VST

MAIN AXES SIMULATION SYSTEM

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1 VST MAIN AXES SIMULATION SYSTEM

1.1 INTRODUCTION

The VST Main Axes Simulation System (VSS) is a PC based system aimed to simulate the telescope main axes hardware during the integration and tests phases of the control software. The VSS will be based on a model of the telescope main axes electro-mechanical system. Its purpose is the implementation of a reliable development tool able to reproduce the real system response in terms of acceleration, speed and position.
The simulation model consists of the following main parts:

- the mechanical model of the telescope main axes, including motors and related drivers
- the tachos model
- the encoder system model

1.1.1 Purpose

This document describes the solutions adopted on the VST to provide a high reliable simulation environment useful during both HW/SW integration and test. The mechanical model is a representation of the axis motor, taking into account both motor inertia and friction factors. The model input is the torque reference value coming from the preload torque control system and the output is the axis (motor) position and speed. The angular speed is the input for the tachos simulation model; the position value is the input parameter for the encoder system model. The angular speed value is the input parameter for the tacho system. This is the model of all encoder signals coming out from the reading heads. Both models are developed using Matlab/Simulink tool and implemented in C language using the Borland C compiler.

1.1.2 Scope

This Document is applicable to the development of TCS applications on both LCU and Workstation. It contains all implementation considerations about the VST simulation environment, needed during integration and system performance optimization phases. The VSS will be implemented in the VCM as described in [10].

1.1.3 Reference Documents

[1] VLT-SPE-ESO-10000-0002, Electromagnetic Compatibility and Power Quality Specifications - Part 1
[2] VLT-SPE-ESO-10000-0003, Electromagnetic Compatibility and Power Quality Specifications - Part 2
[3] VLT-SPE-ESO-10000-0004, Environmental specifications
[4] VLT-SPE-ESO-10000-0015, VLT Electronic Design Specification
[5] VST PDR Document, OAC
[6] VST PDS Preliminary Design Supplement, OAC

1.1.4 Applicable Documents

[7] VLT-INS-ESO-01000-0001, Directive for Preparation of Technical Specifications
[8] VST FDR Final Design Review, OAC, 31/07/00
[9] VST-SPE-OAC-25000-1018-1.0, VST Servo System Software Documentation, OAC, 05/08/00
[10] VST-SPE-OAC-20000-1016-1.0, VST Control Model, OAC, 31/07/00

1.1.5 Abbreviations and Acronyms

ACM	Axis Control Module
A/D	Analog-to-Digital
ADC	Analog to Digital Converter
ADCIDM	ADC Interface Driver Module
ALT	Altitude axis
AZ	Azimuth axis
CDT	Command Definition Table
CI	Command Interpreter
CIDM	Centronics Interface Driver Module
CU	Control Unit
D/A	Digital-to-Analog
DAC	Digital to Analog Converter
DACIDM	DAC Interface Driver Module
DB	DataBase
ECP	Enhanced Centronics Port
EMIM	Encoder Model Interface Module
ESO	European Southern Observatory
FDR	Final Design Review
HW	Hardware
ISA	Industry Standard Association
LCU	Local Control Unit
MCM	Main Control Module
MMIM	Mechanical Model Interface Module
MS-DOS	Microsoft-Disk Operating System
OAC	Osservatorio Astronomico di Capodimonte
PC	Personal Computer
SW	Software
TCS	Telescope Control Software
TMIM	Tacho Model Interface Module
TSM	Timing Source Module
UI	User Interface
UTC	Universal Time Coordinated
VCM	VST Control Model
VLT	Very Large Telescope
VSS	VST Simulation System
VST	VLT Survey Telescope
WS	WorkStation

2 SIMULATION SYSTEM OVERVIEW

The VSS is based on the model of the telescope main axes and related electro-mechanical system (motors, tachos and encoders) composed into different parts. As seen as a black box, the VSS should transform the input parameters coming from the real control system, the two preloaded torque reference signals for motor power amplifiers, into the simulated feedback signals referred to both axis position and speed reference values, obtained simulating the mechanical system, the encoder heads and tacho readouts, opportunely converted using DAC and ADC devices. The timing synchronization reference is implemented using an external waveform generator connected to the standard ECP Centronics port of the PC used to implement the VSS. An overview of the VSS system is shown in Fig. 1.

