

# New electronics architecture in NEMO - phase 2

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## Abstract

NEMO phase 1 has seen a four floors *mini-tower* deployed off Catania harbour. NEMO Phase 2 will consist in the deployment of a full-size (sixteen floors) tower in the final site of Capo Passero.

Experience gained during phase 1 operations pushes us to propose some experimental electronics to be tested during phase 2.

*Key words:* NEMO, neutrino telescope, data acquisition electronics

*PACS:* 01.30.Cc

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## 1. NEMO phase 1 vs. NEMO phase 2

During winter 2006, NEMO collaboration deployed a four floors high *mini-tower* about 25 km off Catania harbour, at a 2000 m depth. This experiment, called *NEMO phase 1*, served the purpose of testing mechanics, electronics and operations for an underwater neutrino telescope in a realistic environment, giving precious data and experience to the collaboration. A scheme of the *mini-tower* is shown in fig. 1.

Next step, *NEMO phase 2*, will see a full-size tower deployed in one of the candidate site for the whole telescope. This tower will be equipped with sixteen floors. The operation site for NEMO phase 2 is located off Capo Passero, in south eastern Sicily.

Fourteen out of the sixteen floors <sup>1</sup> will be equipped with the same electronics used in phase 1, with the exception of a few items that will be discussed. The remaining two “experimental” floors

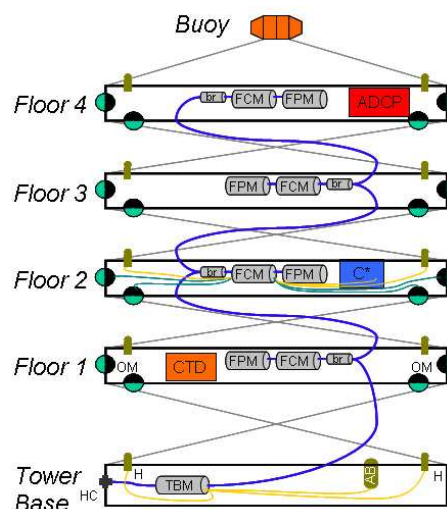


Fig. 1. *Mini-tower* pictorial view. You can see Floor Control Module (FCM) in the middle of each floor and four Optical Modules per floor.

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<sup>1</sup> We will indicate them as “standard” floors.

will be used to test new electronics.

## 2. Electronics architecture in NEMO phase 1

### Floor electronics

Each floor of the NEMO phase 1 mini-tower is equipped with four Optical Modules (OM). Physics data from each floor’s PMTs are collected by 4 Front End Module (FEM) boards, placed inside the optical modules, and sent to shore by one Floor Control Module (FCM) board. This board is connected with an onshore twin FCM board, through a 640 Mb/s optical link<sup>2</sup>.

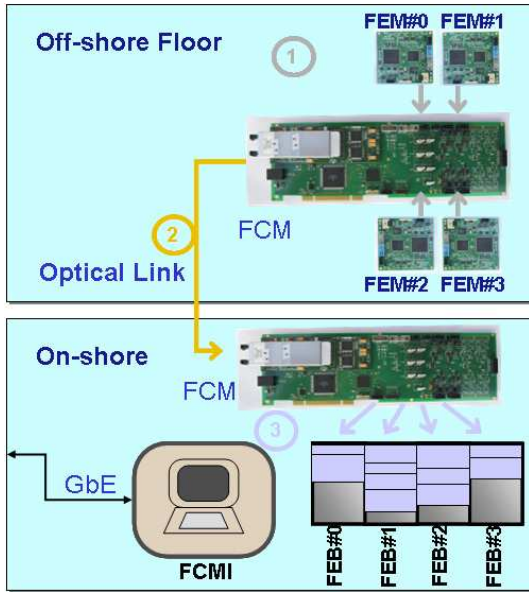


Fig. 2. Functional scheme of NEMO floor electronics, as used in NEMO phase 1

The whole system is synchronous, as the clock signal is transmitted to the underwater electronics via the optical link and distributed to all electronic devices. This allows us to mark sampled data with an absolute timestamp, apart from a fixed delay, that can be measured once and for all by a time calibration procedure<sup>3</sup>. The functional scheme of floor electronics is depicted in fig. 2.

### FEM board

The Front End Module board<sup>4</sup> is equipped with two 8-bit ADC converters at 100 MHz. ADCs oper-

ate in phase opposition, achieving a 200 MHz sampling frequency. Analog signal from the PMT passes through a low-pass filter for bandwidth limitation, and is nonlinearly compressed, to achieve 13 bit equivalent dynamics. An FEM board can be seen in fig. 3.

