TEC System Test:
Noise studies with the final ICB

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- The InterConnect Board
- Noise distributions for all module positions
- Noise on position 6.3/4.3: observations and studies
- Noise performance in the cold
- Summary & outlook
History & Status

• Last CMS week: noise measurements with an almost fully equipped petal were presented, using the “old” ICB version.
• Non-flat noise was observed on two positions (6.3, 4.3).
• A 5 µm thick copper foil placed under these modules made noise flat.

• Since then the ICB was exchanged with the (almost) final version; the measurements were repeated and further studies were performed.
The ICB provides LV and HV, trigger/clock, reset and control signals to devices on the petal, and transmits data from FE-Hybrid to Opto-Hybrid.
Main changes with respect to the previous version:

- **Slow control**: implementation of “DCU on the CCU” & humidity sensors (dedicated temperature sensors that can be read out via a DCU on the CCU when analog power is off)
- **Additional resistors (510 Ω)** in the I²C clock lines of all modules, to limit current in digital lines (otherwise modules are powered via digital power when analog power is switched off, this could damage the CCUs.)
- **Better shielding of digital lines (larger copper areas)**
- **Thickness of copper layers** (6 layers in main board, 4 layers in others) is now 20 μm, as foreseen in the design (was 36 μm before due to mistake from the company!)
System test setup

- Delphi LV supplies
- Patch panel (with relais for control of HV lines)
- ISEG HV supply
- Multiservice cables (10m long)
- Optical ribbons
- DOH
- Power for CCUs and DOH
- PC with FEC, TSC, 4 FEDs
- VME crate with 3 O-FEDs
- Petal in transport frame
Noise distributions on all positions: setup

- **Optical control link** (external DOH)
- Measurements performed with **three Delphi power supplies**
- Four FEDs used for readout → one complete LV group is read out at a time
- All mounted modules were powered and configured
  ⇒ from electronical point of view **no difference to readout of a full petal**

- Petal was thermally stabilized at room temperature (17°C)
- Petal was kept in transport frame during measurements (shielding)
- 10m long multiservice cables were used
- Not all modules were mounted at all times

- Mostly **“Standalone”** DAQ program was used for readout
- Readout mode was mostly **peak mode inverter on** (43, see later)
- Bias voltage was **250V**

- **Analysis code** by Richard Brauer, constant common mode assumed

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Unless stated explicitly, noise distributions were measured without any shielding!
Electrical vs. optical control link

Previous measurements were performed with electrical digital link (Vienna card was broken).

What fraction of the noise was due to the electrical digital link?

⇒ No difference between electrical and optical digital link!

Previous measurements with old ICB and electrical link can be compared with new measurements.
Reproducibility of measurements

How stable are our measurements in time?

In between, the setup was re-organized (two racks instead of one), modules were unmounted several times etc.

⇒ Excellent **reproducibility** of measurements!
Ring 2

Position 2.1

250V bias voltage

- Raw noise
- Common mode subtracted noise

Only three ring 2 modules available.
- Raw noise
- Common mode subtracted noise
- 250V bias voltage
Ring 4

Position 4.1

Position 4.2

Position 4.3

Position 4.4

- Raw noise
- Common mode subtracted noise

⇒ non-flat noise on position 4.3 (as before)
Ring 6

- Raw noise
- Common mode subtracted noise

⇒ non-flat noise on position 6.3 (as before)
250V bias voltage.

- Raw noise
- Common mode subtracted noise

Modules have HV problems and many bad strips. New ring 5 modules are built and will be tested asap.
Ring 7

- Raw noise
- Common mode subtracted noise
⇒ Still non-flat noise distributions on positions 4.3 and 6.3
With the final version of the ICB, the shielding is still necessary on positions 6.3 and 4.3

Prototype shielding foils for main ICB produced at company

5 µm of copper, 100 µm of FR4
Thickness of the shielding

Position 6.3

Foils with a thickness of 17.5 µm are available at the company.

Thicker shield needed than before (5 µm) due to thinner copper layers in the ICB?

⇒ Thickness of at least 10 µm is necessary.

No significant difference between 15 and 20 µm.
Shielding floating or connected to ground:

\[
\Rightarrow \text{No significant difference between grounded and floating shielding!}
\]

Shield will probably be grounded. Modular design, such that both options can still be implemented.
Noise on group 2 is much reduced when group 1 is off.
Noise on group 2 is flat when cable of group 1 is disconnected!
No effect of group 3 is observed.
Comparison of Power Supplies

Comparison between 3 Delphi PSs and 2 Delphi + 1 Lambda PS:

→ Changing PS on group 2 makes almost no difference
→ Powering g1 with the Lambda PS reduces noise on 6.3 significantly

⇒ Noise source is external, but noise is introduced mainly via power connection of group 1
What is so special about group 1?

- Main ICB consists of six copper layers.
- Most outside layer under modules 6.3 & 4.3:
  - 1.25V potential surface for group1
  - 2.50V potential surface for group2
- This is the only area where the power rail of another group (group1) is running in outside layer underneath a module

Does the noise come from this area only?
Reduction of shield surface?

Shield in shape of 1.25V potential area of group 1:

Position 6.3

Shield in shape of 2.50V potential area of group 2:

⇒ **Smaller shields** shaped like the 1.25V potential area of group 1 or the 2.50V potential area of group 2 are not enough!

Main problem apparently: no equipotential plane under the module.
Two **capacitors** added on the ICB between the group 1 and group 2 surfaces, to improve their AC grounding:

\[ \Rightarrow \text{Additional AC grounding} \] due to capacitors between the grounds of group 1 and 2 improves the noise significantly.

