6. Electronics and Controls

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  - ADC/DAC and signal processing
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  - Demodulation
  - Voltage and current drivers

6.1 Introduction

- The electronics and controls must be compatible with AdV and possibly should be used to the great expertise of the collaboration on this issue.
- To get 12-13 dB of stable squeezed light in the audio frequency band the quality of the electronics and controls are crucial. Low noise, robustness and reliability are required
- In the science mode the squeezer and the injection system are not accessible. Thus automatic and/or remotely controlled loocking system are required.
- The parameters of the servoloop should be quickly adaptable to different environmental conditions or hardware modifications.

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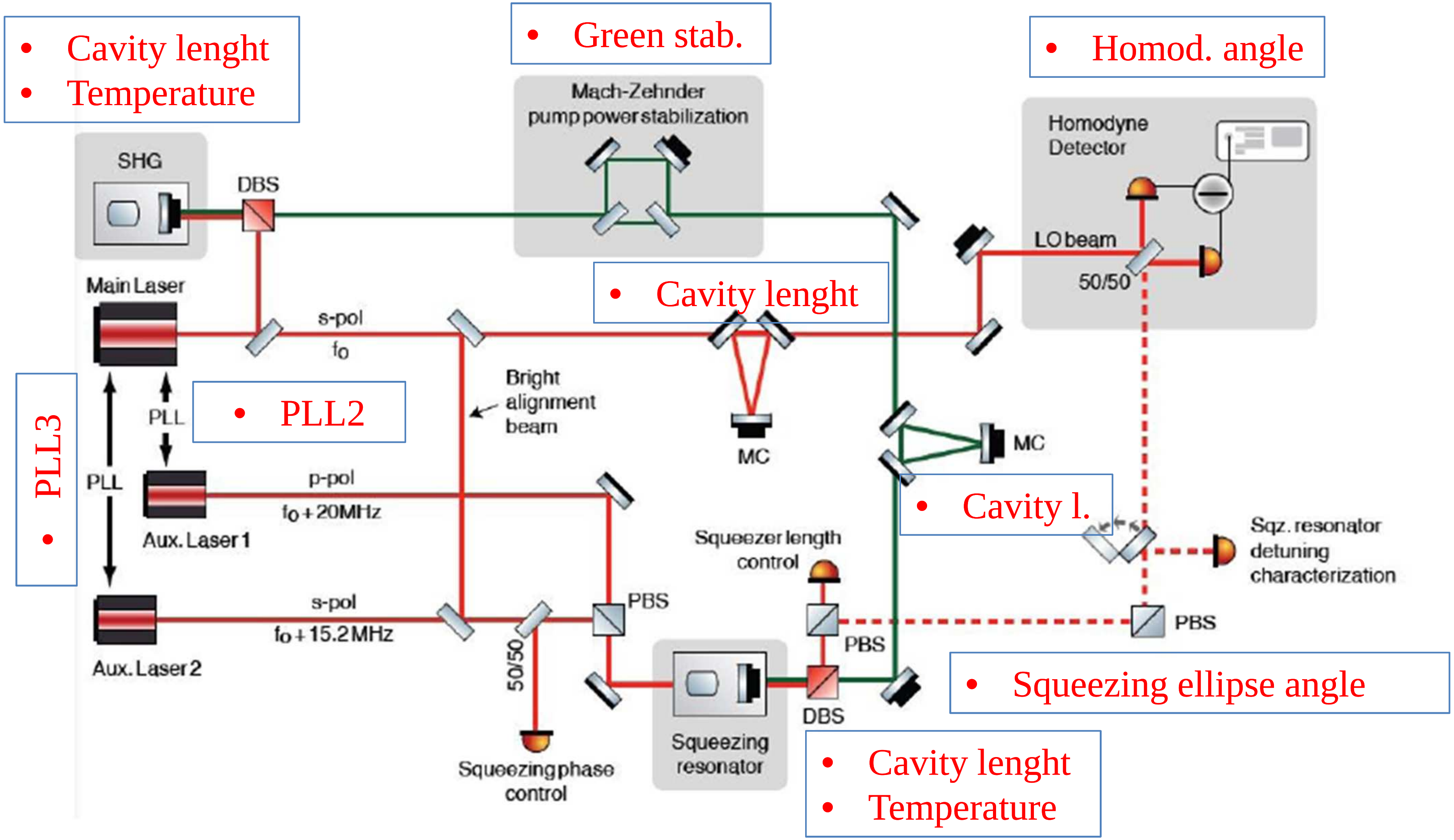
Digital control loops help to meet these requirements