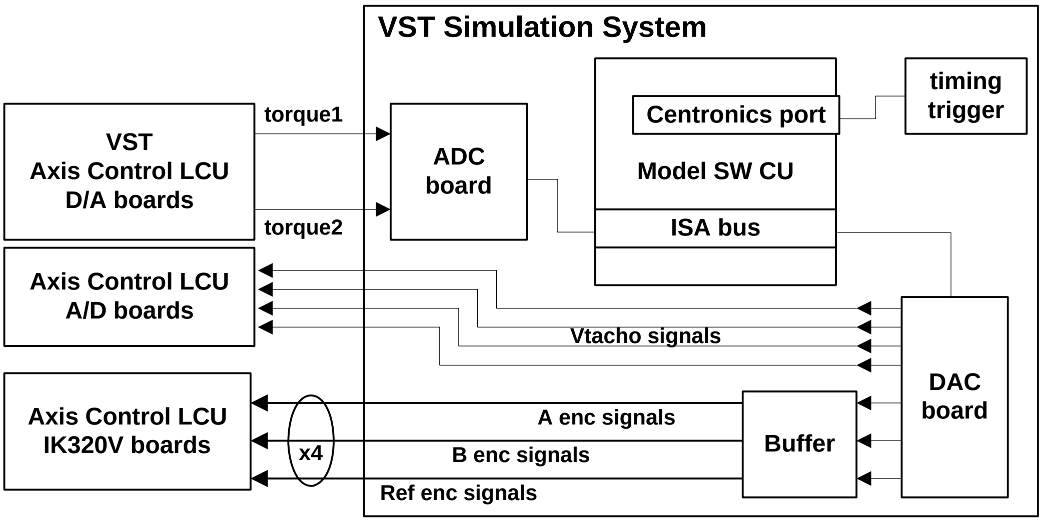

Fig. 1 - VST Simulation System Interface layout

The control core of the VSS is a standard industrial PC CU, equipped with ISA bus I/O ADC and DAC boards. The system models are implemented using a fast error-free C software module running on the MS-DOS environment, for fast control flow processing purpose. The front-end output interface with VST real system is provided with 4 tachos speed signals directly connected to the LCU ADC board and the 12 buffered signals simulating four encoder heads; for each encoder head two incremental signals in quadrature and one absolute reference signal are present; this three signals coming from the DAC board, will be buffered to obtain the 12 signals simulating the 4 encoder heads, connected to the IK320V encoder readout boards. The buffer block shown is a custom electronic interface device providing also single-ended to differential signal conversion. The use of 4 distinct signals for tacho reference values are useful in order to simulate tacho readout fault conditions.

3 THE MATHEMATICAL MODEL

In this chapter the mathematical solutions adopted for the simulation system is described. In Fig. 2 the exploded simulation system block diagram, with internal details, is shown.

