Power Distribution using Rad-Tol Regulators

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Problems with existing scheme:

- Describe limitations and concerns

Proposal to place individual regulators at PP2:

- Features of CERN/ST Rad-Tol regulator
- Implementation for pixels inside PP2 region
- Advantages

Prototyping plans

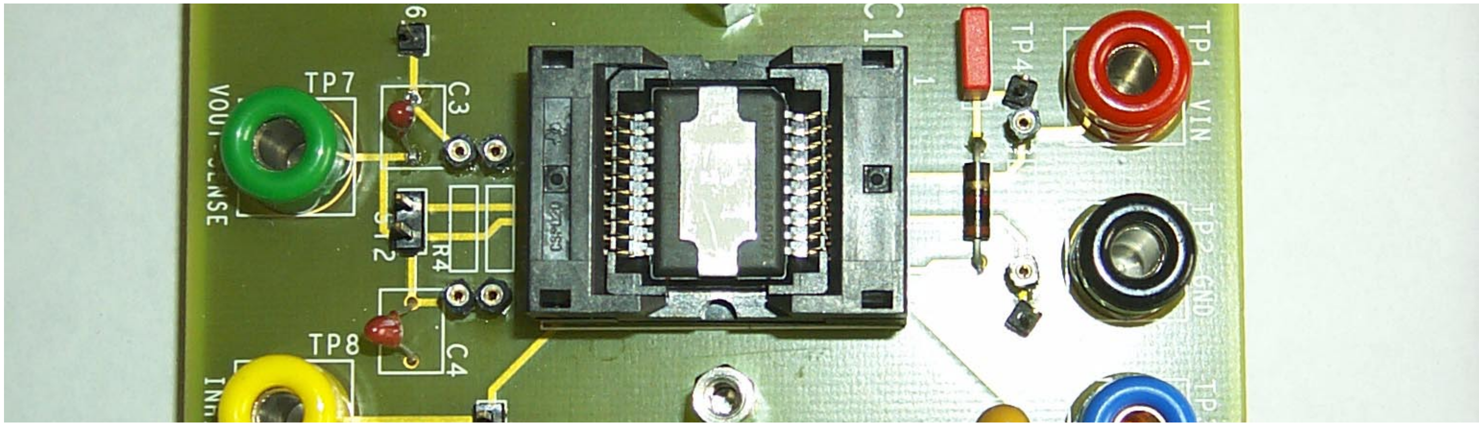
- Build small PC board appropriate for operating a single module

Problems and concerns with existing scheme:

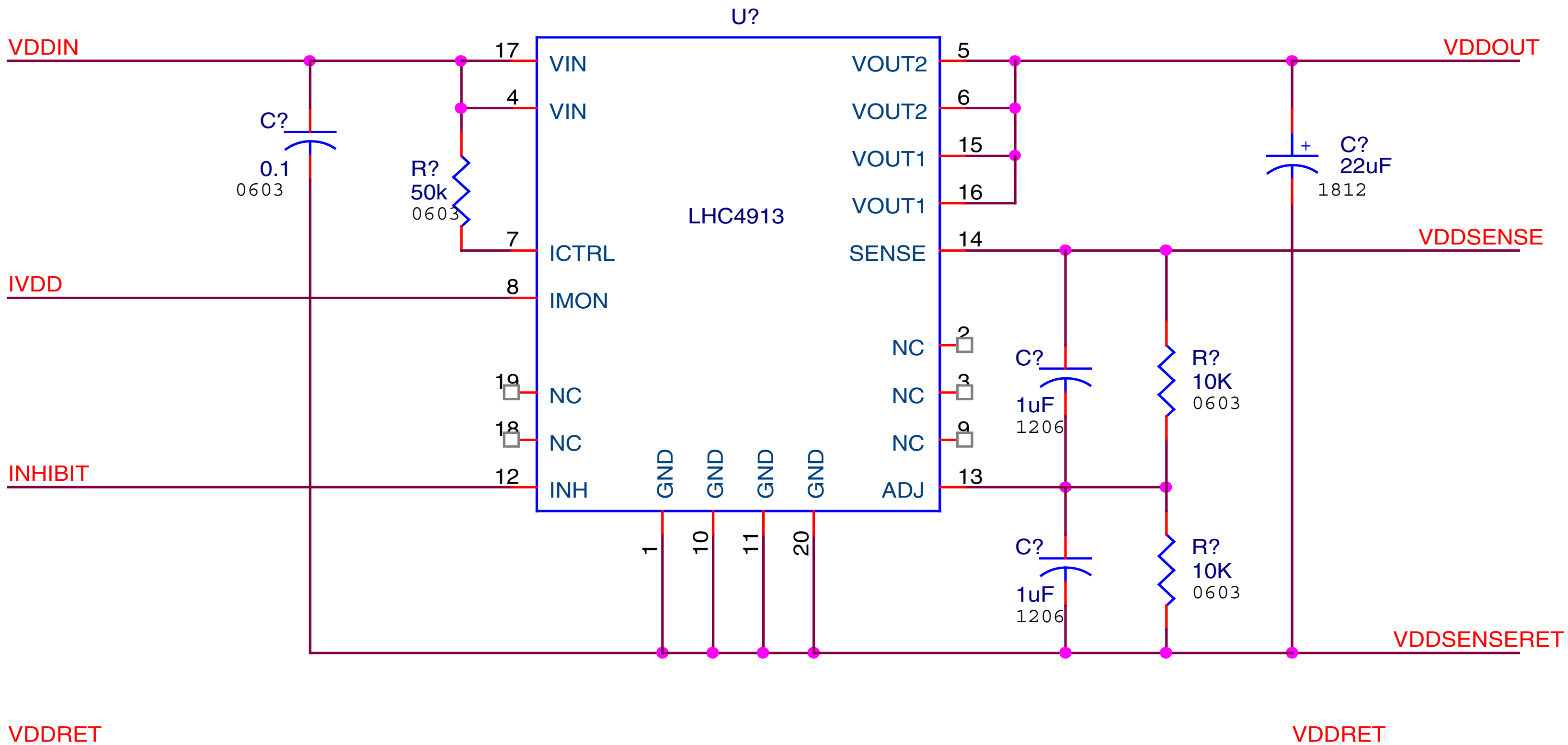
- Very large separation between regulation in USA15 supplies and pixel detector (up to 140m). This makes it difficult to eliminate noise on the power supply lines (active regulation is much more effective than passive filtering), and difficult to control transients induced by changes in current through the high-voltage-drop cable plant.
- For DMILL, the power cables were specified to have a voltage drop (round-trip) of not much more than 2V. In combination with the worst-case supply voltage on the chip of 4V, this still kept the supply voltage itself below the breakdown voltage of the process (about 8V). For 0.25μ, this is no longer possible, because the operating voltage is 2V and the breakdown voltage about 4V. Different transient protection schemes are being studied (they must be rad-hard) to protect the chips against anomalous voltages on the power cables.
- The inner part of the cable plant (PP2 and in) has almost 1.5V drop round-trip, so designing a total voltage drop of 2V requires very large cables for the long conventional run (Type 4), leading to very high costs, dominated by Copper.
- The large voltage drops in the low-mass cable plant cause significant cooling problems, and make it difficult to know the temperature of the cables, and hence their resistance. This makes it difficult to predict the voltage delivered to a module. The 140m total cable length is too long to operate a standard voltage sensing scheme, so the regulation is based on current sensing, and programming a value for the cable resistance into each supply channel.