«Squeezer» control loops



11 control loops

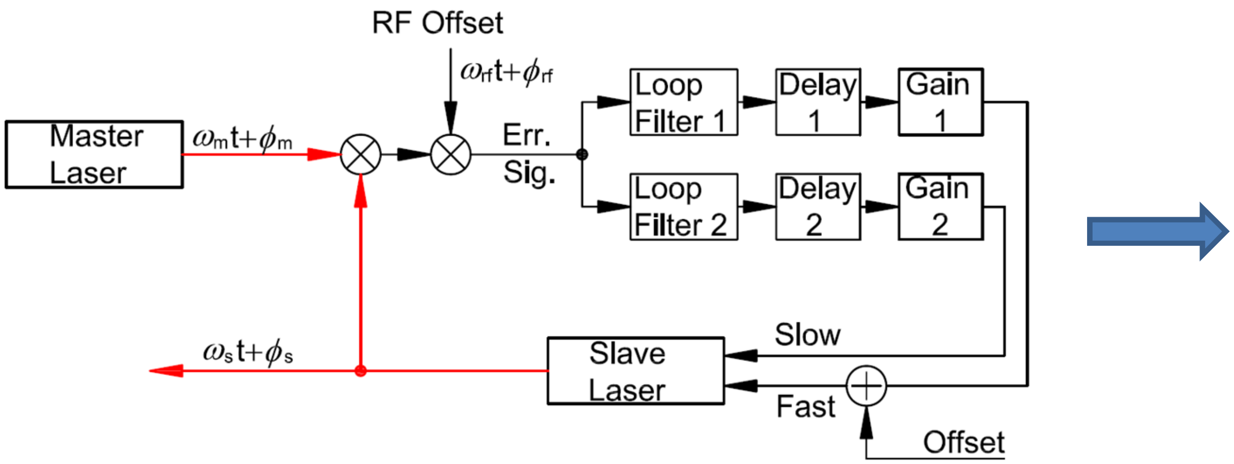
Total control loops

Injection: - Alignment, 4 axis piezo actuator
- Squeezing angle photodiode

Loop	Unitary gain	Loop	Unitary gain
PDH SHG	5-10 kHz	SHG temperature stabil.	100 Hz
PDH IR MC	5-10 kHz	OPO temperature stabil.	100 Hz
PDH GREEN MC	5-10 kHz	PLL OPO length control	Fast 10-100 kHz Slow 100 Hz
PHD OPO	5-10 kHz	PLL Coherent control	Fast 1 MHz Slow 100 Hz
Mach-Zender Green	1 kHz	PLL Main laser	Fast 1MHz Slow 100 Hz
Homodyne angle stabil.	5 kHz	Squezing angle stab.	5-10 KHz
Squeezing angle ITF	10 kHz	Alignement (4 channel)	5 Hz

At least 16 control loops are required

Offset Optical Phase Locked Loop



$\omega_s = \omega_m + \omega_{RF}$

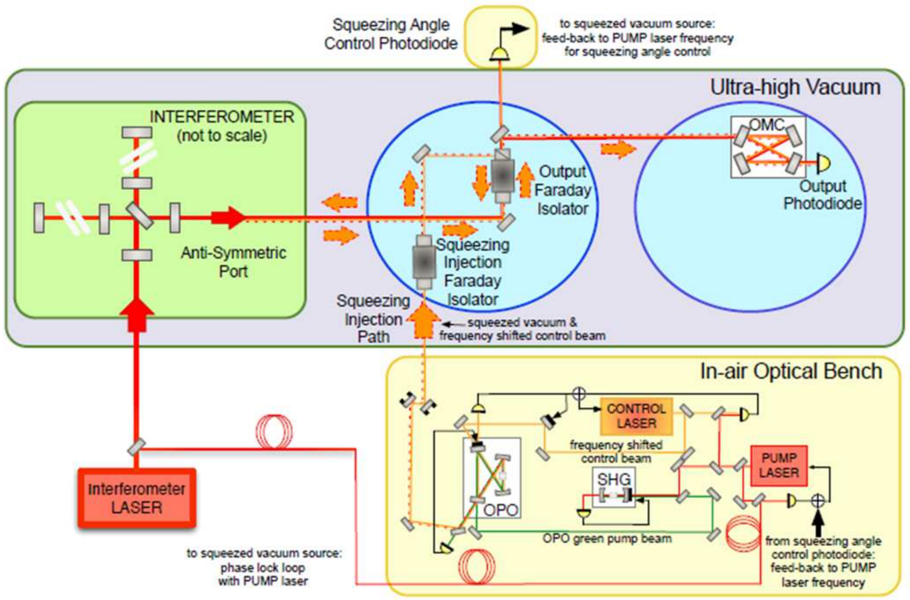
$\phi_s = \phi_m + \phi_{RF}$

Residual phase error (for single pole LPF)

$$\sigma_{\Phi s} \sim \sqrt{\frac{\textit{Laser Line Width}}{\textit{Unitary Gain Bandwidth}}}$$