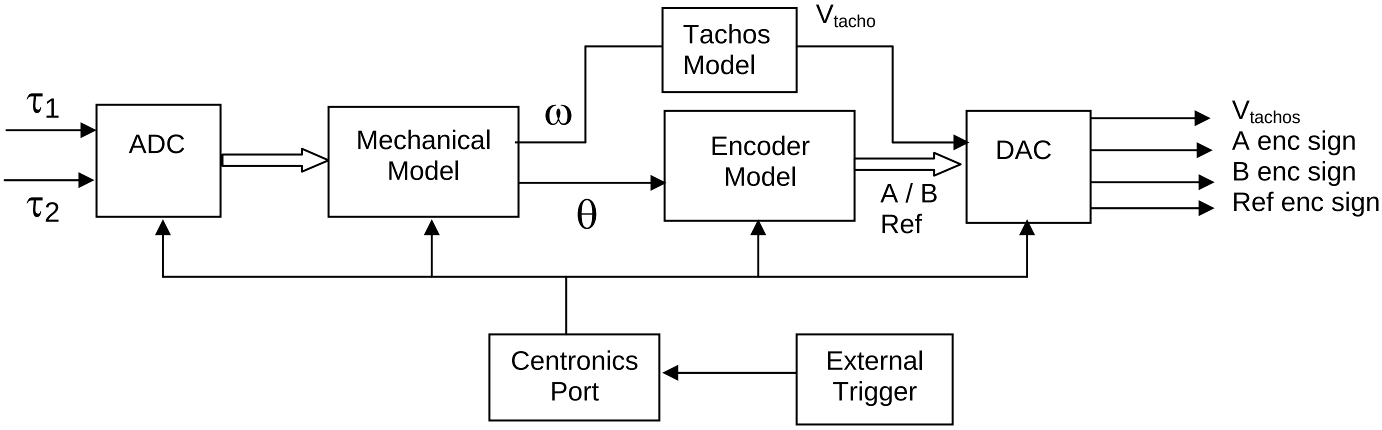

Fig. 2 - The general scheme of the VSS

The two preload torque signals are the input parameter for the first block, passing through an ADC board for the analog-to-digital conversion. These converted signals are the input parameters for the mechanical model. This model operates a double integration of the input parameters obtaining respectively the system angular position and angular speed. The speed parameter is sent to the tachos model that consists only in a proportional model: the speed value, multiplied by a constant K, is converted to the tacho output voltage and is the first input signal for the DAC. The angular position parameter is the input signal of the next block: the encoder model, described in 3.2. Its output is based on three signals: two sinusoids with the same period but with a phase shift of 90 degrees, and a pulse reference signal. The integration step of the mechanical model is triggered from an external signal obtained by an external waveform generator connected to the standard Centronics port.

3.1 THE MECHANICAL MODEL

3.1.1 First order model

In this model the system composed by both telescope and motors is considered as one block. It is implemented by means of a feedback filter. It has two output parameters: the angular speed and position. The speed multiplied by the friction coefficient is the parameter of the feedback. In Fig. 3 the model layout is shown.

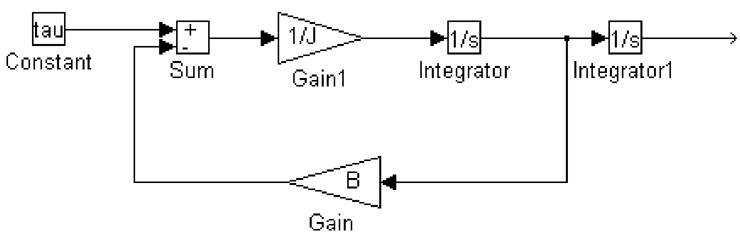

Fig. 3 - The block diagram of the first order model

The motion equation is:

$$\mathbf{J\ d^2q/dt^2 + Bdq/dt = \tau}$$

where J is the inertia of the system, B the friction coefficient and τ the torque.

The value of the parameters for this model are:

B	**1145.9**
J	**3.32e+4**
Tau	**3.0e+2**

The output graphs of respectively, acceleration, speed and position (in Matlab and Borland C), after 250 seconds are shown in the next pictures. The x-axis is expressed in seconds (time).