Proposal to place Rad-Tol regulators at PP2:

- CERN and ST have jointly developed a radiation tolerant regulator using a special bipolar process from ST. It is a high-speed, rad-hard 12V process. The foundry has characterized the process to 0.5MRad and $2x10^{13}$ n/cm^2. First irradiations show operation is OK up to 10MRad and $3x10^{14}$ π/cm^2.
- The part, officially called LH4913, is available in several fixed voltages, and an adjustable voltage version (which is best matched to pixel needs).
- The regulator is a low-dropout design, requiring about 0.5V at 1A and 1.5V at 3A. This makes it a good match to pixel modules (worst-case 1A per supply).
- It supports a remote sensing mode, includes an inhibit input, has an adjustable maximum current, and includes an over-current status output, plus over-voltage and over-temperature protection circuitry.
- It is packaged in an ST package known as Power-SO20, with a footprint of about 16mm long by 15mm wide, and a slug on the top for heatsink cooling:



Schematic appropriate for use at PP2:



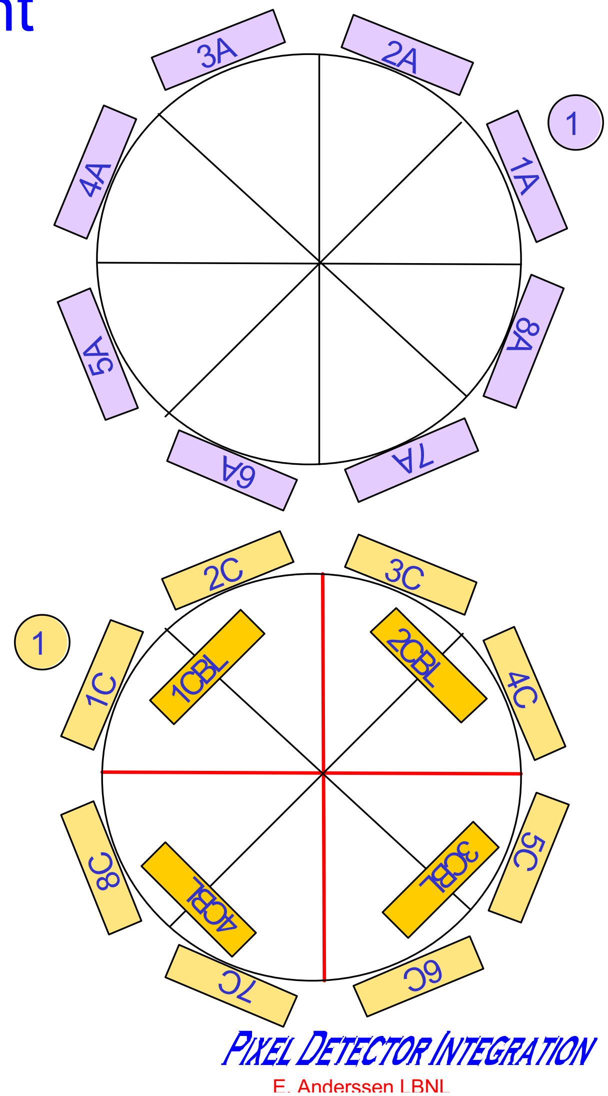
- 50K resistor on ICTRL limits current output to about 1.5A.
- Filtering on input, adjustment nodes, and output is needed. The actual values might be reduced in future versions of the regulator, but we assume these values are actually required. Component sizes (ceramic caps) are given in schematic.
- With resistors shown, output voltage would be 2.5V. Varying this voltage requires adjusting the upper of the two 10K resistors. Zero ohms gives minimum of 1.25V.

