The New High Performance Suspension Control System For Advanced Virgo

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VIRGO

Motivations & Main Goals

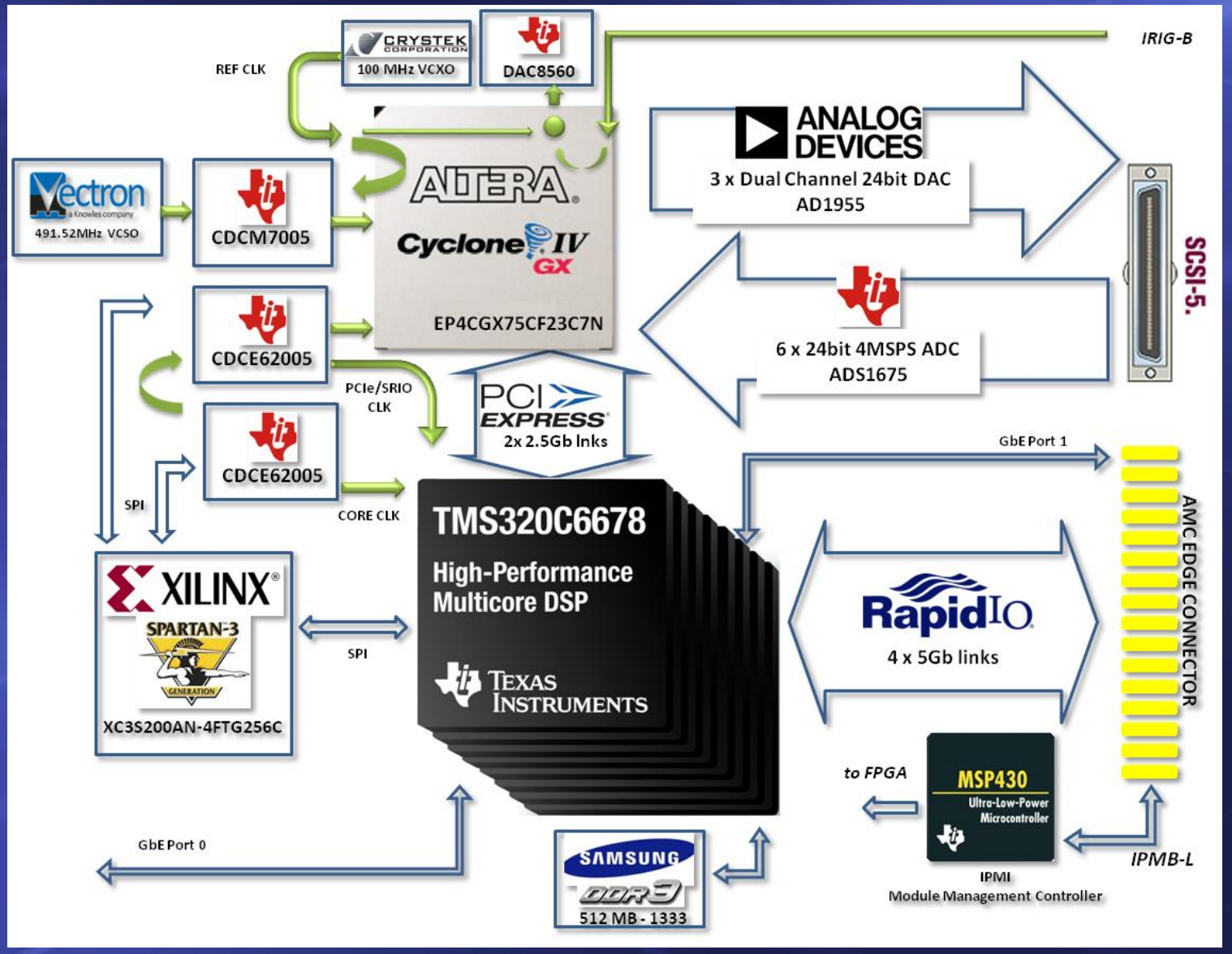
- The old VIRGO Suspensions control system has been in operation since last century (1998)
- In the past we replaced processing units (DSP-based) but we keep on using old front-end analog electronics and data converters (still in use today for some installation task, 17 years after production).
- Few design drivers:
  - Move out of VME standard (limiting board-to-board communication bandwidth)
  - Eliminate physical gap between analog front-end and data converters (in average more than 40 meters STP cabling, multiplied by about 100 signals for each of the 10 mirror suspensions)
  - Get out of the rigid single sampling frequency operation (10 kHz) and move on a more performing and flexible multi-rate system
  - Further increase of locally available computation power to increase data quality analysis capabilities and properly assist control design and implementation mainly for the last stage of suspension and new payload

