Design and Performance of the mDOM Mainboard for the IceCube Upgrade.

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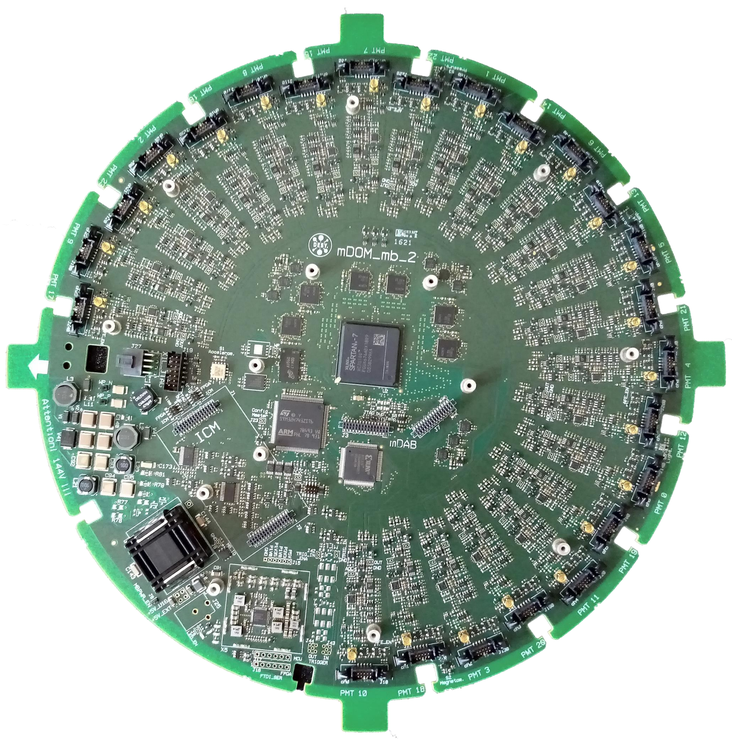
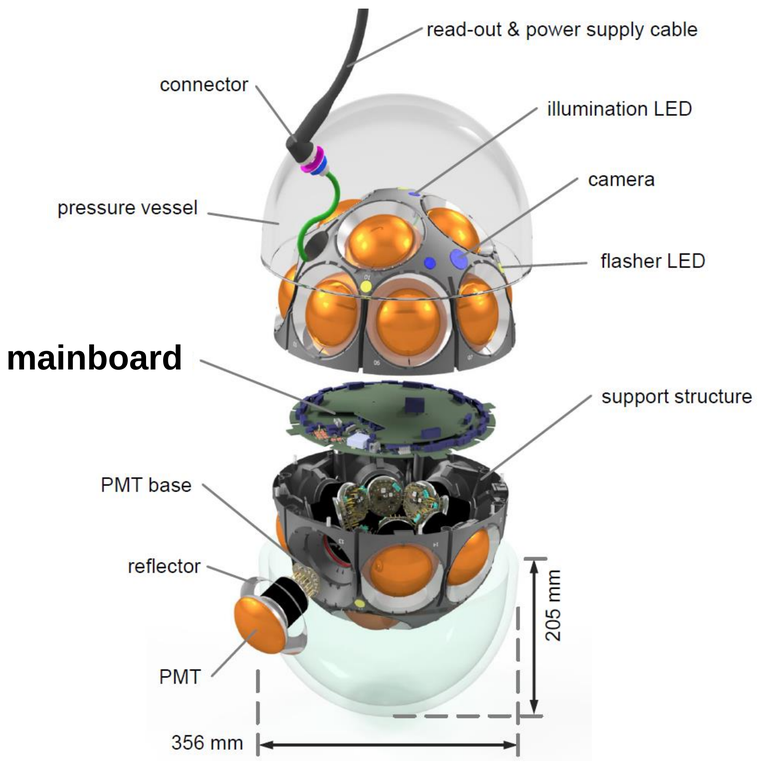
IceCube Upgrade
- ~700 new optical sensors densely instrumented on 7 strings including 402 mDOMs (multi-PMT Digital Optical Modules)
- reduce IceCube's energy threshold to a few GeV
- enhance understanding of the detector systematics via new calibration devices

mDOM (multi-PMT Digital Optical Module)
- 24 three-inch PMTs
- 10 nanosecond flasher LEDs
- 3 photo cameras with illumination
- pressure resistant up to 700 bar