PP2 Feasibility Study

- Summary of PP2 numerology from Eric in Dec 00 meeting:

Service Arrangement

	Patch Panel Octant Name	Barrel Layers 1&2	Disk	Tube Total	6-Module Bundle	7-Module Bundles	Bundle Total	Staves Serviced	Sectors Serviced
Side A	**1A**	**3**	**2**	***5***	(3+6)=**9**	**6**	***15***	12	3
	2A	**3**	**1**	***4***	(3+6)=**9**	**6**	***15***	12	3
	3A	**3**	**2**	***5***	(3+5)=**8**	**5**	***13***	10	3
	4A	**3**	**1**	***4***	(3+6)=**9**	**6**	***15***	12	3
	5A	**3**	**2**	***5***	(3+6)=**9**	**6**	***15***	12	3
	6A	**2**	**1**	***3***	(3+5)=**8**	**5**	***13***	10	3
	7A	**3**	**2**	***5***	(3+6)=**9**	**6**	***15***	12	3
	8A	**3**	**1**	***4***	(3+6)=**9**	**6**	***15***	12	3
Side C	**1C**	**3**	**1**	***4***	(3+5)=**8**	**6**	***15***	10	3
	2C	**3**	**2**	***5***	(3+6)=**9**	**6**	***15***	12	3
	3C	**2**	**1**	***3***	(3+6)=**9**	**5**	***13***	12	3
	4C	**3**	**2**	***5***	(3+6)=**9**	**6**	***15***	12	3
	5C	**3**	**1**	***4***	(3+6)=**9**	**6**	***15***	12	3
	6C	**3**	**2**	***5***	(3+5)=**8**	**5**	***13***	10	3
	7C	**3**	**1**	***4***	(3+6)=**9**	**6**	***15***	12	3
	8C	**3**	**2**	***5***	(3+6)=**9**	**6**	***15***	12	3
Side C B-Layer	**1CBL**			***2***	**4**	**4**	***8***	4	
	2CBL			***3***	**6**	**6**	***12***	6	
	3CBL			***3***	**6**	**6**	***12***	6	
	4CBL			***3***	**6**	**6**	***12***	6	