UDSPT Board

- Result of design effort is a high performance signal conditioning, signal conversion and processing platform that enables users to implement state of the art hard real time control system. Board can be operated in standalone mode or in cooperation with other boards.
- Form factor is a variation of a Double Compact Module PICMG® AMC.0 R2.0 AdvancedMC module (variation consists in a wider board than what specified for a Double Module)
- The key features of the UDSPT board are:
  - Texas Instruments' multi-core DSP – TMS320C6678
  - 512 Mbytes of DDR3-1333 Memory
  - Two Gigabit Ethernet ports supporting 10/100/1000 Mbps data-rate
  - 170 pin B+ style AMC Interface containing SRIO and Gigabit Ethernet
  - IRIG-B input
  - Module Management Controller (MMC) for Intelligent Platform Management Interface (IPMI)
  - Powered by DC power-brick adaptor (12V/3.0A) or AMC Carrier backplane
  - Two on board FPGA: one Xilinx Spartan3 dedicated to processing unit and one Altera Cyclone IV interfacing data converters
  - 6 x 24b 3.84 MHz ADC converters
  - 3 x 24b 320 kHz DAC stereo converters (6 channels individually addressable)
  - Converters sampling frequency DSP IRQs synchronous with IRIG-B signal
  - Fully differential input channels and balanced output channels

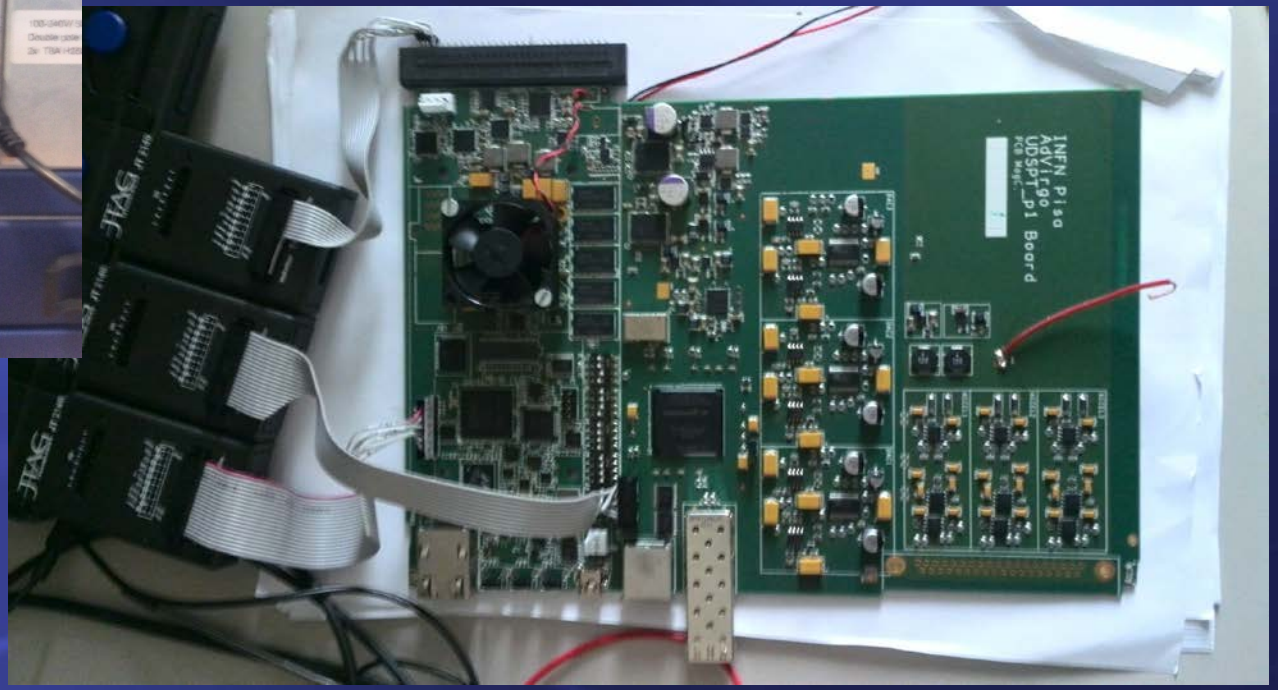
UDSPT Board


VIRGO
INFN
PISA
OPTICAL LINK
TIM
CONSOLE
RESET
LAN1


REF CLK
CRYSTEK CORPORATION
100 MHz VCXO
DAC8560
IRIG-B
ANALOG DEVICES
3 x Dual Channel 24bit DAC
AD1955
Vectron
a Knowles company
491.52MHz VCSO
CDCM7005
ALTERA
Cyclone IV GX
EP4CGX75CF23C7N
6 x 24bit 4MSPS ADC
ADS1675
SCSI-5.
CDCE62005
PCIe/SRIO
CLK
PCI EXPRESS
2x 2.5Gb lnks
GbE Port 1
CDCE62005
SPI
CORE CLK
TMS320C6678
High-Performance
Multicore DSP
TEXAS INSTRUMENTS
XILINX
SPARTAN-3
GENERATION
XC3S200AN-4FTG256C
SPI
RapidIO
4 x 5Gb links
AMC EDGE CONNECTOR
to FPGA
MSP430
Ultra-Low-Power
Microcontroller
IPMB-L
IPMI
Module Management Controller
GbE Port 0
SAMSUNG
DDR3
512 MB - 1333

