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CLIC Note 361

Active Alignment Electronic System for CLIC 30 GHz Modules in CTF2

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Abstract

The active alignment system is capable of positioning accelerator components of CLIC (Compact Linear Collider) with a precision of a few microns. An electronic processing and command system connects the micro-movers and sensors of this system to the CERN-PS complex control system.

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15 June 1998

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Introduction

CERN is studying the feasibility of building a linear collider (CLIC) to obtain electron-positron collisions. The total energy reached in the collisions should be in the TeV range. The CLIC scheme is based on beam acceleration at high gradient (150MV/m) and high frequency (30 GHz) with RF power generation by the Two Beam Acceleration (TBA) method. Pulsed microwave power is extracted from the DRIVE linac by means of power extracting structures and fed into the PROBE linac through waveguide feeders.

To demonstrate the feasibility of the CLIC scheme a test facility (CTF 2) with 30 GHz modules resembling as closely as possible the real CLIC design has been constructed.

As in CLIC, the accelerating, correction and beam detection components of the 30GHz CTF2 modules must be aligned to an accuracy <10 µm. The alignment system used consisting of supports, position sensors and actuators results from developments and tests on two models built for the purpose in the alignment test facility.

A 30 GHz module for CTF2 consists of two girders, one per linac, supporting accelerating or power extracting structures and beam position monitors. An assembly of quadrupoles sit above each girder on independent supports. CTF2 will require two modules for phase 1.

Supports and displacement system

The accelerating or power extracting cavities and the beam position monitors sit on girders on pre-aligned vees. The girders are supported by inter-girder articulation supports. This support fixed at the rear of a girder has two micromovers with link rods for the vertical movement, one micromover with link rod and a screw stop for the horizontal movement and two link rods to support and adjust the front of the next girder. The distance between two articulation points is 1.41m. The quadrupoles sit on a rectified metallic plate supported by three micromovers with link rods for the vertical, and two micromovers with link rods and a screw stop for the horizontal movements.

The micromovers of an inter-girder articulation and the micromovers of the nearest quadrupoles sit precisely on a metallic plate. This plate is aligned and fixed on a concrete block which is integrated into the floor. There is one concrete block for two modules.

Girder

- Silicon-carbide
- Length with extremity plates : 1.40 m
- Cross section : 0.6 x 0.12 m
- Side thickness : 7.5 mm
- Module of elasticity : 2100 daN/mm²
- Density : 2.65 g/cm³
- Thermal expansion : 4.8 x 10^{-6}
- Very good thermal conductivity
- weight : ~ 12 Kg
- Tolerance for adjustment of the vees and the extremity support plates < 5 µm

Micromover

- Stepwise motorisation
- Length at mid course : 155 mm
- Diameter : 60 mm
- Travel : ± 4 mm
- Resolution : 0.2 µm
- Repeatability : 1 µm
- Maximum load along the thrust axis : 400 N

Alignment: Method and sensors

The alignment system has two principal functions. The first is to pre-align the elements so that the beam cam pass through the aperture and produce signals in beam position monitors. These signals are then used to move the girders and the quadrupoles for making the definitive alignment. The second function is to maintain the elements in this position.

The Wire Positioning System (WPS) is used to position the girders and the quadrupole supports. The reference for each linac is a wire under tension. The spatial position of the wires is fixed by four reference systems, one at each extremity of the two modules. The reference systems combine an Hydrostatic Levelling System (HLS) and a WPS which are put in their theoretical place by geometrical measurement from the local survey network. The inter-girder articulations and the extremities of the quadrupole supports are fitted with WPSs which are precisely located with respect to the axes of the accelerator components. The sensors measure the distance between the sensor axis and the wire in two directions, one vertical and the other horizontal perpendicular to the accelerator axis. An accelero-tiltmeter is also required on each girder and each quadrupole support to measure the transverse tilt and the vibrations of the supports.

Main characteristics of the instruments

Wire Positioning System (WPS)

- Two axes
- Measurement range : ± 5mm
- Resolution: 0.1 µm
- Repeatability: 1 µm
- Bandwidth: 0-10 Hz

Wire

- Carbon + aramid fiber (Kevelar)
- Apparent diameter: 0.50 mm
- Weight of 100m : 20 gr + 16 gr
- Elastic limit: ~ 300 N
- Mass of counterweight used : 6 Kg

Tilt Meter System (TMS)

- **The instrument measures the *tilt* and the acceleration in two axes**
- **Resolution : 10^{-7} radian**
- **Repeatability : 10^{-6} radian**
- **Bandwith : 0 to 100 Hz**
- **Measurement range : ± 3.10^{-3} radian**

Hydrostatic Leveling System (HLS)

- Measurement range : 5 mm
- Resolution : 0.2 µm
- Repeatability : 1.2 µm
- Separate external electronics