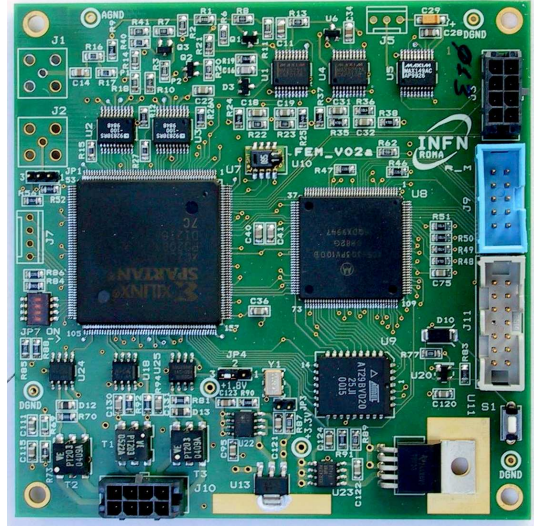


Fig. 3. FEM board

Sampled data are packed and sent serially to FCM through a 20 Mb/s differential link line. Two more 5Mb/s differential pairs are used to exchange control data with FCM and to receive clock signal.

Moreover, FEM board manages PMT high voltage and monitors optical module environmental parameters.

Real-time 8 bit sampling at 200 MHz frequency, would require a data transfer rate of 1 Gb/s. In fact, we use a zero-skipping procedure to avoid sending useless data: FEM samples continuously PMT signals, but sends onshore only samples over a certain threshold. With a convenient threshold value, this is equivalent to sample only pulses generated from photon hits on PMT.

During running time of NEMO phase 1 (See [1]), an 80 kHz average hit rate was measured<sup>5</sup>, and an average sampled pulse size of 120 bits was noticed. This means an average data rate of 10 Mb/s for each FEM. Thus, the 20 Mb/s serial link between FEM and FCM is large enough.

<sup>2</sup> Future developments of NEMO may see optical link on the tower backbone replaced by an electrical one.

<sup>3</sup> Time Calibration procedure is described in [2].

<sup>4</sup> A detailed description of FEM board can be found in [4].

<sup>5</sup> This rate is mainly due to PMT’s dark current and  $40K$  decays. See [3]

## FCM board

The Floor Control Module offshore board may be considered the hub of the whole apparatus. The board is shown in figure 4. It oversees the optical

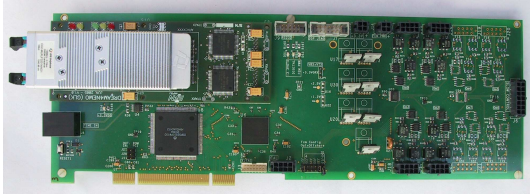


Fig. 4. FCM board

link with the on-shore system. It recovers the clock from the optical link serial stream and distributes it to all peripherals, including FEM boards. It collects physics data from front end and send them onshore. It gets environmental data from peripherals, including FEMs and Slow Control board<sup>6</sup>. The FCM communicates also with the timing calibration board and, in phase 2, it performs AES3 interface with hydrophones sampling board.

Onshore, the FCM is plugged on a PCI slot of a PC. It manages the optical link and transfers data to the PC via PCI bridge. It also manages all the Slow Control commands.

## Differences between NEMO phase 1 and NEMO phase 2 “standard” floors

Some changes from NEMO phase 1 will occur even in fourteen phase 2 “standard” floors.

The AC Floor Power Module<sup>7</sup> will be replaced with a DC one.

A real-time sampling of hydrophones acoustic signal will be performed at a 192 kHz rate, using AES3 standard audio format. Thus, hydrophones may be used for bioacoustic measurements and for acoustic neutrino detection as well as for their main purpose of acoustic positioning of the telescope apparatus.

The Time calibration board will be moved from inside FCM to inside OMs to avoid the use of optical fibers.

<sup>6</sup> Slow Control board is an interface to all commercial instruments used to monitor the underwater environment.

<sup>7</sup> Labeled FPM in figure 1.

## 3. Electronic devices clustering

Experience gained in NEMO phase 1 mini-tower deployment allows us to make some considerations about apparatus engineering. Integration between mechanics and electronics is a time consuming and labour intensive task. This leads us to search for an arrangement which concentrates of electronic devices on each floor, making integration easier. Moreover, we expect these changes to minimize power dissipation and reduce the number of mechanical connections.

Two paths seems to be practicable to reach the goal: either place all electronics boards inside optical module or gather up all devices inside the floor control module. We will discuss the latter solution<sup>8</sup>.

