DC-DC Conversion Powering Schemes for the CMS Tracker Upgrade

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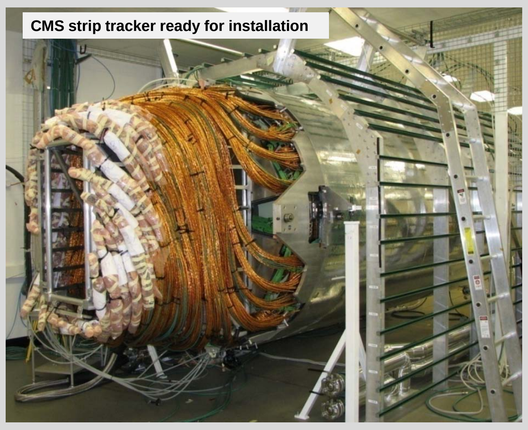
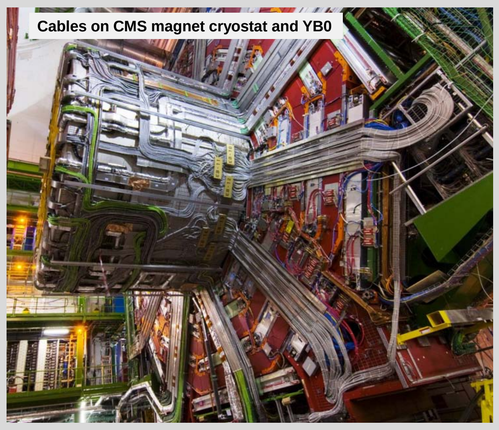
Power provision for the CMS tracker

Today, the CMS strip tracker needs 33kW;
CMS pixel detector needs 3.8kW

→ Power consumption will increase for SLHC:
more readout channels, additional functionality...



50m long cables → 50% Ohmic losses, too much material



Services nested with others and cable channels full

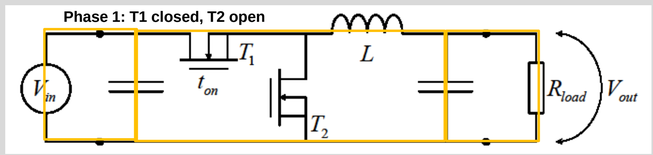
Novel powering schemes have to be exploited for the CMS strip tracker and pixel detector upgrades

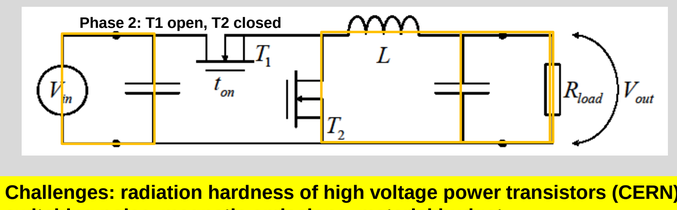
A DC-DC conversion powering scheme

Idea: deliver detector power at higher voltage and lower current
P = U x I = (rU) x (I/r)
r = conversion ratio ~ 5-10

→ Ohmic power losses in supply cables are reduced by factor $1/r^2$
→ Motherboards and cables can be thinner → less material

DC-DC buck converters used to convert rU back to required voltage U

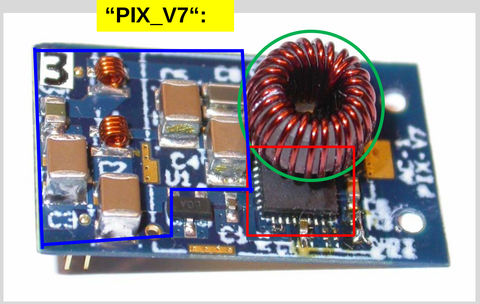


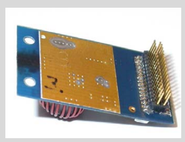


Challenges: radiation hardness of high voltage power transistors (CERN), switching noise, magnetic emissions, material budget