Electronics

New development

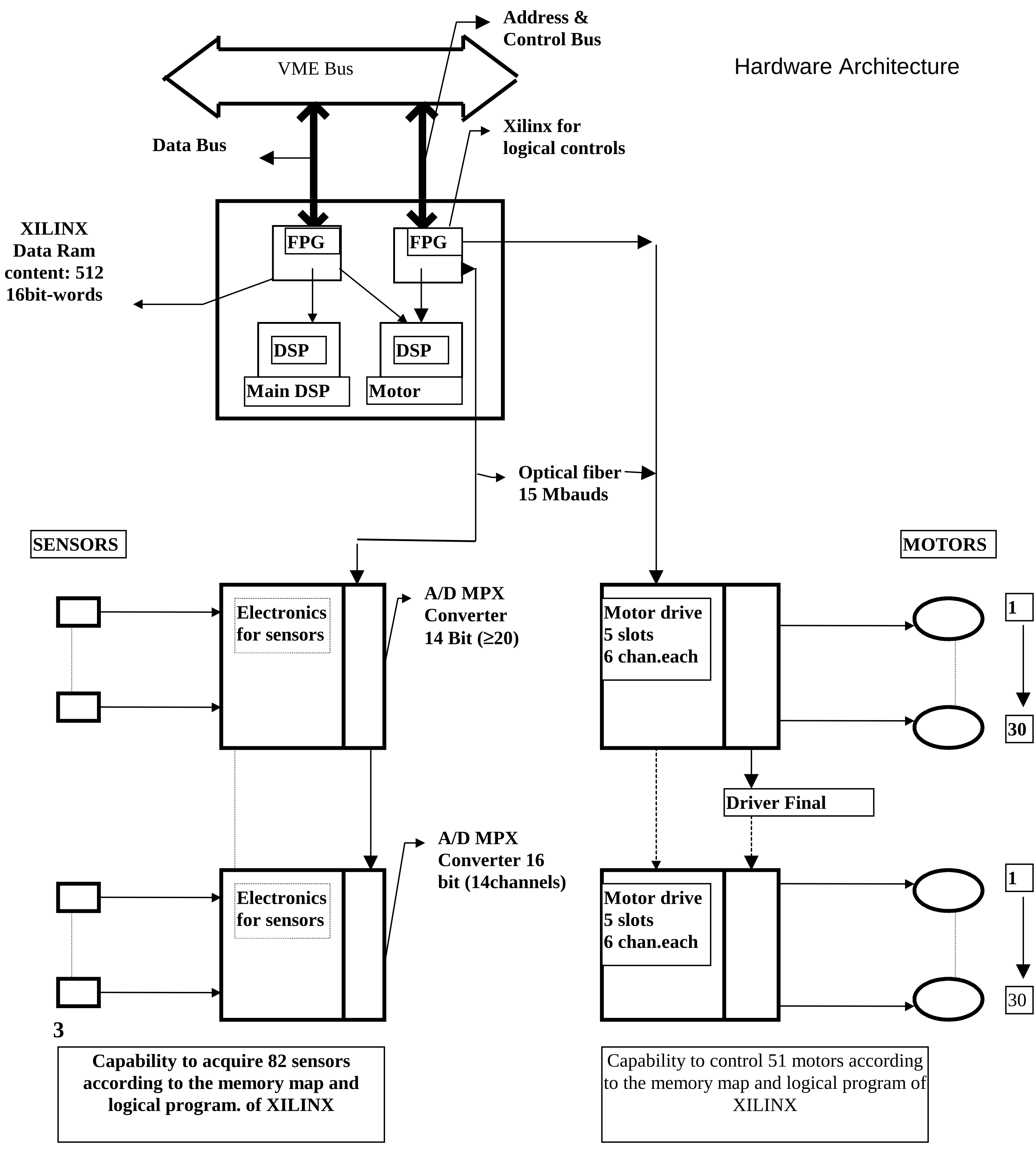
This system, which is now being fabricated, will provide: increased alignment precision, higher processing speed, simultaneous and synchronised displacements, decreased equipment volume, reduced cost and easier and more flexible use. Version 1 processing was executed by the CPU of the VME controller whereas it is done by local units in version 2.

These local units consist of VME Alignment Main Control Card (AMCC) modules operating in slave mode. Each AMCC module contains two DSPs (Digital Signal Processors), one dedicated to motor movement control and the other to the alignment control algorithms, acquisition control and communication with VME bus. Logical circuits and volatile memory are contained in two Logic Cell Arrays (LCA). The DSP clock rate is 40 MHz.

Each motor driver circuit can manage up to 6 motors. There are 5 motor driver circuits in each 3U Europe crate. Two daisy-chain optical fibers connect the driver crates to the AMCC. Asynchronous communication is used in order to avoid problems caused by delays in optical fiber transmission.

Analog signals are captured using 16 bit acquisition systems with 14 or 20 differential channel. Extra care has been taken to ensure that the 16 bit A/D's precision is not degraded by crosstalk with the multiplexing (MPX). The acquisition systems communicate with the AMCC via 2 additional optical fibers.

There are 102 actuators and 164 sensor signals involved in the system. Two AMCCs control all motors and sensor signals with an average response time of 1 ms. The decentralised processing of this system allows the number of elements to be increased up to 64 groups of 6 motors and up to 62 acquisition groups (14 or 20 channels per group) without degrading the response time. Communication by optical fibbers ensures high precision and immunity to electronic noise.



Hardware Architecture

The application program, which is available in the “Console Manager” of any Operation workstation, is built around a full screen graphic representation of the two 30 GHz modules and their components. Direct interaction on this picture allows individual control of active equipment by knob widgets. This is completed by “normal operation facilities” like starting or stopping the alignment process for a beam or introducing manual offset position corrections for each girder or quadrupole.

Conclusion

The system is now operational and it has been successfully operated for the first time with a beam in CTF2. In closed loop in respect with the wire we maintain continuously the elements in a < 5 micron window . Next year we install two new modules with the new electronic control system. In addition of the strong integration and performances described below, we hope to be able to test the possibilities of the alignment control system for the CLIC machine.

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