SPMD Power trade-offs

PD power, output voltage, nodecount, cable length

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Purpose

This presentation explores the main parameters (operating voltage, delivered power) for the power standard to be developed for single-pair multidrop.

This allows us to evaluate the maximum cable length and number of nodes that can be supported.

Calculations are made to show what power can be delivered to PDs, taking into account power stability and regulatory limits.

Structure of the exploration

In a first set of calculations we calculate what power can be delivered by only considering the stability of the power system. Based on this calculation we know what ampacities are required.

In a next step we look at the ampacities and check them against current regulation. An adjusted calculation is then made taking both stability and regulatory limits into account.

Assumptions in the calculations

1. Source is set to the minimum voltage for a given voltage range.
2. Conductor resistance is based on copper at 60 °C
3. No resistance from connectors is taken into account (resistances are thus too optimistic).
4. Following ampacities per conductor from NEC 2020 Table 725.144 corrected to 45C ambient are used:

AWG	"small bundles" of 8-19	"large bundles" of 92-192
24	0.57 A	0.28 A
23	0.63 A	0.32 A
22	0.74 A	0.37 A

Note: this table is designed for 4-pair data cable. Work needs to be done to verify if these numbers hold for single-pair cable.

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Assumptions in the calculations

5. All power is consumed at the far end of the cable, representing the worst case.
6. Three voltage (ranges) are considered: 24 V, 48 V, and 57 V. In each case a range of $\pm$3 V is assumed, so the output voltage is 3 V below the nominal in the calculations.
7. Stable operation factor is chosen at 0.7 (see next slide).
8. Calculations done for AWG24, AWG23, AWG22, and AWG18 (only shown #24, see other file).

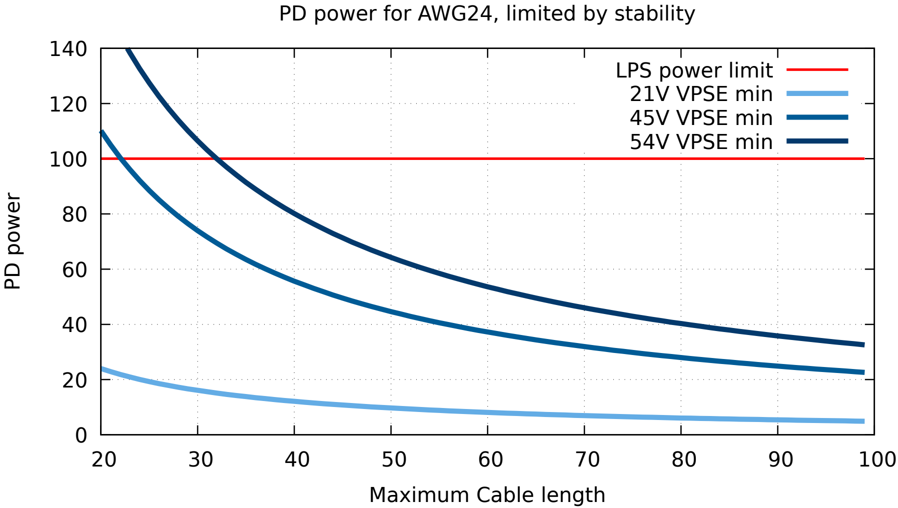
Power supply stability

See ➠lehr_1_0500.pdf from 802.3af for background.

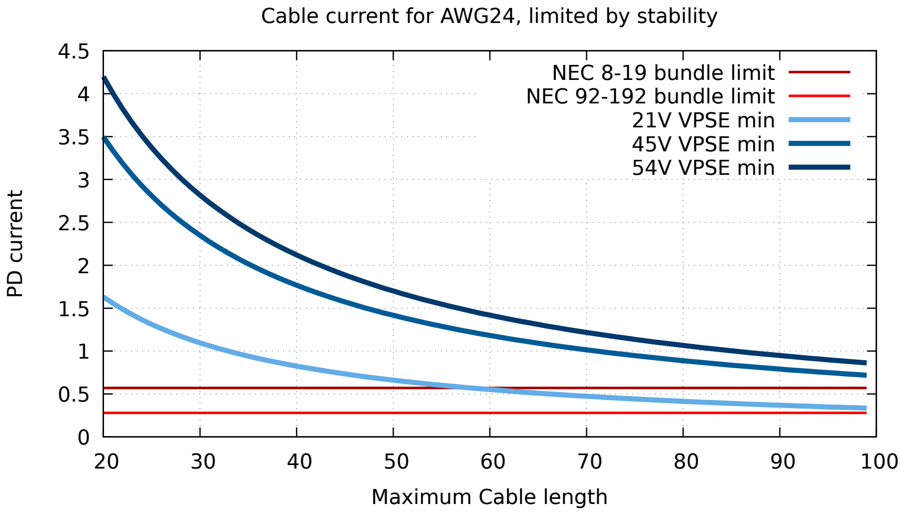
A supply delivers the largest amount of power when the cable impedance is equal to the load impedance. This is also a very unstable operating point. For stable operation $V_{load} \gg 0.5 \times V_{source}$.