UDSPT Board

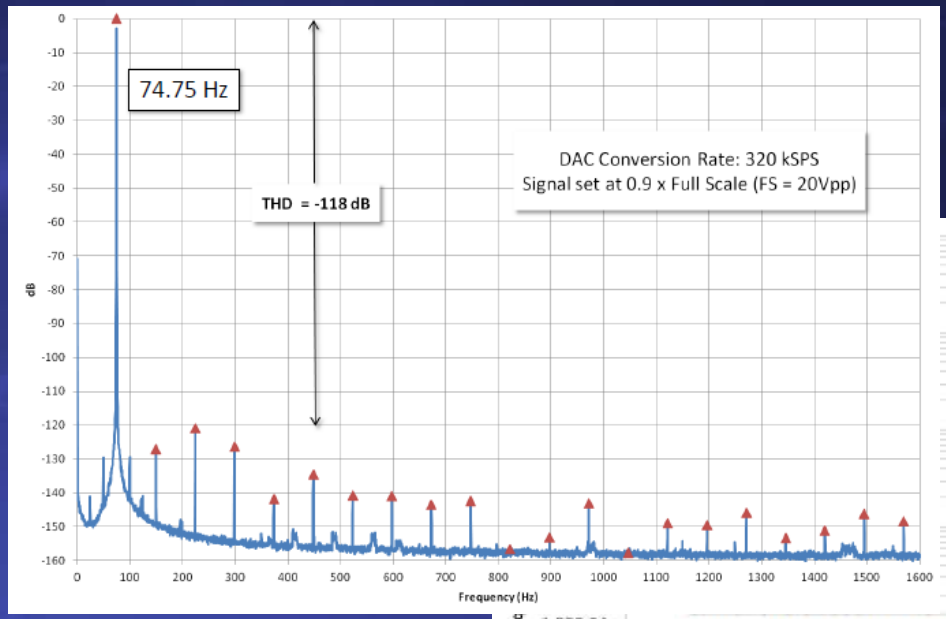
- Board complexity (250 different parts, a total of 2500 components) was compensated by a modular design. Processing, data converters and front-end occupy pre-defined areas. Strong effort in interfaces design