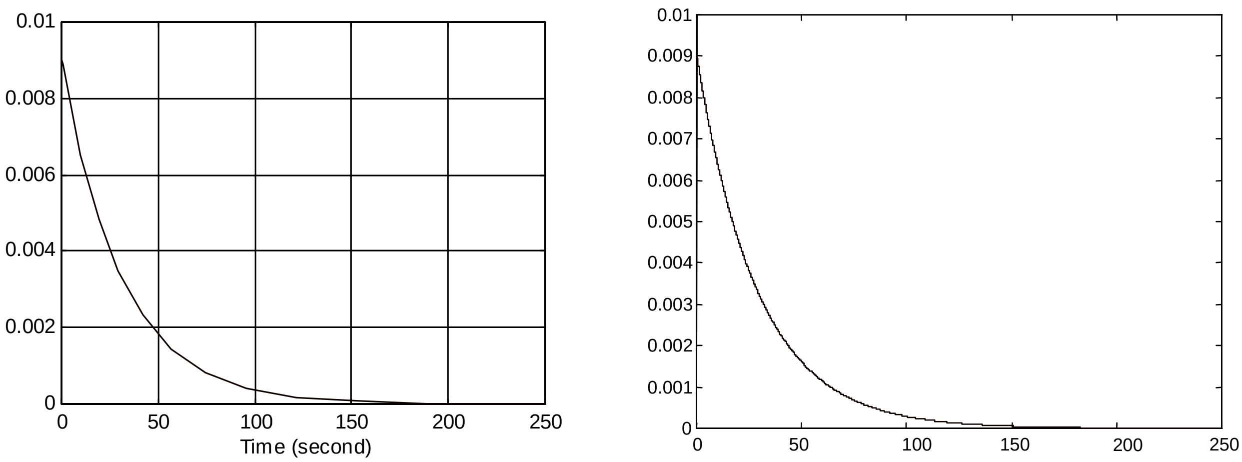

Fig. 4 - The graph of the acceleration in the first order model

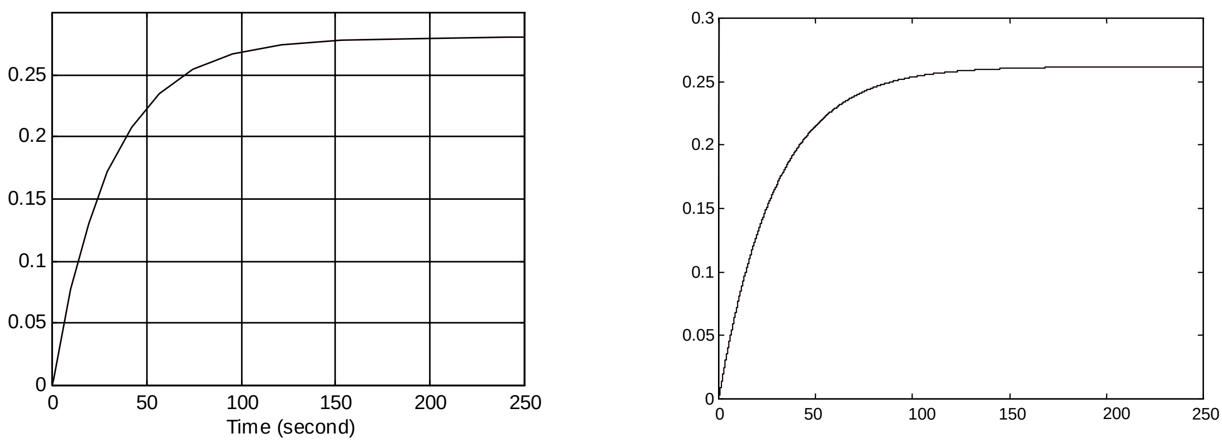

Fig. 5 - The graph of the speed in the first order model

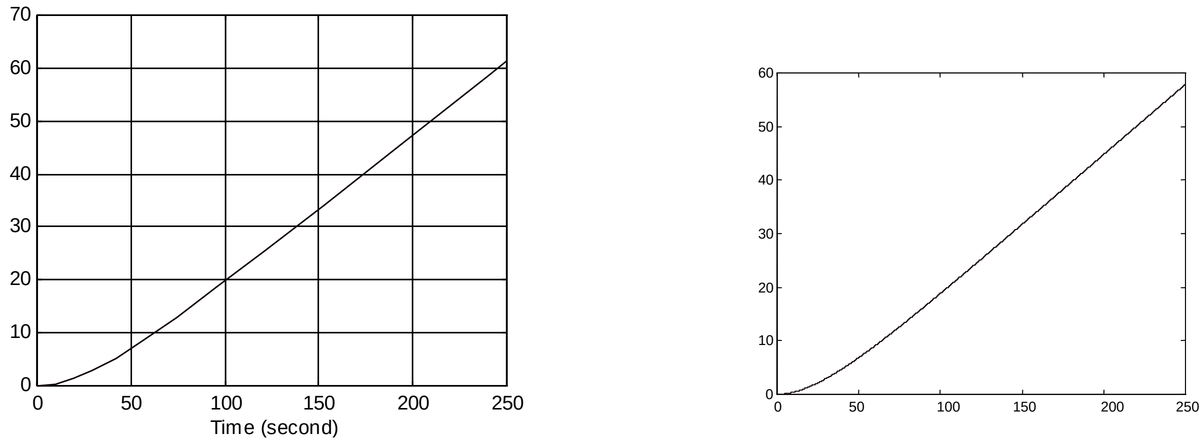

Fig. 6 - The graph of the position in the first order model

3.1.2 Second order model

The second order model is a more complex version of the first one. In this model the telescope and motors are considered as two different blocks. In

Fig. 7 the system model layout is shown.