DC-DC buck converters for CMS

"PIX_V7":





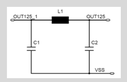
A = 28 x 16 mm²
M ≈ 2.5g
3.8% of a radiation length

ASIC: AMIS2 by CERN
I_{out} < 3A
V_{in} < 12V
f_s configurable, e.g. 1.3MHz

PCB:
2 copper layers a 35µm
0.3mm thick
Large ground area on back for cooling

Toroidal inductor:
L = 450nH
R_{DC} = 40mΩ
Plastic core

Pi-filters at in- and output

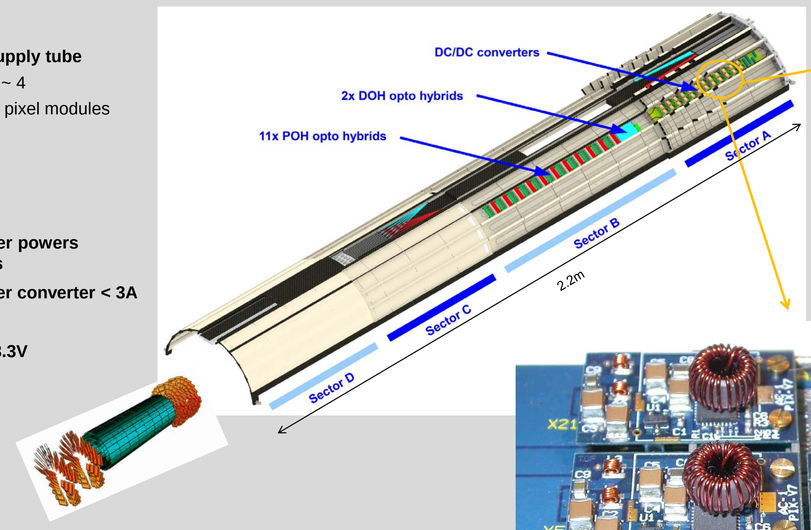


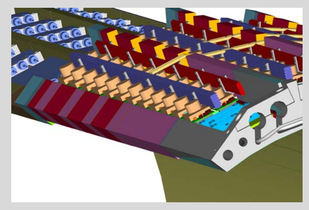
Shield
Shielding of magnetic field;
reduction of conductive noise through segregation;
cooling contact

Integration into the future CMS pixel system

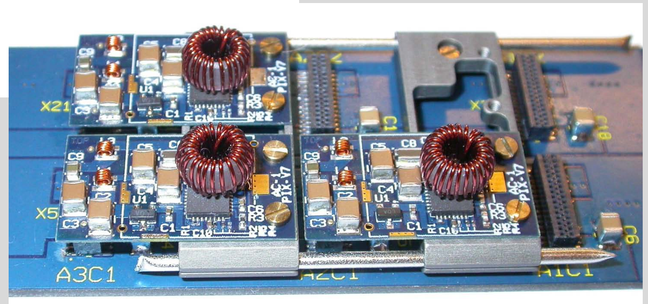
Integration onto supply tube
- ✓ Pseudorapidity η ~ 4
- ✓ Large distance to pixel modules
- ✓ Sufficient space
- ✓ CO_2 cooling

• 1 DC-DC converter powers 1-4 pixel modules
• Output current per converter < 3A
• Vin = 12V
• Vout = 2.5V and 3.3V





• 26 DC-DC converters per channel
• Power dissipation ~ 50W per channel



→ 2 000 DC-DC converters required for pixel upgrade (~ 2016)