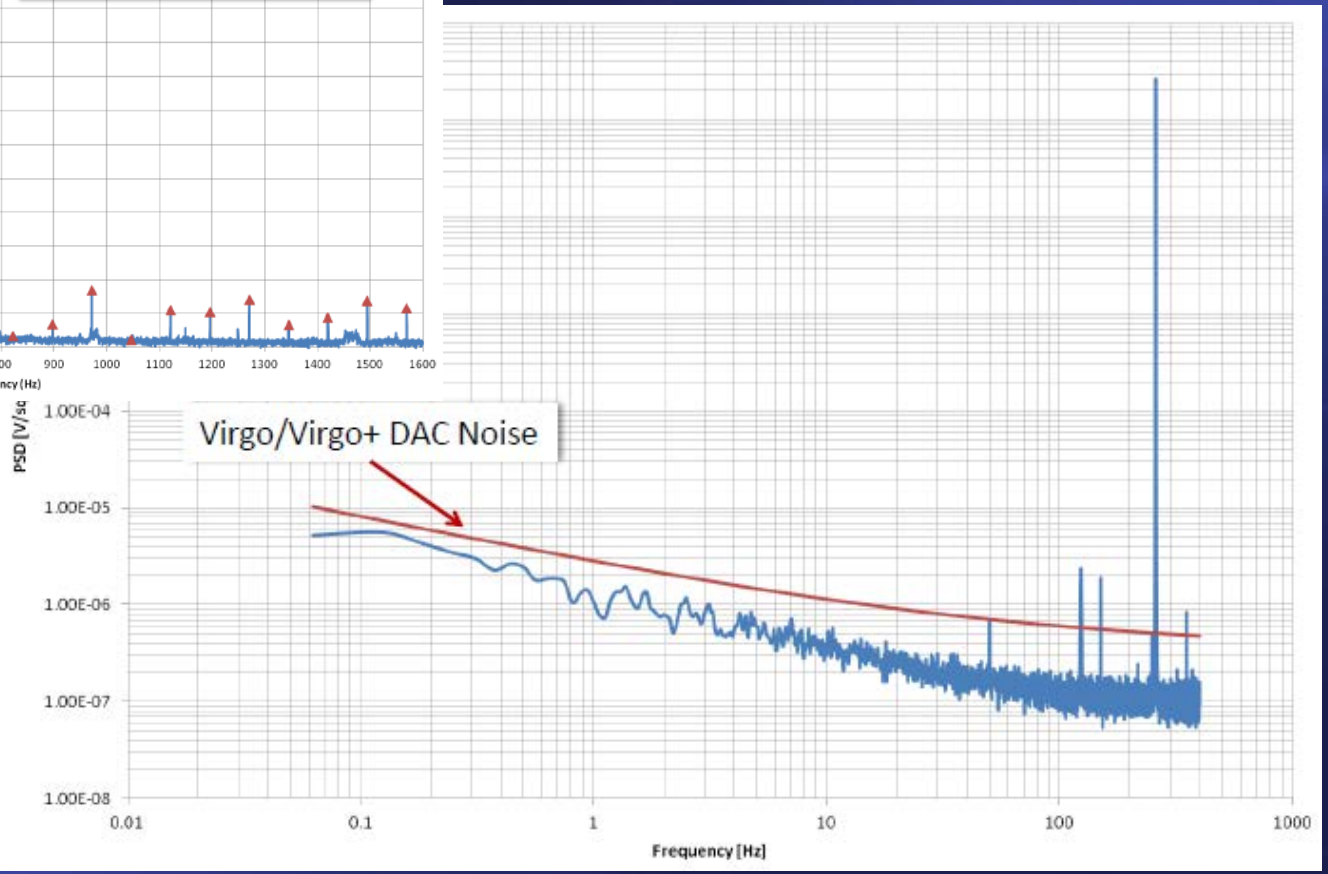


Performances

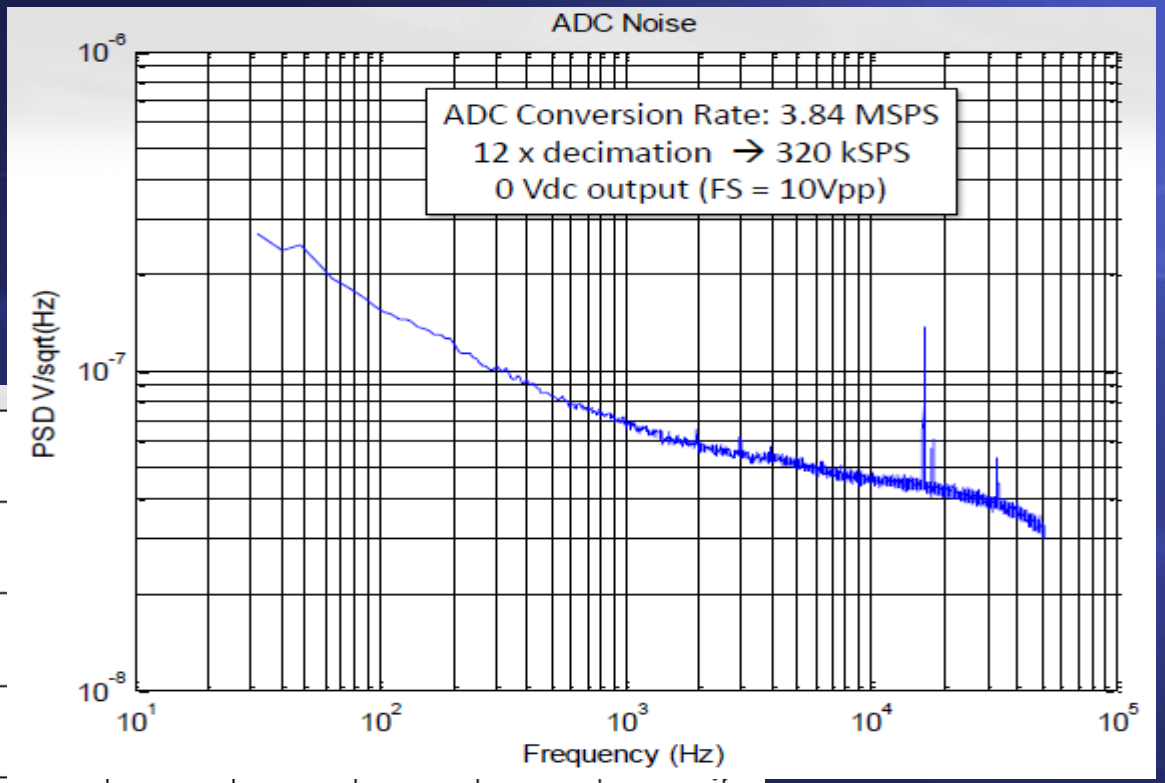
- Digital I/O
  - Gb Ethernet (tested up to 30 MB/sec) System - Rest of The World communication
  - PCIe (tested up to 400 MB/sec) On Board Communication
  - SRIO (tested up to 1.6 GB/sec) Board-to-board communication
- DSP Software
  - Tested operation up to 320 kHz sampling rate (3.125 usec interrupt request repetition cycle)
  - Matrix(n,m)*Vector(m,1) double precision multiplication requires 0.5*nm+n+m nanoseconds →
    - State space with 3 inputs, 3 outputs and 12 states requires less than 200 nsec