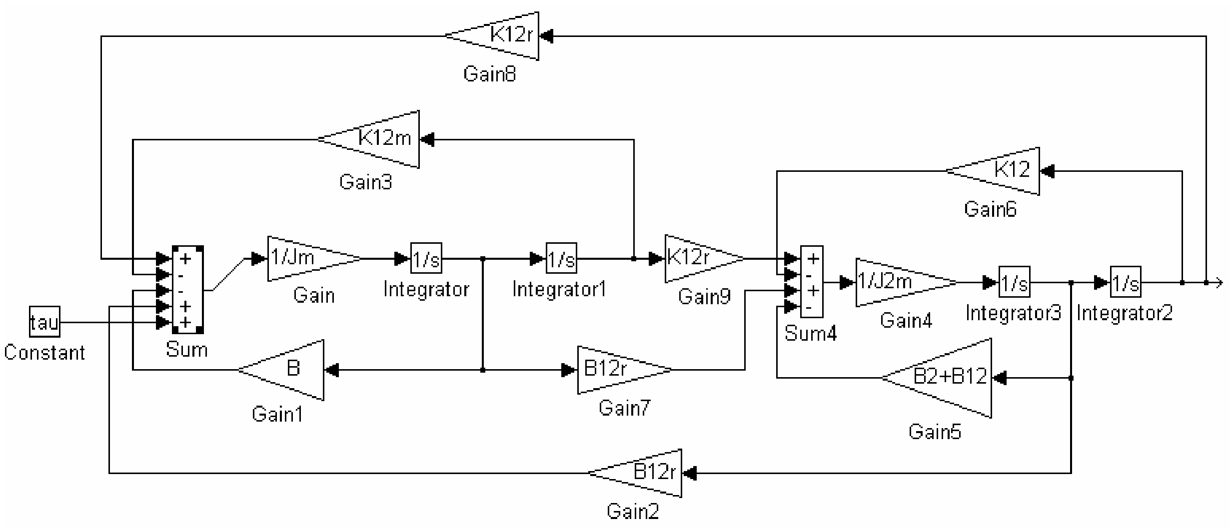

Fig. 7 - The block diagram of the second order model.

The motion equations are:

$$J_1\, d^2q_1/dt^2 + B_1dq_1/dt + k_{12}(q_1-q_2) + B_{12}(dq_1/dt - dq_2/dt) = \tau$$

$$J_2\, d^2q_2/dt^2 + B_2dq_2/dt + k_{12}(q_2-q_1) + B_{12}(dq_2/dt - dq_1/dt) = 0$$

The value of the parameters for this model are:

R	**17.44**
K12	**3.2e+8**
Jm	**1.525*4**
J1	**R^2*Jm**
J2	**1.5e+4**
J3	**1.82e+4**
J2m	**J2+J3**
B1	**4*22.4689**
B2	**1145.9**
Bm	**B1/R*R**
B12	**0.05*2*sqrt(K12*(J2+J3))**
B	**(B1+B12)/(R*R)**
B12r	**B12/R**
K12m	**K12/(R*R)**
K12r	**K12/R**
Tau	**3.0e+2**

The output graphs of respectively, acceleration, speed and position (in Matlab and Borland C), after 250 seconds are shown in the next pictures. The x-axis is expressed in seconds (time).