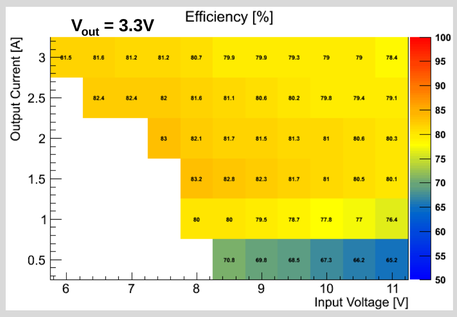
Power efficiency

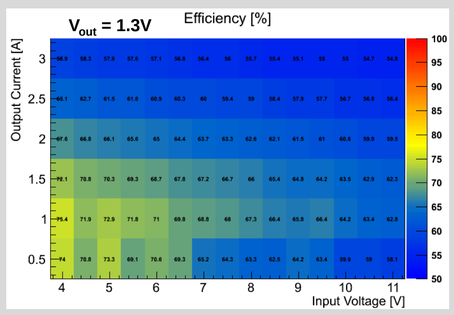
• Phase 1 conditions:
V_{out} = 3.3V or 2.5V, I_{out} < 2.8A,
conversion ratio of 3-4
→ 75% - 80% efficiency

→ Efficiency sufficient for phase-1

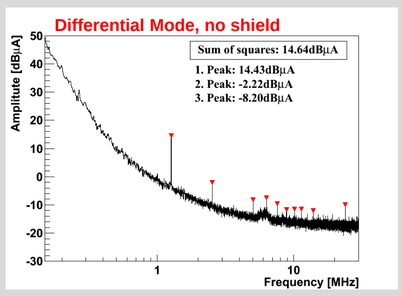
• Phase 2 conditions:
V_{out} = 1.25V, I_{out} = 3A,
conversion ratio of 8-10
→ about 55% efficiency

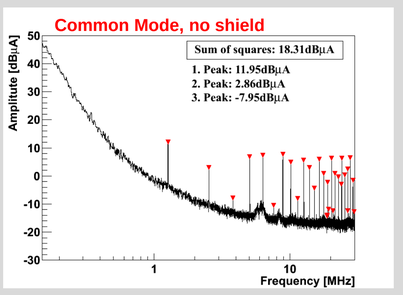
Possible solution for phase-2:
combination with an on-chip "switched capacitor" converter with r = 2



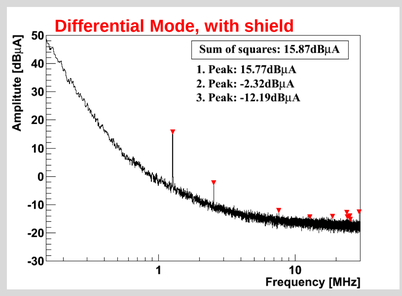


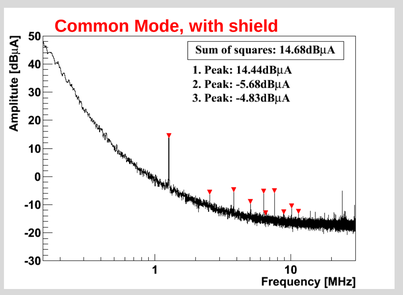
Conductive noise emissions





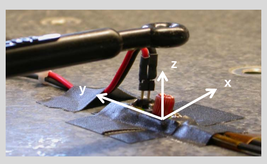
PIX_V7 output noise
V_{out} = 3.3V
V_{in} = 10V
f_s = 1.3MHz
L = 450nH



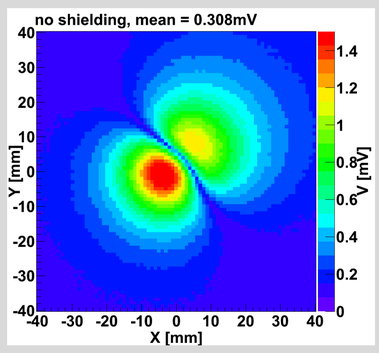


→ Conductive noise emissions are low
→ Shield reduces high-frequency components (segregation between noisy and quiet parts of PCB)

