VMM frontend: power and cooling
SRS frontend status

VMM3a SRS hybrid:
- 25 hybrids pilot production received (for GDD users)
- 25 Wafers ordered with shared contributions from RD51-CERN, Bonn Univ, ESS -Lund
- minor PCB revisions (PCB thickness) for mass production 4Q19
- Addition of VMM cool wrapper (this talk)

-SAMPA SRS hybrid:
- Collaboration was set up between S.Paolo and CERN GDD
- start with 64-channel version same footprint as APV/VMM
VMM3a pilot production

4 pre-production already in use, 20 under acceptance test
Power consumption VMM hybrid

- **Chip Power 1 x VMM3a**
  1.2V @ ~ 800mA from external P2 power line through 4 LDO’s
  ∑ ~ 1 Watt

- **Chip power Spartan FPGA + Flash**
  2.5V @ 120mA from external P1 power line through 1 LDO
  ∑ ~ ¼ Watt

- **LDO linear power converters + uPower ADC**
  2V(P2) -> 1.2V : 0.8V*800mA =0.64W
  3.3V(P1) -> 2.5V : 0.8A*120mA = 0.1 W
  2 x uADC 2.5V * 1mA -> negligible
  ∑ ~ ¾ Watt

- **Single VMM3 hybrid (total nominal):**
  2 x VMM3 + Spartan + LDO’s + uADCs

**Total:** ~ **3W**
Bottom side dissipation

2x VMM3a ASIC below Globtop (2W)

Spartan FPGA (1/4 W)

Flash (1/10W)

Bottom-side dissipation $O(2 \frac{1}{4} \text{ Watt})$
TOP side dissipation: 5 x LDOs

View from top when plugged on detector.

- IC7 VDD 1.2V, 150mA Charge amplifiers
- IC6 VDD 1.2V, 400mA Analogue circuits
- IC9 VDDAD 1.2V, 200mA ADCs
- IC5 VDDD 1.2V, 150mA Digital and SLVS drivers
- IC8 Voux 2.5V 0.1A FPGA and Flash

Note: IC5-9 are 2-Ampere CMOS LDO’s of type ADP174ACPZ-R7

P2 nominal estimated ~ 850mA/ASIC

J2

J1

Crimp Contacts Samtec CC79L-2024-01-L

Wire SCem 04.01.61.600.6 0.5 mm2

Note: IC6 has highest power dissipation and is hotter than the other LDO’s

Note: The auxiliary power cables/connector shown here are optional. By default VMM hybrids get powered via the HMDI link.

Top-side dissipation $\mathcal{O}(3/4 \text{ Watt})$
Cooling motivations

- ASIC lifetime
  (exponential) function of die temperature
  main factor electromigration fail fraction
  VMM specs recommended operation below 50 C
- Noise & gain
  ENC @ preamplifier, leakage currents increase with T
  gain defining capacitor changes with T
- Detector gain
  keep constant and in ambient range (20C)
4 cooling concepts VMM

1.) cooling bar on detector frames, no wrapper
2.) flat wrapper for ventilated cooling pipe
3.) flat wrapper for 4 mm dia cooling pipe
4.) profiled wrapper for convection cooling
5.) profiled wrapper with cooling snake (in-out)
1- cooling bar below hybrid (without wrapper)

VMM hybrid on detector plane with cooling bar

placement pitch for arrays of VMM hybrids: 50 mm
-> Power to be dissipated $W = 3\text{Watt}/50\text{mm}$

so far no known detector implementation
VMM cool wrapper concept
heat transfer bottom to top

• Heat from VMMs transferred from bottom to top side via:
  4 metal heat contacts + heat conductive tape/ Si compound

• VMM junction temperature stabilizes at $O(45..55 \, \text{C})$ with
  a.) ventilated flat wrapper: $T_{\text{junct}} \sim 47 \, \text{C}$
  b.) profiled, black wrapper, convection-only: $T_{\text{junct}} \sim 55 \, \text{C max}$
flat wrapper parts
(ventilated air cooling)

MMCx shells

Bottom ALU wrapper plate

VMM hybrid

Si-grease on hot chips
2-3 W/mK

flat ceramic coolers
5..6 W/mK if ventilated

Ceramic coolers tape-glued on top ALU wrapper
flat wrapper topside assembled
(for ventilated airflow)
flat wrapper sandwich
(4 mm dia cooling pipe)

grounding wire M2 plug
profiled wrapper
( convection cooling )

Preferred solution without ventilation
profiled wrapper
= custom production
Top side profiled cooler

commercial offer (Radian Heatsinks) modified from round to square pillars (cost reason):

NRE ~ 1kFs
~ 5 Fs/cooler > 500

Order 5 samples (NRE free) for tests

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bottom plate for all wrappers

bottom side plate: only holes, no profiles

ALU prototype designed and 10 pc produced at CERN with water cutting
~ 15 Fs/ pc , try to find cheaper for volume (500+) production

Bottom plate . dxf file for water cutting machine
Bottom side hybrid with VMM wrapper

- HRS connector
- MMCX grounding shell
- Pressfitted MMC shells
- M2.5 x 12 bombhead brass
- Cut washer M3
- Brass Nut M3
- 2x MMCX for neighbor VMM cluster feature
- 3mm ALU wrapper bottom plate (direct thermal contact with VMMs)
profiled VMM wrapper\textsuperscript{Plus}
(cooling towers + cooling snake I/O)

Probably only solution to keep VMM junctions at recommended O(40C) ➔ will be tested when custom profile cooler will be received
VMM cool wrapper
(all details)

VMM top cooler 3mm Aluminium (airflow)

Thermal contact Top/Bottom B:
2 x MMCX shells (Brass) MMCX-J-P-H-ST-TH1

Thermal contact Top/Bottom A:
2 x M2.5 x 12 mm Brass screws

Thermal budget top side:
5 x LDO’s ADP1741- LFPC-16 ~ total 1W dissipation
thermal contact to cooler: conductive tape (BG405792, 1.5mm)
+ Si Compound on each LDO

Gap on top 2.74mm
PCB: 1.1 mm incl. traces
top to bottom 12.2 mm

Stackheight below hybrid 5.2mm

Click-in-jack (shell only) for detector frame:
MMCX-J-P-H-ST-TH1

2x neighbor channel connector:
MMCX-J-P-H-ST-TH1

Thermal budget bottom side:
2 x VMM3a (each 1W over 21x21 mm2) globotopped: thermal conductivity 1.3 W/mK
heat transfer to plate: Si Compound thermal conductivity 2.5 W/mK

VMM bottom cooler 3 mm Aluminium (on detector frame FR4)
Cooling tests
( Eraldo and Yan)

Photo: trending curves of internal + external temperatures

Temperature probes: Top, Bottom
VMM junction temperature via I2C readout of micro ADCs on VMM3a
Conclusions

VMM hybrids should not be used without cooling.

A variety of VMM cooling solutions, tests ongoing, custom cooler parts on order.

Small systems: convection cooling with profiled wrapper recommended.

Medium size systems: ventilated flat wrapper appropriate.

Larger systems: cooling pipes (4 mm Dia.) with waterflow.

Low noise systems: profiled wrapper with waterflow.