This implies the realization of a new FCM board to perform all tasks of four FEMs and one FCM. In this solution, analog signals from PMT are carried directly to the FCM where the ADCs are placed.

Optimum solution, from a device gathering point of view, would be to leave no active electronic devices inside OMs, with copper wires bringing signal such as PMT high voltage level from FCM to OM and twisted pairs carrying PMT analog signals. Negative effects of such an arrangement would consist in difficult monitoring of environmental parameters inside OMs. Furthermore, some electronic devices could be needed anyway inside OMs.

A more realistic compromise will see inside OMs a line driver (*i.e.* signal amplifier which will let us free to use longer cables) and a very simple control board managing HV, monitoring environmental parameters and communicating with FCM with a slow serial line, and any calibration hardware required<sup>9</sup>.

This configuration shall be tested on one of the “experimental” floors of NEMO phase 2 tower.

## 4. New FCM board

As we discussed in the previous section, a new FCM offshore board will integrate four FEMs and one FCM.

<sup>8</sup> In fact, we will describe in section 5 a new board, assuming that is placed inside FCM, but it could be placed inside one of the four floor OMs as well, removing the FCM. The only price to pay is an asymmetrical length of copper links from PMTs to the board.

<sup>9</sup> Time Calibration could be simplified because on each floor we need only to estimate analog signal latency through a copper cable of known length.

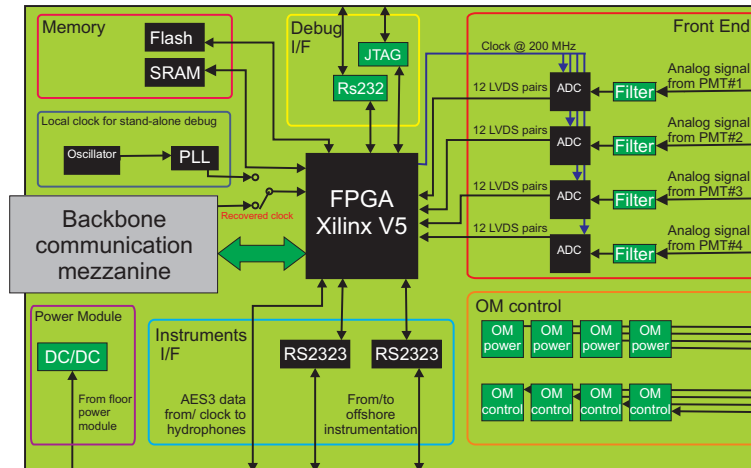


Fig. 5. New FCM board block scheme

The front end modules integrated on the new FCM board will consist of four (one per OM) 12 bit 200 MHz low power ADC converters<sup>10</sup>. 12 bit dynamics will allow us to range from single to multiple P.E. hits with no need for analog compression. Thus, we can remove nonlinear components which simplifies charge calculation and pulse waveform reconstruction.

Interfaces to backbone, proprietary mezzanine and other peripherals, such as hydrophones, time calibration and slow control, will remain unchanged.

A block diagram of the board is shown in figure 5.

A real-time 12 bit sampling at 200 MHz frequency would lead to a 9.6 Gb/s data rate from each floor. Applying over threshold sampling (zero skipping) as described in section 2, and considering as an upper limit the 20 Mb/s data rate per floor for an 8 bit sampling, we can expect from the new board a data rate lower than  $4 \times 30 Mb/s = 120 Mb/s$ .

Knowing that most of the pulses coming from phototubes are originated from S.P.E., *i.e.* their amplitude is small and 8 bit dynamics is enough to sample them, we may think to introduce a sort of data compression, using 12 bit sampling only for pulses that needs it, and 8 bit for all the remaining. In such a way we may lower the data rate.

This architecture implies the transmission of PMT analog signal over the distances separating OMs from FCM. In NEMO phase 1 this distance measures  $\sim 8$  m. This distance could increase in the future, but we don't expect it to exceed  $\sim 10$  m.

For such distances transmission of PMT signal over a simple copper wire could be imagined.

For longer distances a line driver that matches cable impedance could be needed between PMT and cable.

A benefit of analog transmission of PMT signal is to remove constraints on data flow from OM to FCM.

## 5. Conclusions

NEMO phase 1 electronics architecture is fully scalable. Thus, the main issue of NEMO phase 2 is to test a full-size tower with "standard", fully reliable, electronics. Nevertheless, it seems to be reasonable, looking forward to the huge size of neutrino telescope, to test a new electronics architecture that can simplify engineering operations.

## References

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<sup>10</sup> 14 bit ADC with comparable specifications recently appeared on the market.