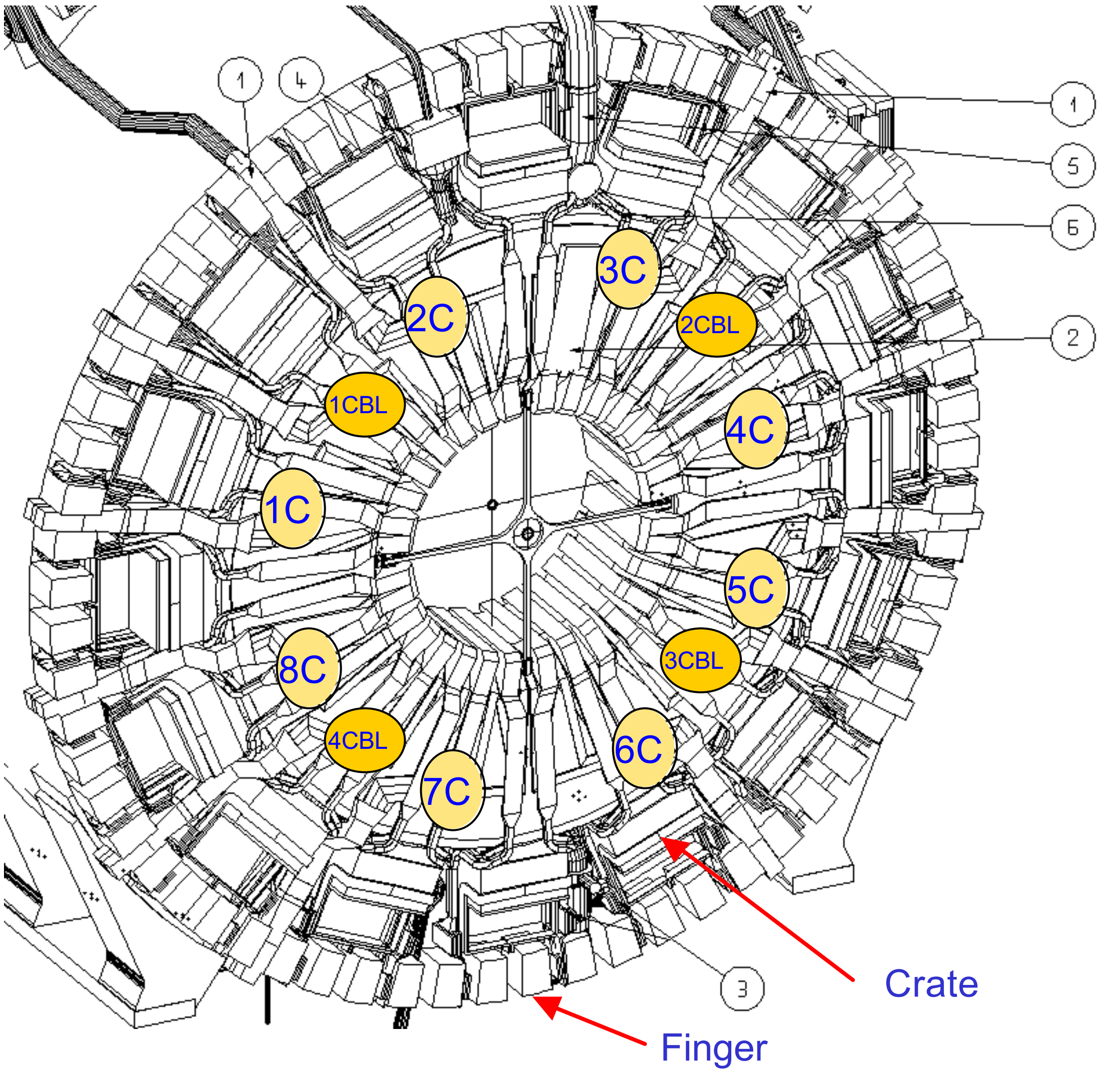


December 2000
Mechanics

Numbering scheme for each side looking
At IP from that side —position# coincides