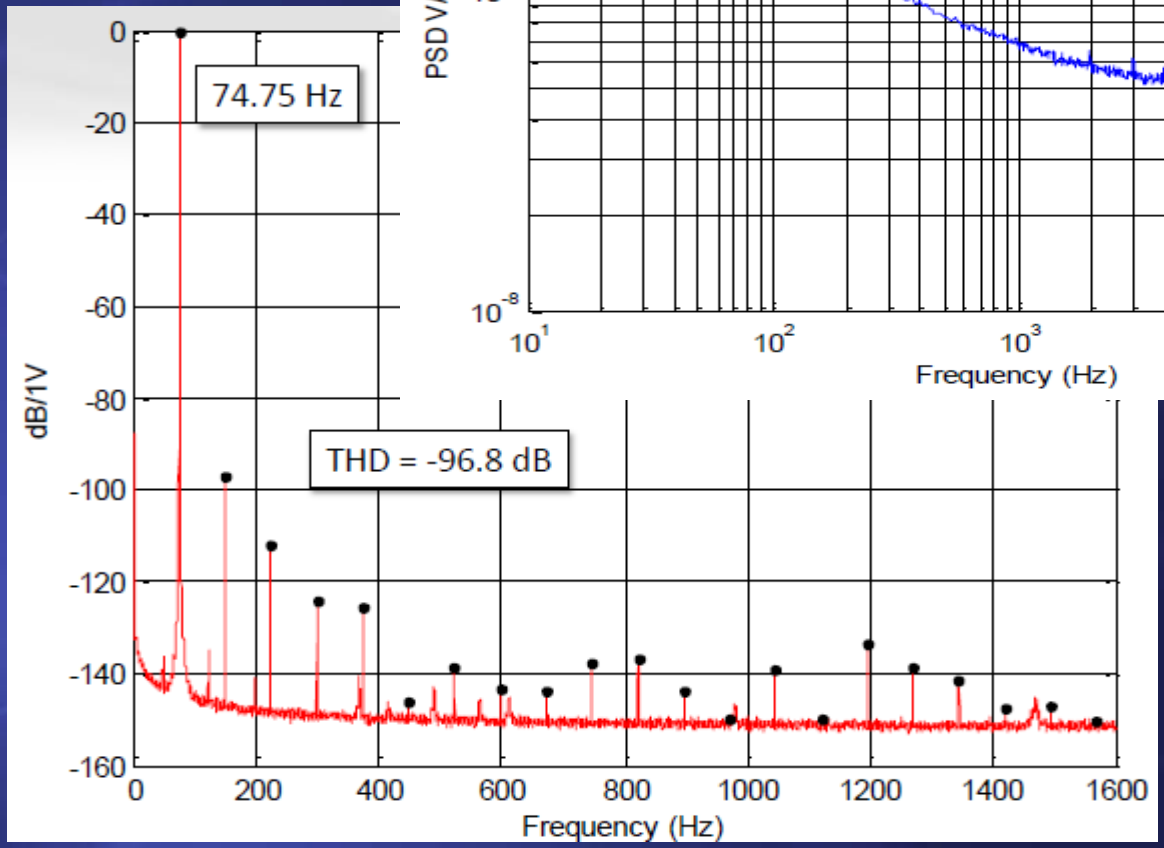
DAC Performances



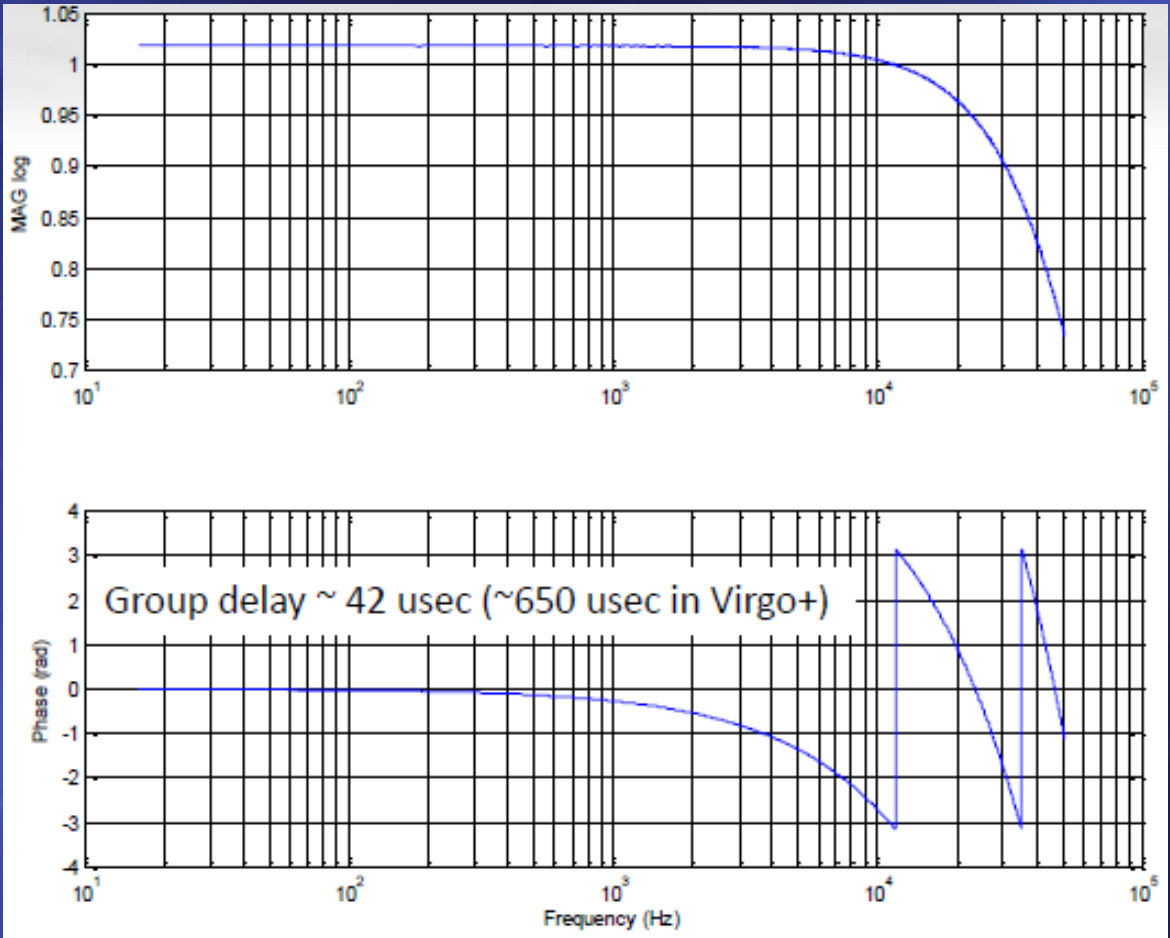


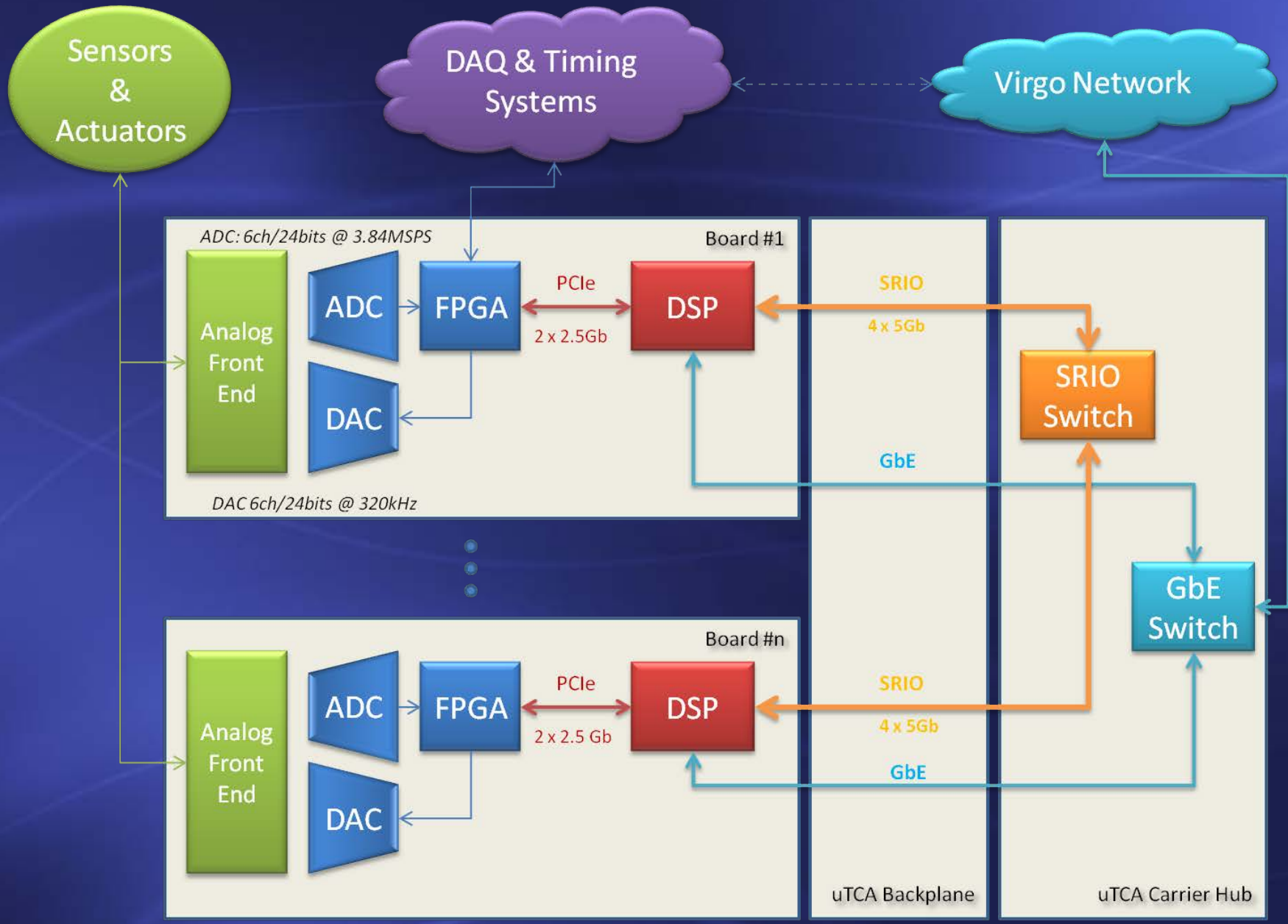
ADC


ADC Noise
ADC Conversion Rate: 3.84 MSPS
12 x decimation → 320 kSPS
0 Vdc output (FS = 10Vpp)
PSD V/sqrt(Hz)
Frequency (Hz)


74.75 Hz
THD = -96.8 dB
dB/1V
Frequency (Hz)

ADC-DSP-DAC Transfer Function



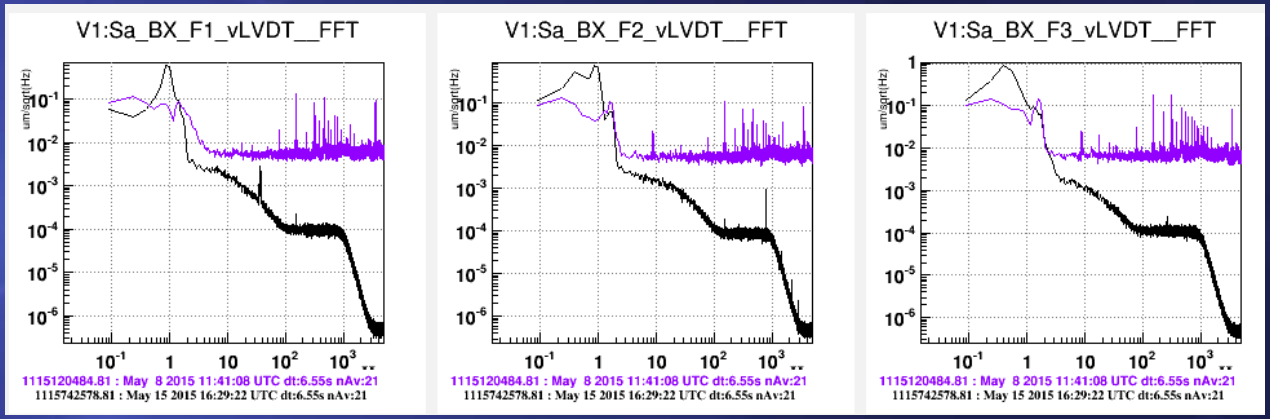

Sensors & Actuators
DAQ & Timing Systems
Virgo Network
ADC: 6ch/24bits @ 3.84MSPS
Board #1
Analog Front End
ADC
FPGA
PCIe
2 x 2.5Gb
DSP
DAC
DAC 6ch/24bits @ 320kHz
SRIO
4 x 5Gb
SRIO Switch
GbE
GbE Switch
Board #n
Analog Front End
ADC
FPGA
PCIe
2 x 2.5 Gb
DSP
DAC
SRIO
4 x 5Gb
GbE
uTCA Backplane
uTCA Carrier Hub

Result:

In a single 6U x 19” crate we can concentrate 72 ADC + 72 DAC channels supported by 720 GFLOPs, 12 x 1 Gb Ethernet ports + 12 x 1 Gb Optical Link for digital IO and a total power consumption less than 500 Watts

Performances: ADC Noise & EM Noise Immunity

- Performances tests on BS suspension went beyond our expectation. Placing converters at front-end electronics level, together with introduction of digital demodulation, drastically improved noise immunity. Following picture shows improvement in vertical position sensors readout.



Installation

- Board production was completed last July and installation is progressing fast. The following table summarizes installation status updated to July 28th.