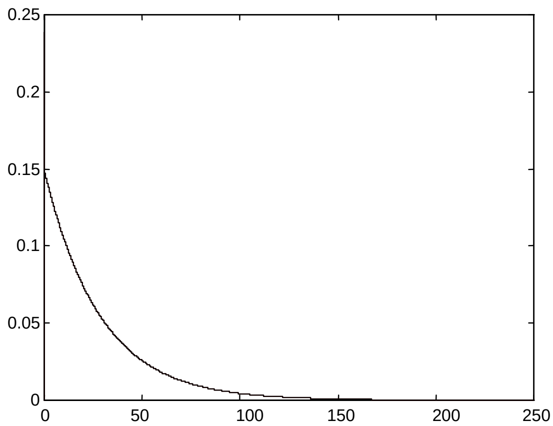

Fig. 8 - The graph of the acceleration in the second order model

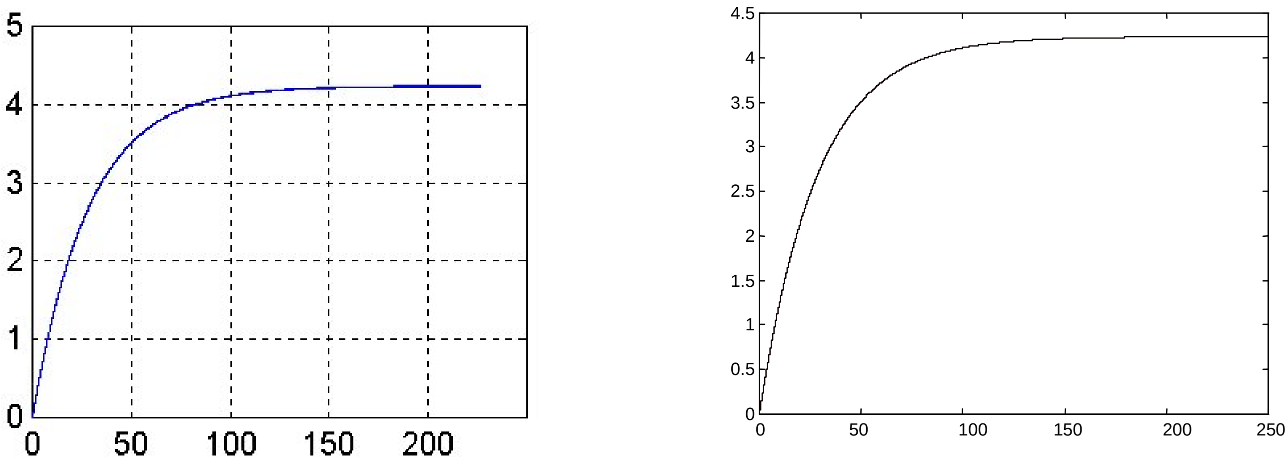

Fig. 9 - The graph of the speed in the second order model

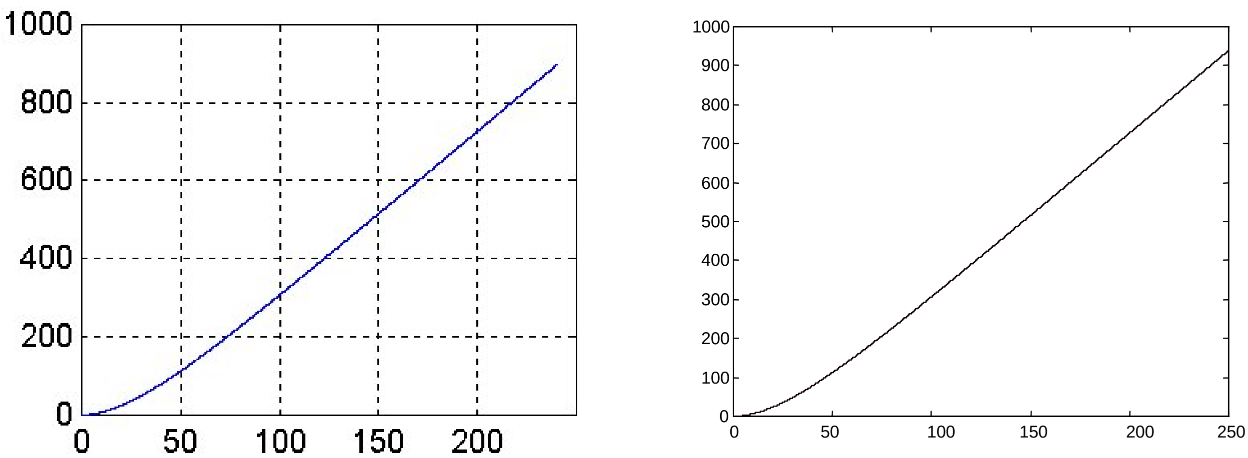

Fig. 10 - The graph of the position in the second order model

As shown in the above graphs, the software module represents a good simulation of the VST electro–mechanical system.

