedure was shown for any given op. conditions
- There is a value for Worst Case Vs_min (at maximum load and channel length) for flexible, easy design, covering most of use cases, and alow standartization of Vs operating range. HOWEVER this need further evaluation if it fits automotive industry needs were both system ends are closed system and different Vs values allow optimization and cost reduction.

Open Questions Required for further investigation

- What are the use cases for connecteding the application (e.g. sensor with is DC/DC converter) therough the power channel to the following voltage sources:
  - A) Directly to Battery Voltage (i.e. w/o boosting the battery voltage and regulate it to steady fix value)
  - B) After DC/DC converter at Battery side for fix stable Vs.
- In case A what will be the guaranteed Vs_min
- Does the application above may be connected to existing main PS module that supplies different voltages that some of them >12, 14, 24V?
- What are the distribution of alll the above use cases?
- Other?

Discussion/Questions

Thank You