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
- Summary & outlook
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!)
Delphi LV supplies

ISEG HV supply

Patch panel (with relais for control of HV lines)

Optical ribbons

DOH

Power for CCUs and DOH

PC with FEC, TSC, 4 FEDs

VME crate with 3 O-FEDs

Multiservice cables (10m long)

Petal in transport frame

System test setup
I²C communication problem

Problems with I²C communication observed due to the 510 Ω resistors in the I²C clock lines: all chips worked when addressed directly after reset, but no communication with APV after DCU or AOH had been addressed!

- Clock fall time longer than data fall time due to new resistor.
- Clock must be low when data changes, otherwise start condition!
- Chips pull data line down (i.e. clock low condition fulfilled) for different clock levels: $U_{\text{clock\_low}} = 0.9\text{V}$ for AOH and DCU, but $U_{\text{clock\_low}} = 0.4\text{V}$ for APV.

When DCU is addressed and data changes, clock ist still high for the APV → APV misinterpretes this as start condition.
I²C communication problem

By chance, remaining bits form APV broadcast address (63) and APV is activated (but protocol is wrong) → communication fails.

Solution: capacitors (≈ 1nF) added in the I²C data lines of all modules → longer fall time also for data → clock is low for APV as well.
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 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**
- Bias voltage was **250V**
- **Analysis code** by Richard Brauer, constant common mode assumed

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.
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.
Ring 3

- Raw noise
- Common mode subtracted noise

250V bias voltage
Raw noise

Common mode subtracted noise

⇒ non-flat noise on position 4.3 (as before)
- 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. Only three modules available. New ring 5 modules are being built.
- Raw noise
- Common mode subtracted noise
Shielding of the ICB

⇒ 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
Thicknness of the shielding

Position 6.3

⇒ Thickness of at least 10 µm is necessary.
   No significant difference between 15 and 20 µm.

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 5 µm would be sufficient.
We would prefer to use 17.5 µm here also.
Additional shield on second ICB (ring 2 ICB) is not necessary.
Shielding floating/grounded

Shielding floating or connected to ground:

⇒ No significant difference between grounded and floating shielding!

Will probably be grounded.
Modular design, such that both options can still be implemented.
Effect of groups 1 and 3 on group 2

Switch off power or disconnect power cables of groups 1 and 3:

⇒ 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 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

Setups not exactly comparable (cables)!!

(No measurement with HP PS, because we observe oscillations on one of our HPs. Sent back to company)
Also for the Lambda PS the noise on 6.3 is slightly reduced by the shield.
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 group 1
  - 2.50V potential surface for group 2
- This is the only area where the power rail of another group (group 1) 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:

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!

Effect of shield due to capacitive coupling *between* the two potential areas!?
A capacitor added on the ICB between the grounds of group 1 and group 2, to improve their grounding:

⇒ Additional AC grounding due to capacitor between the grounds of group 1 and 2 improves the noise significantly.
Test with 45 m long multiservice cables is encouraging: noise on position 6.3 is much reduced (due to higher inductivity)
Increase of MS cable inductivity

Use of magnetic rings to increase cable inductivity:

⇒ Increase of cable inductivity with ferrit rings did not reduce the noise (both for short and long MS cables)
Cable shields floating/grounded

Grounding of the aluminium shields of the MS cables:

⇒ Less noise when shields are grounded on one side and floating on the other side!

Similar effect with AC grounding (via 10 μF capacitor)
Non-flat noise without bias voltage

No difference between 0V and 5V bias voltage. With a bias voltage of 10V, the noise is already much flatter than with HV off.
Conclusions

- Noise measurements were carried out using the final version of the ICB.
- Noise distributions are acceptable on most positions.
- Consistent with measurements on previous ICB version, non-flat noise appears on two positions only: 4.3 and 6.3.
- On these positions noise from an external source (power supply) is induced via the ICB on the module.
- With a 17.5 μm thick copper shield all noise distributions are flat.

- Problems with I²C communication due to new current limitation resistors have been solved by adding capacitors in the I²C data lines.
- Delphi PS introduces much more noise than the Lambda PS.
- Next week Marvin Johnson, a noise expert from D0, will visit us.

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

- Test of slow control functionality (read out of temperature & humidity)
- Test of noise sensitive positions on the back petal ICBs, starting with a mock-up petal
- Study of noise performance of a front petal in the cold
- Readout of a two petals in one control loop, starting with a fully equipped front petal and a partly equipped back petal
  * noise behaviour
  * performance of the control loop with the final DOHM
  * test of the redundancy
Parameter settings

cdrv = 0
csel = 8
imuxin = 34
ipcasc = 52
ipre = 98
ipsf = 34
ipsp = 55
isha = 80
isp Gale 0
issf = 34
muxGain = 2
vfp = 30
vfs = 60
vpssp = 35
ical = 29
mux resistor = 15
apv mode = 43
opto gain = 2
HV = 250V

Mainly default values from Marcos module testing document.

Exceptions: isha, mux resistor, vpssp changed during measurements after discussion with TOB people