3.2 THE ENCODER MODEL

The encoder system implemented on VST main axes, HEIDENHAIN ERO 7081, generates three signals for each reading head. Two are periodic signals and one is a absolute reference pulse. The periodic signals can be approximated by a bell-shaped curve obtained easily with one period of sinusoid; the period α is equal to the encoder resolution; the range of the sinusoid portion is between –90° and 270° in order to obtain the mentioned bell-shaped curve, approximating the real head signal. The bell-shaped curve is expressed in the next formula:

$$y = 1/2\left[sin\left(2\pi/\alpha * t - \pi/2\right) + 1\right].$$

In the real case, one single period occurs when the reading head goes from the middle of one black mark to the middle point of the next one, passing through the white mark. This range gives the sinusoid period α.
In simulation case, we calculate the axis position p from the mechanical model; then β = *p module* α is computed, representing the angular distance from the first point of the bell-shaped curve. β is the output of the encoder system model and simulates the output signal of the reading head (i.e. the **A enc signal** as shown in Fig. 1 and s

Fig. 2). The second signal generated from the encoder system is the same sinusoidal signal shifted by 90 degree respect to the first one, (i.e. the **B enc signal** as shown in Fig. 1 and s

Fig. 2).
The absolute reference pulse, (the **Ref enc signal**), is generated when the reading head crosses one encoder absolute mark. Several distance-coded reference marks are present on the glass disk of the encoder. These reference marks are placed on the glass disk according the following rule: even reference marks are placed at fixed distance, the odd one at different distance from the preceding; the reference marks position can be expressed, in terms of encoder resolution, according the following formula:

$$(i + 1000) \text{ and } (i * 1000 + 500i + 1) \quad \text{with } i = \{0,..,250\}$$

The presence of the absolute reference marks allows the encoder system to re-establish the correlation between axis position and encoder readout after a power failure simply by traversing two reference marks. When the angular position p is equal to the position of one of the reference marks, a pulse function with width equal to the period α is generated.

4 THE SOFTWARE MODEL

The VSS is implemented on MS-DOS environment in order to reach high performance in terms of workflow processing and system response. The language used is the ANSI C. The simulation control software system is composed by several modules, involved in low and high level operations:

- ADC driver sw module
- Timing source generator sw module
- Centronics interface driver sw module
- Mechanical model sw module
- Encoder model sw module
- Tacho model sw module
- DAC driver sw module
- VSS Main Control Module