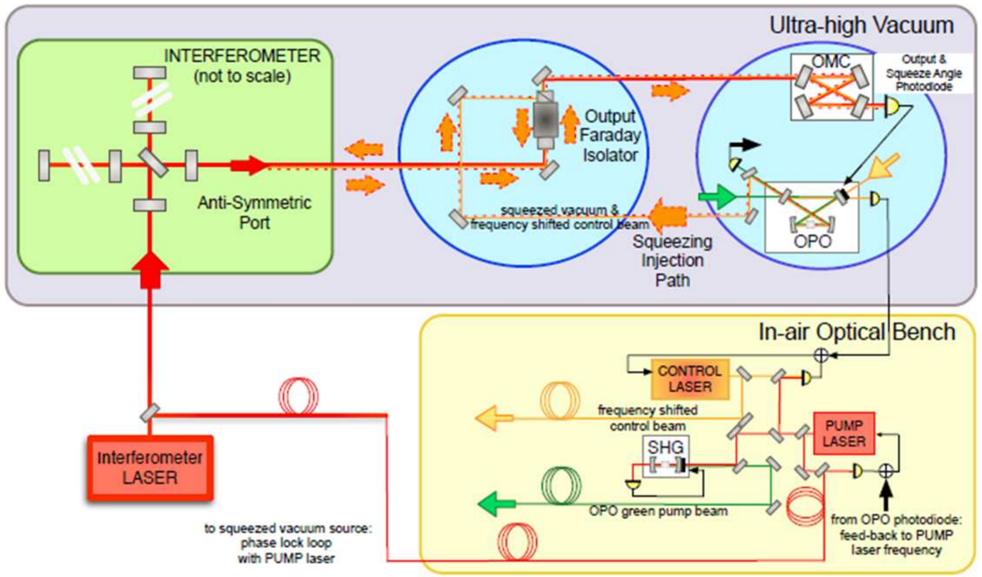
Required Unitary Gain Bandwidth order of (0.5-1) MHz

- OPLL never used in Virgo
- Careful design of the loop filters is required otherwise outside the Virgo DAC capabilities