Physically across ATLAS.

- Eight panels per side, plus four for B-layer, or 20 in total.

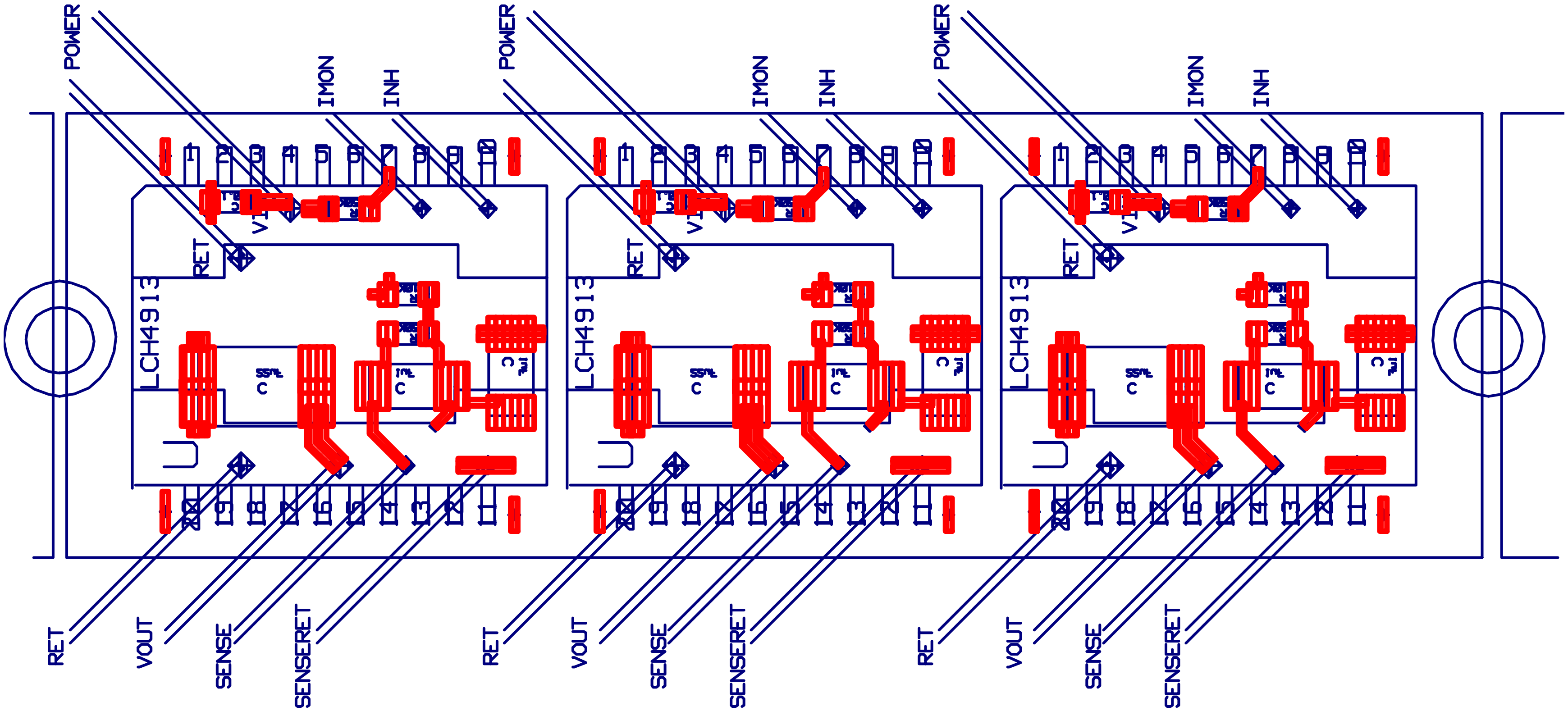
Location of PP2 boxes:



- Maximum of 15 bundles in one PP2, with nine 6-way and six 7-way bundles, for a total of 96 modules.
- If the 7-way ends up being 8-way for spares, total is 54+48 modules.
- Assume that we maintain at least a 1V drop across regulator to keep it regulating.
- This leads to a worst-case power dissipation, in the regulators alone, of 2W per module, or 200W for a PP2 box.

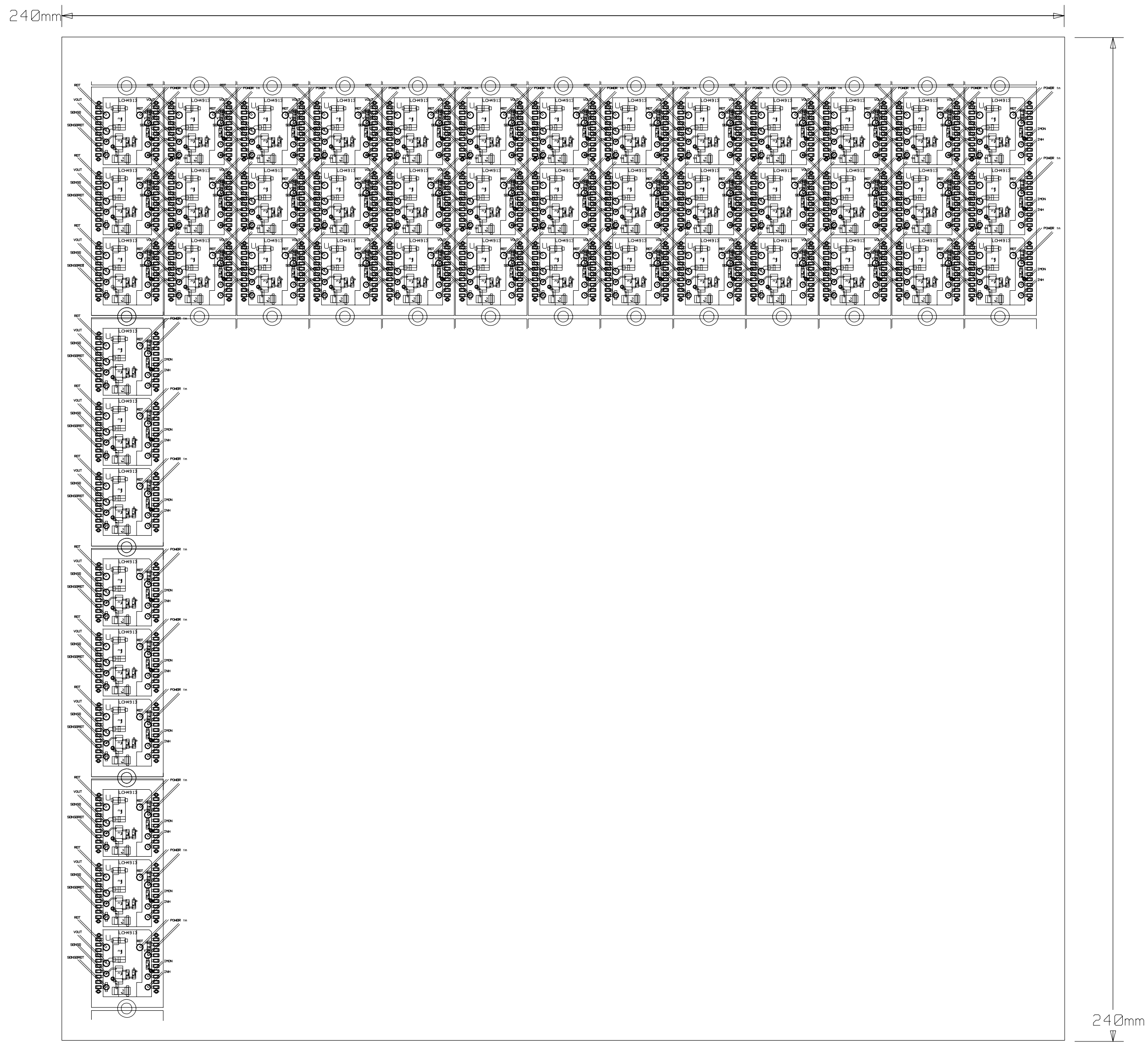
- Approximate size of a PP2 box is 280x280x50mm. The sides of the box will be covered with connectors for incoming Type 2 and outgoing Type 3 cables.

- Layout of "unit cell", as shown in previous schematic, is repeated either two or three times to create a small board which provides all power required by module.



- The regulator is on the bottom of the card, and all passive components are on the top side of the card (red traces). All through-hole wire connections would also be made from the top side, under the regulator footprint.
- Individual cards would be screwed to both sides of cold plate, placing regulators in good thermal contact. Wiring harnesses would connect to box sides.
- The module size as drawn here is roughly 17x55mm, with layout above.

- Each of these module cards is electrically independent of all others in the box. They can then be arrayed 4x13 onto cold plate in the allowed space:

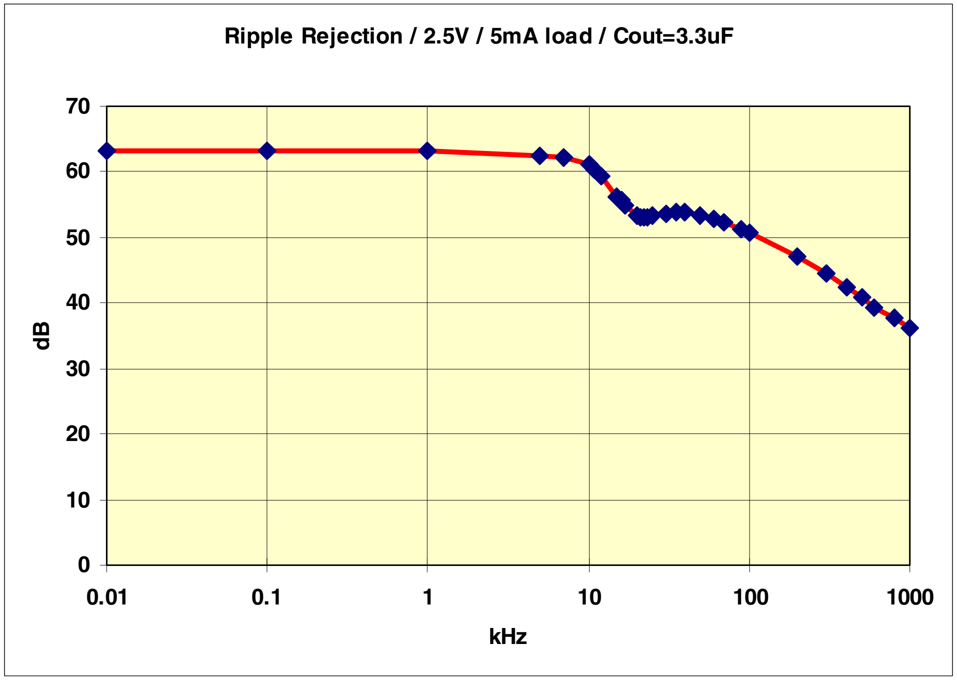


- Conclude: even for three supplies/module, the required components fit into box.

Advantages and Disadvantages of PP2 Regulators

Advantages:

- Location of linear regulator with good noise rejection relatively close to the pixel detector (7m) will provide much improved noise rejection:



- An AC sine wave noise component was applied to input, in addition to standard DC input.
- Roughly a factor of 1000 noise rejection (60 dB) was achieved over most of the frequency range.
- Higher frequency noise is well-controlled by decoupling capacitors.

- Regulator is implemented in 12V process, with Max input rating of 14V, so it will provide excellent transient protection against voltage transients on its input, severely reducing concerns about transient protection of modules themselves.

- The relatively high input voltage rating relaxes the major constraint on voltage drops from USA15 to PP2. Principle issue is to always retain the minimum drop-out voltage across the regulators (1V proposed here, which has at least 0.5V safety margin). The Type 4 cable could now easily have a 1-2V drop (assuming the large power dissipation can be handled), reducing its cost by a factor 4 or so (savings in the millions of CHF...)
- The remote sensing capability of the regulator is used to control the voltage directly on the module (assuming the necessary sense lines can be run to the end of the Pigtail, and bonded across to the power pads on the Flex3). This allows an automatic compensation for the expected drops of 600mV in the Pigtail, 500mV in the Type 1, and 150mV in the Type 2 cable. There is no need to carefully control the temperature of the low mass power cables in order to know their resistance. With the proposed decoupling on the ADJ pin, the regulator should be very stable.

Disadvantages:

- This new power system is not frequently accessible (requires “short move” access), and so reliability is a major issue. Every effort would need to be made to carefully engineer the system for reliability, and to burn-in all components. Given the independence of all channels, it is difficult to think of any “fail-safe” scheme short of doubling the number of regulators and keeping one set inhibited while the other is active.
- Such a sensing scheme can be dangerous in case of cable faults. However, if we always operate with a relatively low dropout voltage (necessary to control power dissipation !), then the regulators cannot generate any large voltage transients themselves.

Prototype Plans

- Presently have layout for a small three regulator board which can be inserted into a prototype power cable at the relevant place.
- Have 15 sample parts of the LH4913, adjustable version. Sockets are impossible to find, so we plan to solder them to the test boards.
- These boards would be used in the lab to begin evaluating the proposed scheme, in comparison to the baseline scheme without regulators.

Next Steps:

- Would like to find some other institute to take responsibility for this component, preferably a group already active in the power supplies.
- Full scale PP2 box would need to be built, and extensive reliability and radiation qualification work would need to be carried out to validate the design (and especially the regulator).