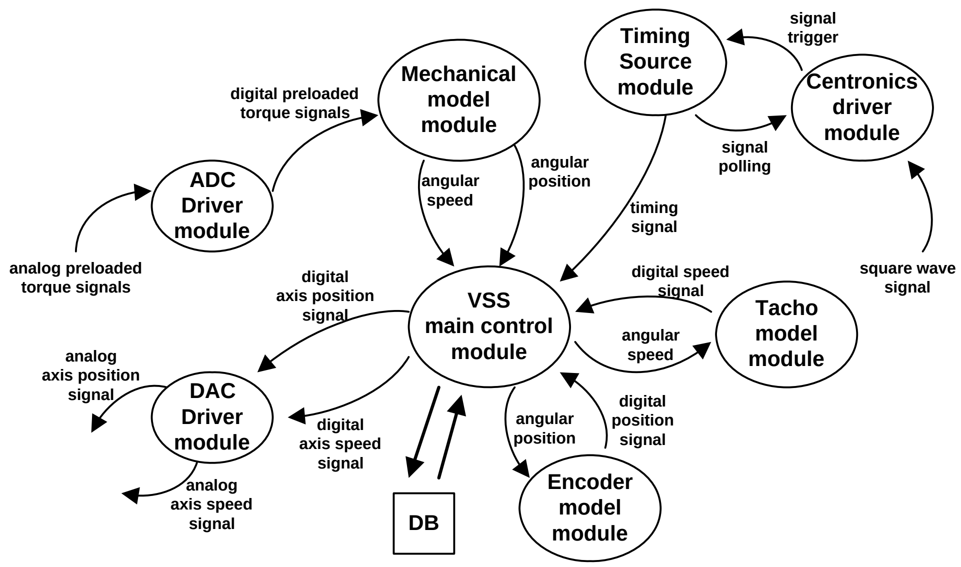

Fig. 11 - VST Simulation System Software layout.

In Fig. 11 the simulation system software layout is shown. The main control module is responsible of the coordinated workflow control. It receives the timing trigger signal that activates the model signal calculations and gives available the simulated axis position and speed reference values. In the local DB there are stored all the model parameters.

The mechanical model sw module is based on the implementation of both first and second order model for the calculus of the angular position and angular speed. From the initial value of the acceleration is possible to obtain the values of the speed and position by double integration. Every integration step is triggered by the timing signal generated by the timing source generator sw module. The signal generator send a square wave signal on the pin #12 of the parallel port of the PC unit. A dedicated function read the state of the pin with a polling on the parallel port. When the front end of the square wave pull up, the state of the pin is on and so one integration step done. If the period of the square wave is 1sec., the mechanical model sw module updates the speed and position parameters every second.

4.1 THE ADC INTERFACE DRIVER MODULE

The ADCIDM (ADC Interface Driver Module) is the software module dedicated to the handling of ADC boards, installed on ISA bus of the VSS Control Unit. These boards are used to interface directly the VSS with the VST axis control LCUs in order to receive the analog preloaded motor torque input signals and to convert them into digital signals to be processed by the VSS.

4.2 THE CENTRONICS INTERFACE DRIVER MODULE

The CIDM (Centronics Interface Driver Module) is the software module dedicated to the interface with the standard Centronics parallel port built-in of the VSS Control Unit. This device is connected to an external wave generator, used as system timing source trigger during simulation loop.

4.3 THE MECHANICAL MODEL INTERFACE MODULE

The MMIM (Mechanical Model Interface Module) is the software module dedicated to implement the mathematical model designed for the mechanical, (telescope+motors), simulation system. Particular attention was dedicated to the mathematical formulas implementation, in order to match the speed and accuracy requirements of such a simulation system.

4.4 THE ENCODER MODEL INTERFACE MODULE

The EMIM (Encoder Model Interface Module) is the software module dedicated to implement the mathematical model designed for main axes encoder system.

4.5 THE TACHO MODEL INTERFACE MODULE

The TMID (Tacho Model Interface Module) is the software module dedicated to implement the mathematical model designed for axis speed reference simulation system.

4.6 THE DAC INTERFACE DRIVER MODULE

The DACIDM (DAC Interface Driver Module) is the software module used to implement the software interface with the DAC boards, installed on the ISA bus of VSS Control Unit. These boards are used to convert the digital axis position and speed reference outputs of VSS sent to the VST main axes control LCUs as feedback signal in the servo system.

4.7 THE TIMING SOURCE MODULE

The TSM (Timing Source Module) is the software module dedicated to the implementation of the interface with the external wave generator, in order to have a timing trigger source for calculation loop. The external timing trigger signal is generated from a dedicated external device. The typical waveform used is a square wave. The integration step of the routine in the mechanical model is triggered by this signal. Exactly, when the front end of the function shifts from low level to high level, the routine is implemented and the speed and position value of the model are incremented. The external timing source guarantees a calculation timing able to give the position and speed reference values inside the main servo system loops. The only necessity of a synchronization between the VSS and the VST servo loop can occur when output signals are not simultaneously available in the ADC and IK320V input registers. There is, in this case, the possibility to implement a strobe signal communication from the LCU I/O board that gives the trigger for next calculation loop of VSS.