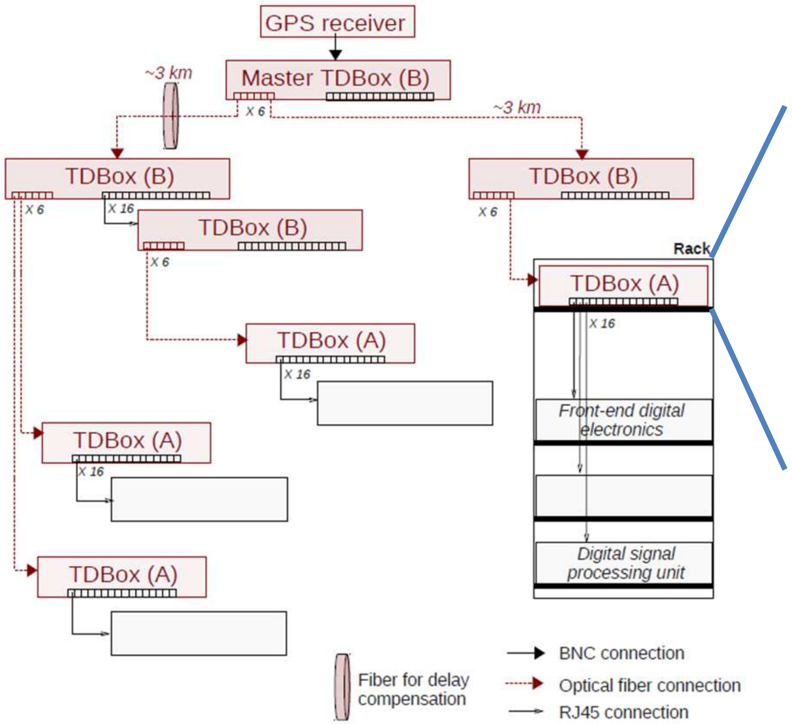


Old LIGO set-up

New LIGO set-up



Time reference for AdV



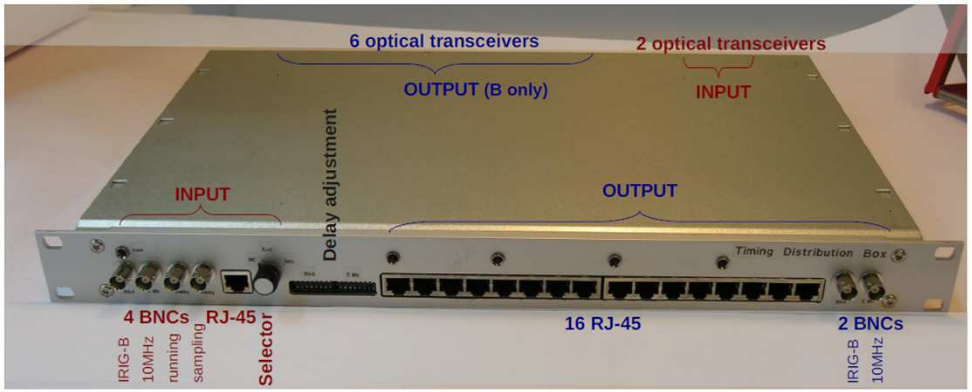


Figure 14.3: Photo of a Timing Distribution Box.

The input GPS time is transmitted to 16 RJ-45 ouputs that can be used as time reference for ADC, DAC, DGG …

ADC/DAC and signal processing

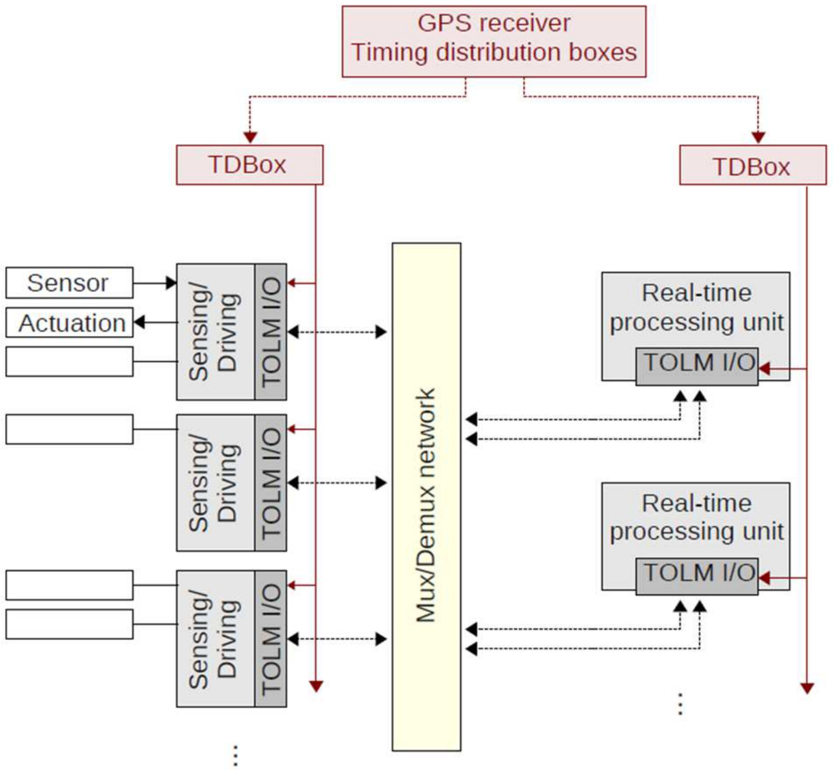
The Pisa INFN group is developping an ADC/DAC board with the following properties (AdV TDR SAT)

- ADC: Sampling rate 1 MHz 24 Bit
- DAC: Max. 300-400 kHz 24 Bit
- FPGA DSP on board for signal processing
- 4 channels for each board
- Ethernet for external comunications
- Object oriented