Shielding of the magnetic field

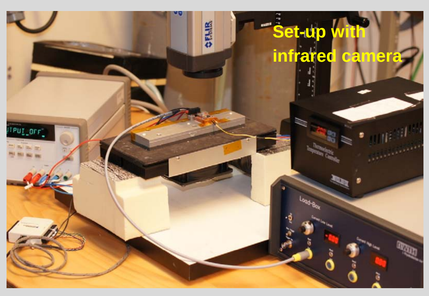


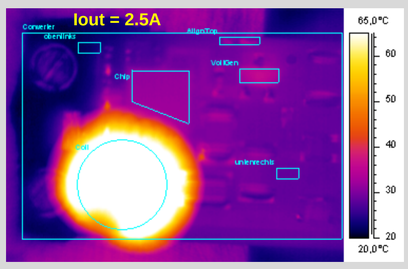
Magnetic field measured with pick-up probe and spectrum analyzer

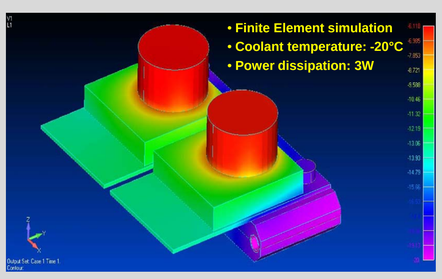


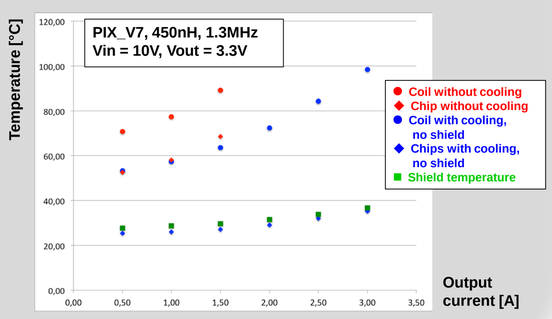
→ Shielding with 90µm thick Aluminium cap is sufficient

Cooling performance



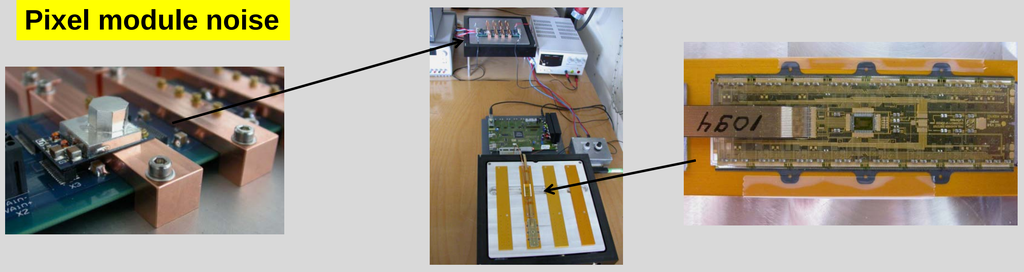


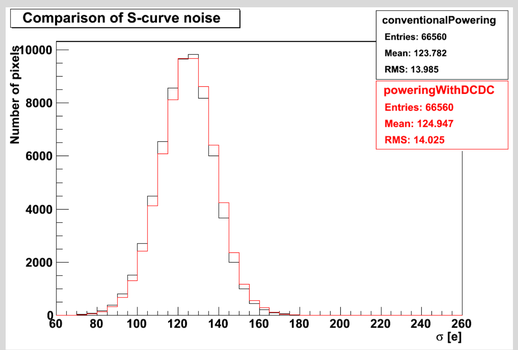


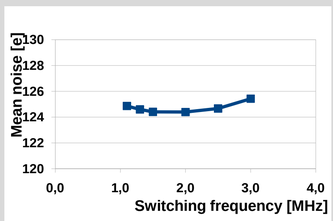


→ Measurements with infrared camera and FE calculations indicate ΔT of ~ 15K to coolant temperature

Pixel module noise







Noise of CMS pixel modules measured with and without DC-DC converter
→ no significant increase due to DC-DC converters!

➔ DC-DC buck converters with a conversion ratio of ~ 4 will be used for the CMS pixel upgrade; R&D for phase-2 is ongoing.