The calculations dealing with stability take $V_{loadmin} = 0.7 \times V_{source}$ to satisfy this. For reference, in PoE the lowest stability factor is 0.79.

Maximum power based on stability



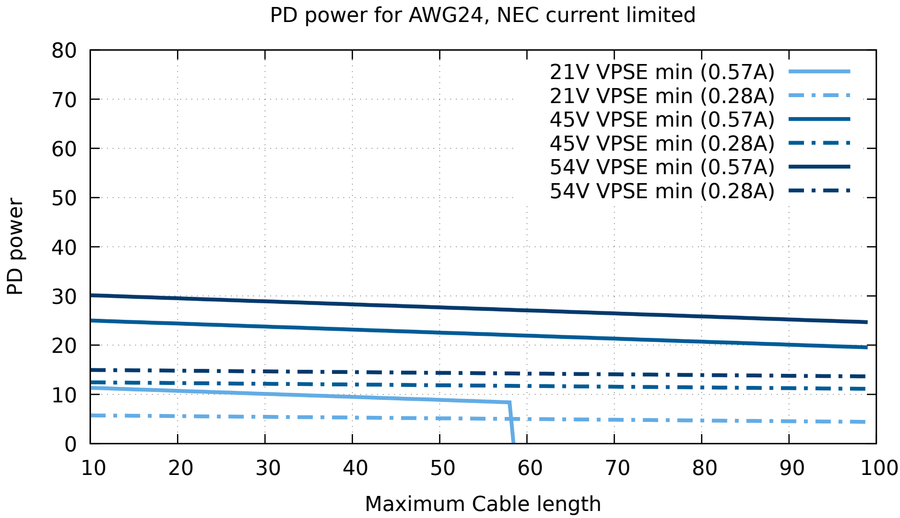
Conductor current when only looking at stability



Maximum power based on stability - observations

- Looking at only stability, it is possible to transfer large amounts of power.
- The resulting conductor currents are infeasibly high
- For the “60V” output voltage stability is not an issue, other limits are reached long before stability becomes an issue
- For the “24V” output voltage stability will be a limiting factor depending on cable length
- In all cases, the NEC current limits must be taken into account to create a viable standard
  NOTE: The numbers used in the presentation are for 4-pair cable and can only be a first approximation of limits.

Maximum power with current limited



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Power per node

The power per node for the 75m / AWG24 (small bundles) case is (in Watt):

Voltage	32 nodes	24 nodes	16 nodes	12 nodes	1 node
57V	0.82	1.09	1.63	2.18	26.15
48V	0.66	0.88	1.31	1.75	21.02
24V	0.23	0.31	0.46	0.61	7.34

and for large bundles:

Voltage	32 nodes	24 nodes	16 nodes	12 nodes	1 node
57V	0.44	0.58	0.88	1.17	14
48V	0.36	0.48	0.72	0.96	11.48
24V	0.15	0.20	0.30	0.40	4.76

Desired power per node

Ideal would be to have "number of supported nodes" $\times$ "default power per node" available in all cases. This allows any system to boot up and allow Data Link Classification to work and get PD power allocated.

The default power per node is the power that a device get allocated when power is applied. This needs to be enough to boot and enable communication. In our experience, 1W is a feasible number.

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Observations

- For the higher voltages, there is no great gain in available power to be made by shortening the maximum length down from 75m
- Voltage of 57V is a bit shy of allowing 1W per node for 32 nodes at the high current limit (small bundles)
- Power/temperature measurements for single-pair cable are needed to get the right numbers
- 24V is only stable until about 40m with the high current limit
- 24V power is very limited at the lower current limit, mismatched with 32 node count

Conclusions

The combination of #24 cable, with 75 meters, and 32 nodes, powered by a 54V-60V source almost allows every node to get the desired 1W for small bundle sizes.

Power/Thermal measurements on single-pair cable are needed to make sure we are picking the right numbers.

24V will be much more power limited. Higher minimum gauge cable or shorter maximum cable length can be a solution. It will be hard to design any devices to work in both voltage ranges.