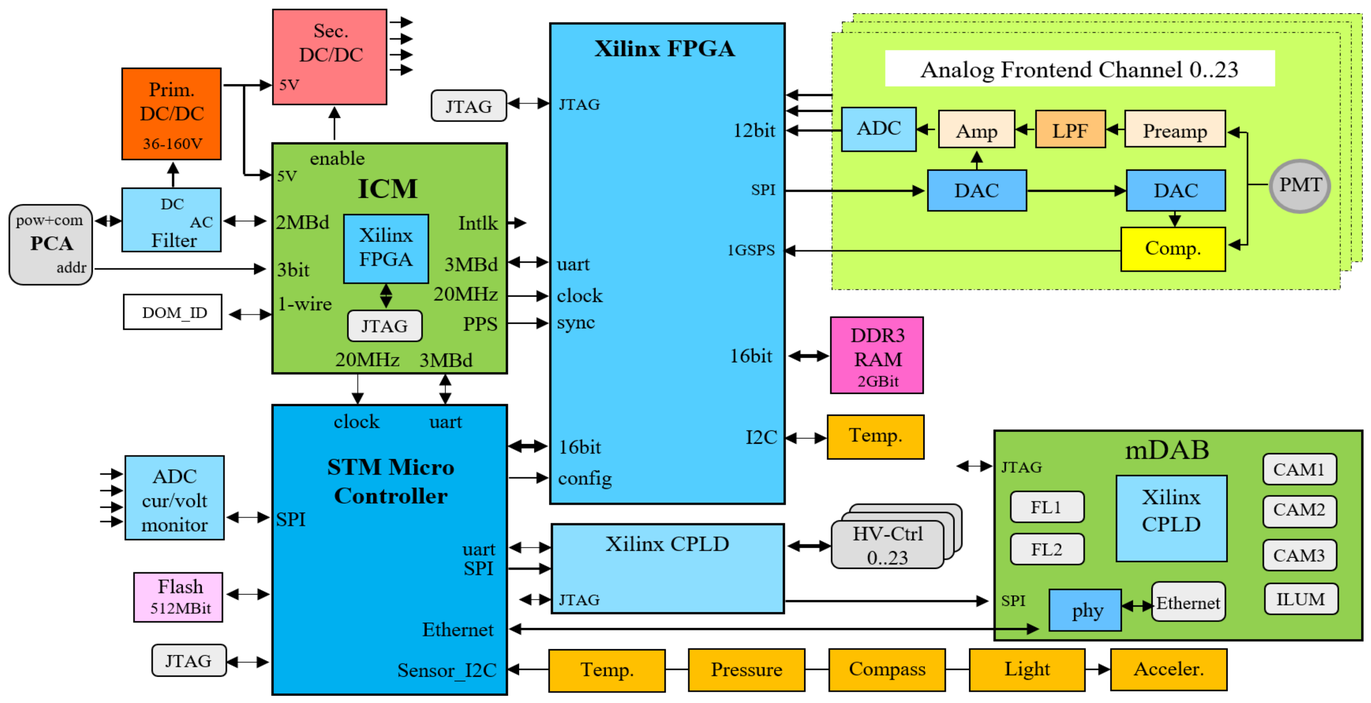
mDOM Mainboard
- limited available volume and demanding requirements
- each channel sampled continuously at 120 MSPS, 12-bit
- 0.2 photoelectrons trigger threshold
- discriminator output sampled at 960 MSPS for nanosecond leading-edge time determination