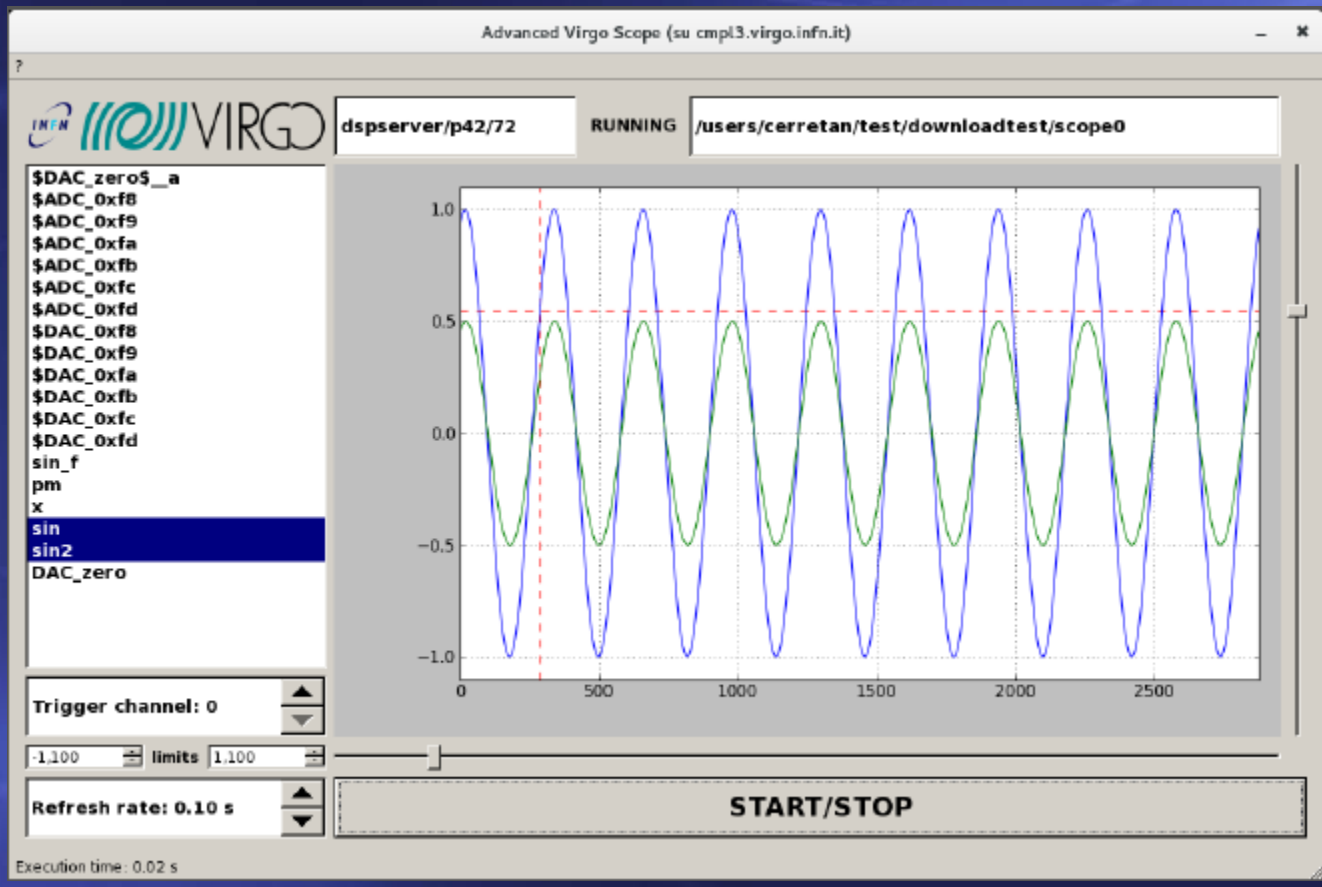
	BS	*WI*	*NI*	*PR*	*SR*	*IB*	*OB*	*MC*	*WE*	*NE*	*BPS*	*Total*
Total	15	15	15	15	15	14	7	14	15	15	1	141
Installed	12	10	12	7	12	12	6	0	2	2	1	76
To be installed	4	5	9	8	3	2	1	14	13	13	0	65
%	73	67	40	47	80	86	86	0	13	13	100	54

Software Supervisor

- For initial AdV, software shall support about 150 boards. At system startup eaach board loads boot code via tfpt from a dedicated boot server. This code is actually a sort of basic OS. In a second phase software supervisor (tango-based) downloads in each processor the hard real-time code.

Real Time Scope

A nice tool for system debugging is a real-time scope that can access any single variable declared into the source code. Work is in progress to provide real-time fft and few more functionalities



Conclusions

- A new system to control suspensions and mirrors was developed and installation is almost completed.
- Still some work in progress on software side and, as usual, will almost never end
- Extensive use of supervising software, mysql databases and third parties tools will simplify operation and maintenance