No effect for \( C \leq 1 \mu F \) \( \Rightarrow \) noise frequency is relatively low \( (f = 1/(2\pi Z C)) \)
Comparison short/long MS cables

Later in CMS multiservice cables of (probably) 45m length will be used.

⇒ Test with **45 m long multiservice cables** is encouraging: 
noise on position 6.3 is much reduced (due to higher inductivity)
Cable screens floating/grounded

Grounding of the aluminium screens of the MS cables:

⇒ Less noise when screens are grounded on one side and floating on the other side.

Similar effect with AC grounding (via 10 μF capacitor)
Visit of Marvin Johnson last week: various bad grounding configurations tested, e.g. cable screens grounded on both ends:

**Position 6.3**

No degradation of noise with shield and capacitors!

Shield is more beneficial than the capacitors, but still slight improvement found with capacitors.
Sinus signal (10Vpp) from pulse generator connected to screens of MS cables to induce currents in the cables:

No degradation of noise due to bad grounding or external sinus signal on the cable screens ⇒ **the system is robust.**
Noisy edge strips

Relative large edge strip noise on all detectors.

- Edge strips show jumps in pedestal
- Effect not seen on a hybrid with pitch adapter

These jumps are in phase for all modules!
Noisy edge strips

Variation of the spill size for the strip 128:

⇒ Length of the “steps” corresponds to the spill size.

Length of the “steps” does not depend on the trigger frequency.
Noisy edge strips

Reason found by Laurent: with calibration inhibit on the effect is not present: very flat noise, almost no increase of noise at APV edges.

Calibration circuit of the APV is located in the corner of the chip → only edge strips are affected.

Other detectors look equally nice.
Running a petal in the cold - Setup

Any problems (mechanical stress, noise,...) in the cold?

- Cooling machine for copper plates (-23°C)
- Cooling machine for petal (-25°C)
- Box actively cooled by two copper plates
- Multimeter for sensor readout
- Thermal isolation layer around box
- N₂ for cooling system
Running a petal in the cold - Setup
Running a petal in the cold - Setup

Simple setup
→ no cooling test, but **test of electronics performance** in the cold!
Cooling inserts have old design and also a bad contact to the cooling pipe.

- Petal cooling: cooling fluid at -25°C
- Box cooling: cooling fluid at -23°C
- Box flushed with pre-cooled N₂, relative humidity ≈ 5%
- DCUs were read out during measurement whenever possible
- DCU conversion formulas & constants by Wim, no special calibration performed
- Additional pt-100 temperature sensors in the air and on frame, hybrid, AOH of one module
- Electrical digital link used

Plots show results using the “final” setup: shield of thickness 17.5μm, three 22 μF capacitors soldered on the ICB between the two potential surfaces.
Running a petal in the cold - Temperatures

Temperatures measured with the pt-100 sensors:

- $T_{\text{hybrid}} < - 8 \, ^\circ\text{C}$
- $T_{\text{AOH}} < - 13 \, ^\circ\text{C}$
- $T_{\text{frame}} < - 16 \, ^\circ\text{C}$
Running a petal in the cold - Temperatures

DCU temperature measurements, e.g. module 6.3:

- \( T_{\text{silicon}} \approx -15^\circ C \)
- \( T_{\text{hybrid}} \approx 0^\circ C \)
- \( T_{\text{DCU}} \approx -8^\circ C \)

Good agreement for \( T_{\text{silicon}} \). All silicon sensors between -10°C and -16°C.

Large deviation and spread in \( T_{\text{hybrid}} \). All hybrids between +6°C and -12°C.

But: all hybrids cooled down by \( \Delta T \approx 40^\circ C \)
Optical bias was adjusted before each run.
Running a petal in the cold - Noise

Position 3.2

Position 4.2

Position 3.3

Position 4.3

to be checked with calibration run
Running a petal in the cold - Noise

Noise in electrons, using the information from calibration runs:

Very preliminary!
First conclusions from running the petal in the cold:

- The ICB works in the cold environment, except that ...
- ... on three positions the $I^2C$ access to all chips was lost during cooling, recovered during warm up! To be investigated...
- Shape of noise distributions have not changed
- No problems on position 6.3
- Decrease of noise not visible in ADC counts
- First studies indicate that noise in electrons is decreased by roughly 15% in peak mode:
  - e.g. detector 3.2: from $\approx 700$ e$^-$ at room temperature to $\approx 550$ e$^-$ in the cold
  - detector 6.1: from $\approx 900$ e$^-$ to $\approx 800$ e$^-$
Conclusions

- Noise measurements were carried out using the final version of the ICB.
- Noise distributions are acceptable on most positions.
- Non-flat noise is observed on two positions: 4.3 and 6.3.
- On these positions noise from an external source (e.g. power supply) is induced via the ICB on the module.
- With a 17.5 μm thick copper shield all noise distributions are flat.
- With shield and capacitors on the ICB, the system is very robust.
- Many thanks to Marvin Johnson for his help!

The front petal ICB has been ordered from the company, the boards are expected to be delivered in April.
Parameter settings

\begin{itemize}
  \item cdrv = 0
  \item csel = 8
  \item imuxin = 34
  \item ipcasc = 52
  \item ipre = 98
  \item ipsf = 34
  \item ipsp = 55
  \item isha = 80
  \item ispare = 0
  \item issf = 34
  \item muxGain = 2
  \item vfp = 30
  \item vfs = 60
  \item vpasp = 35
  \item ical = 29
  \item \textbf{mux resistor = 15}
  \item \textbf{apv mode = 43, later 47}
  \item \textbf{opto gain = 2}
  \item \textbf{HV = 250V}
\end{itemize}

Mainly default values from Marcos module testing document.