The Mainboard, located at the mDOM's Equator





Block Diagram

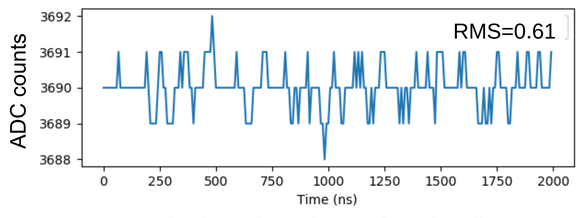


Analog Frontend

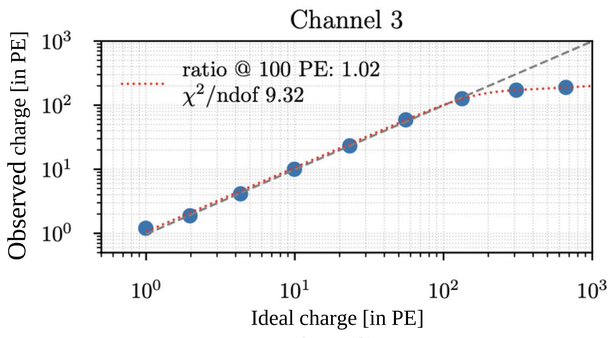
Specification

Input voltage	40V to 160V DC
Power consumption	9W max.
PMT Size	3“
Analog channels	24
Dynamic range	0.2PE to 150PE
Typical noise	< 0.7lsb RMS
ADC resolution	12bit
ADC Sampling rate	120MSPS
Trigger threshold	0.2PE to 150PE
Discriminator, ToT sampling rate	960MSPS
Event buffer	2Gbit DDR3 RAM
FPGA	Xilinx Spartan 7
MCU	STM32
Communication (custom, via ICM)	2Mbit/s, half duplex, modulated on power lines
Temperature range	-70°C to +50°C

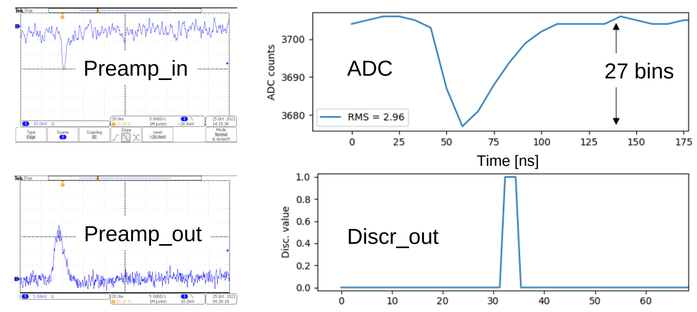
Main Features
- very low power consumption while maintaining required bandwidth
- dynamic range from 0.2PE to 150PE
- good linearity
- careful PCB design to reduce the noise by digital parts and the power supply
- ADC baseline noise for all channels below 0.7 lsb RMS
- DC-coupled input (PMT signal) avoids any signal droop effects
- PMT signal directly connected to the discriminator for exact ToT measurements
- precise 16-bit DACs to adjust the discriminator threshold and the ADC baseline
- Pulse-shaping low-pass filter
- precision (0.1%) gain-setting resistors



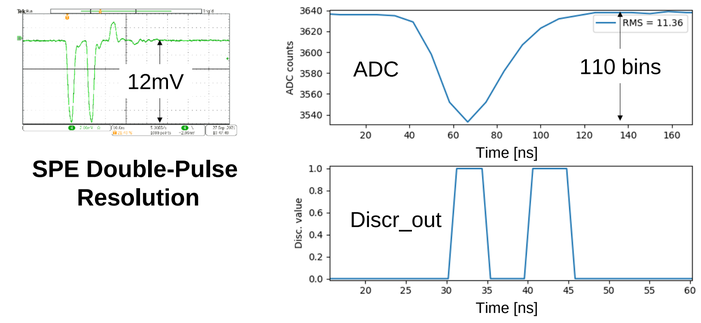
Typical analog channel noise figure



Linearity



Digitizing an SPE signal



SPE Double-Pulse Resolution

Deutsches Elektronen-Synchrotron DESY
A Research Centre of the Helmholtz Association