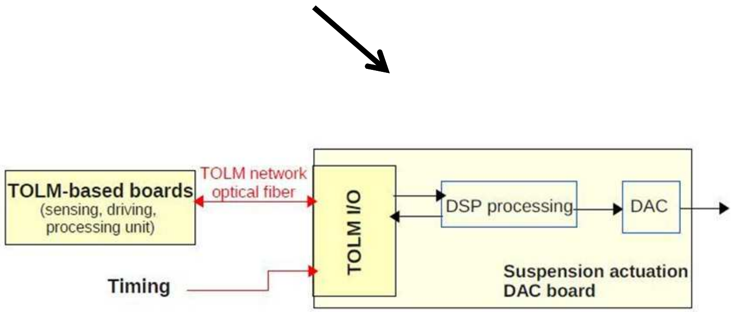
Problem

The second release is currently under test but due to lack of man power is not known when it will be ready for the collaboration

Alternative Architecture (to be discussed with LAPP)



- ADC 800 kHz 18 Bit
- DAC 20 kHz real time processing both computer assisted or in board via DSP



Advantage: The boards are ready and available.
Drawback: For many servo loops 20 kHz pheraps is too slow (check with LAPP wether the DAC can work faster. Answer yes).

RF Generators: requirements

Use	Mod. Freq. [MHz]	Channels Nr		Locked Ch
PDH SHG	80	1	EOM	
		2	Demodulation*	
PDH IR MC	80	3	Demodulation	
PDH G. MC	120	4	EOM	
		5	Demodulation	
PHD OPO	40	6	EOM	
		7	Demodulation	
PLL to Virgo main laser	?	8	Rf offset	
PLL coherent Control	15	9	Rf offset	
		10	2Ω Demodulation	
PLL OPO length control	20	11	Rf offset	

Phase noise is critical for Coherent control (RPN<**20 mrad-rms)**

* The required number of rf signal should be reduced using the digital demodulation (see later)

RF Generators proposal

- Digital RF Generator: Direct Digital Synthesizer based on the Analog Device 9910 , 14Bit 1Gs/s
  - Up to 3 AD9910 board can be synchronized to the AD9910 master board.
  - For each channel the frequency, the phase and the amplitude are selectable via an USB interface.
  - Phase Noise (data sheet) @100 MHz: - 133 dBc/Hz at 100 Hz
    - 152 dBc/Hz at 10 kHz
- Prototipe in use in Padova
  - Master output power 30 dBm (1W/50 Ohm), slave 10 dBm
  - Phase noise to be measured
  - Reference time (extern. or integrated synthesizer, GPS?)

- If a larger phase stability is required. Crystal Oscillators as Wenzel -120 dBc/Hz at 100 Hz, - 165 dBc/Hz at 10 kHz.

Photodiode electronics

Fast photodiode

Photodiode	Freq. [MHz]	Photodiode	Freq. [MHz]
PDH SHG	80	PLL to Virgo main laser	?
PDH IR MC	80	PLL Coherent Control	15
PDH G. MC	120	PLL OPO length control	20
PHD OPO	40	Homodine	100

- So far Virgo has not covered the band above 50 MHz but in AdV the frequency should rise to 130 MHz (TDR pag.264)
- Test in progress by Rome I (OPA847), Padova (LMH6624), LAPP
- The "standard " photodiode selection is in progress. Please contribute

Company	Model	Cap. [pF]	Dark current [nA]	Efficency [A/W]
Perkin Elmer	C30619	8	1	0.9
Fermionics	FD500	15	2	0.9

Photodiode & electronics DC Bias (EGO)

- 12 Stabilized output voltage (range ±3.5 to ±19 Volt selectable)
- 6 pin connector (1GND, 2 postive bias, 1 negative bias, 2 ±electronics)
- Max current for each channel 450 mA
- Cable: 3 twisted shielded pairs (Belden 9503)
- LEMO connectors: LEMO ERA.1S.306.CLL and LEMO FFA.1S.306.CLAC66

Demodulation

- Currently the demodulation is done with a commercial mixer (minicircuits) mounted on the same board as the transimpedence amplifier.
- This architecture will be preserved as long as the new demoduladion electronic (LAPP) will be available.

New Demodulation electronic (LAPP)

-400 MHz 16 Bit ADC
-Digital demodulation and low pass digital filter on board (DSP)
-Flexible design
-High stability and low phase noise

Photodiode electronics

Quadrant Photodiode

High Voltage Amplifier (piezo driver)

- At least 5 PZT stack (200 nF) must be driven at high voltage. Typical maximum voltage (bipolar) 200 Volt. Bandwidth serveral tens of Hz.
- It is not clear whether also the sensing mirror need to be driven at high voltage. If yes at least other 6 channel are required
- Presently we are using PI E-464

High current amplifier (Peltier driver)

- At least 2 High current (order of 2 A) tension to current converters are required for the Peltier units (SHG and OPO crystal).