The Solid Power distribution considerations

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General consideration

description

Assumption here is a 50 plane detector.
Each plane will be equipped with two analogue amplifier boards and two ADC-FPGA boards.
So total 100 analogue and 100 ADC-FPGA boards.
The detector will be built up in sub modules. Here it is assumed that a sub module is 10 planes.

One can distinguish 3 power supply needs:

- For the SiPm bias , this will need a power supply with a voltage between 25 and 85 V this is distributed via the analogue board

- The digital board requires a 5V or 3.3V power supply with reasonable current requirement

- The analogue board need a ~ 7V power supply with low current requirements.

It is not considered to have for the analogue and ADC-FPGA board the same power supply.

Reliability

The experiment has to run minimal 5 years. max 8years. So reliability calculation have to made for

8 years. The experiment is expected to run 24/ 24 7/7/

(one year == 364 * 24 = 8740 hour)

The power supplies are supposed to be placed that they can be easily accessed.

So initial there could be a trade off between price and reliability (so take in account to exchange the power supplies at half the life time by example).

Also it is assumed that the power supplies are efficient enough so they don't need water or forced air cooling.

general requirements

1. The power supplies have to be compliant with the Belgium "Europese laagspanningsrichtlijn " .
   This is compatible with the EU "The Low Voltage Directive"
   (http://ec.europa.eu/growth/sectors/electrical-engineering/lvd-directive/index_en.htm)
   1. special attention is needed for the kind of mains isollation has to be provided in respect to the grounding requirements (current to deal with) of the experiment.
2. The total maximum power should not exceed xx W as this is the maximum power that can provided by the current foreseen mains network of Br2.
3. Remote control ? Is it a requirement that the power supply can be switech off remotely.

Bias power supply

The current per board does mainly depends on the bias control chip ADL5317.
The bias quiescent current depends on the output current. This is assumed to be low << 1 uA / SiPm. So total ~ 10uA for a board. 3mA per control chip is here used.
For t he moment the Hamamatsu S12572-050 is the base line .
This has a break down voltage range from 55 .. 75 V. It is not expected the over-voltage to be supplied will be higher then 3V. So a max voltage of 78V has to be provided to the SiPm's.
The bias controller can not supply voltages above 75V . So 80V is the maximum voltage to supply to the controller chip

So total a 3A @ 80V power supply (== 240 W) .

Consideration could be to remove the controller chip on the board :

- Will lower the current requirement from 3A to 100 mA.
- the controller act also as noise reducer but this can be done with capacitors and resistors as the SiPm current is very low but not constant so one has to monitor the bias voltage on teh board.
- the controller act as extra handle to cope with the high spread in the breakdown voltage (according the data sheet). The later one could be mitigated by have the controler chip on a small PCB for the planes where SiPm's are with Vbr in the low ranges.

Digital power supply

general remarks

The currents that the eventual power supplies can apply are relative high so the individual boards should be equipped with a fuse to avoid fire in case a LDO (or DC/DC) will fail.

5 V power distribution base line

As base line the digital boards need a 5V power supply with a current requirement of 6A.

So total 600 A == 3000W .

Distribution of such a current to many boards makes a busbar approach obvious.

But a 600A system has also a lot of disadvantages :

- the 600 A is only a total. So for the last sub module you need only 120 A. So a lot of copper not efficient used.
- One has to consider full shorts . This will give very high peak currents. A peak current of 6000 A will give a force of 144 N between the bars.
- Not easy to find a 5V 600A power supply
- 3000W x .2 (80% efficiency) = 600 W , can this be air cooled?

So one could consider to have a star distribution at the 5V power supply to 5 x 120 A and have bus bars of 120A on the sub modules. Still a peak current of 6000A (defined by the power supply) is possible.

Alternative use 5 power supplies of each 120A (TDK-LAMBDA 100A ~ 170Euro) . This increase the number of available power supplies and limit the implication with very high currents. But it introduce a careful thinking about the "common" connection in case the power supplies are not close to each other and also ground loops between sub modules.

48 V power distribution

The DC/ DC converter advantage and disadvantages

This assumes a DC / DC converter on the board.

As the board needs only 3.3V[1] So it make more sense to have 48 -> 3.3 V Dc/Dc converter (assuming the required Voltage output tolerances can be reached by the DC/DC converter) .

An example could be CC30-4803SRP-E   TDK-Lambda 77Euro /pc (@ 100 pc)

If there is 6 A / board the losses in the LDO's is 10W /board (1020 W total ~ 1/3 of the total dissipation for a 5V distribution system) in respect to a

3.3V supply.

A DC/DC of 90% efficiency will give a dissipation of ~ 2 W.

1 This has to be confirmed by the ADC-FPGA board.

The disadvantages are clear , the high price and extra PCB area needed and an higher failure rate ce (in respect to a LDO device) .

total current	boards	current /board	
600	100	6	[A]
DC/DC losses	10	198	[W]
	LDO 3.3 lost	1020	[W]
	5	3000	[W]
600	3.3	1980	[W]
rend DC/DC	0.9		
input power		2200	[W]
output currer	24	91.67	[A]
output currer	48	45.83	[A]
5 power mod	24	18.33	[A]
5 power mod	48	9.17	[A]

Illustration 1: spreadsheet used to caclulate losses

The 48 V power supply unit

As the total needed current is below 50 A the current requirements are "manageable" .

Also in comes in the range of a terminal distribution instead of a busbar distribution.

Possible supply could be (only short investigation) HDS3000PS48 XP power , 48V, 62.5A. (3000W) 1000 Euro

Or in case of 5 power supply LCL500PS48 XP power 500W 225 Euro (*5 =1125).

48 power supply distribution summary

- The currents are easy manageable ("cheap current distribution via terminals)
- The power dissipation on the boards is reduced resulting on 10W/ board less power , making passive cooling more likely to work.
- The 48/3.3V DC/DC converter needed on the board is
  - expensive
  - need board space
  - need to respect the requested voltage tollerances.
- The power supplies (AC/DC) are not substantial more expensive then the 5V onces.

alternative power supply distributions

mains

One could use one power supply per plane inside the electronic box limit the distribution current to a minimum. On a first thought not very attractive as

- one has to provide on all metal structures a grounding that agrees with the max mains current (expect to be at least 25A)
- the own dissipation of the power supply goes into the volume

12 V etc

One of the disadvantages of the 48V power supply is that this is not a very common power supply. For 12V power supply threre are more offers. But of course ther currents increases so that advantage disapear. Despite the broader offer on a first glance the prices are not substantial lower.

3.3 V

Has the advantage less LDO disipation at the boards. But it is not clear how to guarantee the required tollerances for all the board. As the prices of the AC/DC converster are mostly watt driven the prices are slightly lower in respect to 5V AC/DC converters with the same current rating. The la voltage tollerances could be compensated with a 4V distribution +LDO but 4V power supplies are hard to find. A3.3 V distribution scheme has still the disadvantages of high currents.

Analogue power supply

The voltage on the analogue board has to be 5V . This is done by a LDO. So the power supply voltage before the LDO has to be ~ 7 V + 20 % - 10 %.

The current per board will be less then 400mA. So for 100 boards 40 A will be needed. The power supply of SM1 can be used (40 A out) . There is a spare.

Also the analogue board has to be equipped with a fuse.