EUROPEAN SOUTHERN OBSERVATORY

Organisation Européenne pour des Recherches Astronomiques dans l'Hémisphère Austral
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LA SILLA OBSERVATORY

GPS INDEPENDENT TIM CLOCK

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CHANGE RECORD

Revision	Date	Section/Paragraph	Remarks
Issue 1.0	22/10/2002	All	First Issue
Issue 1.1	05/11/2002	Several	Reviewed by G. Andreoni Typo corrections, addition of acronyms, clarification and further explanation of some points.

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1. INTRODUCTION

1.1. PURPOSE AND SCOPE

This document briefly describes the actual time generation and distribution systems used at La Silla Observatory.
Additionally a new alternative of time distribution system presently under test, in prototype form, in our electronic laboratory is presented.

1.2. REFERENCE DOCUMENTS

[RE1] La Silla time distribution system requirements. M. Mornhinweg.
[RE2] Time Reference System of the ESO Very Large Telescope Werner R. Lange, Martin Ravensbergen.
[RE3] Time Reference System of the VLT Martin Ravensbergen, Krister Wirestrand.
[RE4] GARMIN GPS 25 LP Series Technical Specification
[RE5] VLT Time Reference System TBDB Test Report F. Biancat VLT-TRE-ESO-17300-0848.

1.3. APPLICABLE DOCUMENTS

[AP1] Time Reference System, Time Interface Module, Technical Manual M. Ravensbergen. VLT-MAN-ESO-17300-473
[AP2] VLT Time Reference System Datum Unit Test Report F. Biancat VLT-TRE-ESO-17300-0849.
[AP3] La Silla EconoGPS Clock Preliminary Technical Documentation Version 2.0 M. Mornhinweg.

1.4. ACRONYMS & ABBREVIATIONS

GPS	Global Positioning System
TIM	Time Interface Module
GITC	GPS Independent Tim Clock
VME	Versa Module Europe
OCXO	Oven Controlled Crystal Oscillator
TBDB	Time Bus Distribution Box
IRIG	Inter Range Instrumentation Group
TBD	To Be Defined
VLT	Very Large Telescope
NTT	New Technology Telescope
EPLD	Electrically Programmable Logic Device
PPS	Pulse Per Second
A/D	Analogue to Digital Converter

I/V	Current to Voltage Converter
LSB	Least Significant Bit
TTL	Transistor Transistor Logic
USART	Universal Synchronous Asynchronous Receiver Transmitter
ST	Sidereal Time
CPU	Central Processing Unit
LCU	Local Control Unit
PWM	Pulse Width Modulation
PLL	Phase Locked Loop
UTC	Universal Time Coordinated

2. ACTUAL TIME REFERENCE SYSTEMS

2.1. NTT and 3.6 TIME SYSTEM

Since the upgrade to the Very Large Telescope (VLT) control system of these telescopes, they use as a time reference source a Global Positioning System (GPS) disciplined Rubidium oscillator Time Interface Module (TIM) signal generation system located at the New Technology Telescope (NTT). The signal distribution is done via optical fibres to the different Local Control Units (LCU) requiring precise timing. The time signal is a serial 1Mhz carrier with all the relevant information coded on top of it in the form of Pulse Width Modulation (PWM). A “1” is represented by 80% duty cycle and a “0” by 20% duty cycle. A standard [AP1] specialized Versa Module Europe (VME) module called TIM receives this signal by extracting the clock using a Phase Locked Loop (PLL), decoding the data stream containing both the Universal Time Coordinated (UTC) and the Julian date and presenting it in a suitable format to the LCU. Since the PLL extracted clock is also used as a clocking signal for a programmable counter chain the TIM can act as an interrupter to the Central Processing Unit (CPU). This allows for the synchronization of processes even in different LCUs. For further information please refer to [RE2], [RE3], [AP1], [AP2].

2.2. 2p2 D154 and SMALL TELESCOPE TIME SYSTEM

The system is based on a Cesium frequency reference with suitable electronics for generating both UTC and Sidereal Time (ST) signals. Originally the distribution of these signals was done using Inter Range Instrumentation Group (IRIG-B) coding. During the years the system was modified and today we have the UTC signal distributed using Manchester code and the ST signal is still distributed using the IRIG-B scheme. In both cases the signals are distributed to the different telescopes via copper wire twisted pairs. For further information please refer to [RE1].

3. GPS INDEPENDENT TIM CLOCK PROTOTYPE

3.1. OVERVIEW

The core of the **GPS Independent TIM Clock** GITC is built in a VME module, which operates controlled by a MVME167 CPU running the necessary control and interface software. All the system is housed in a VME crate, which additionally contains an

Oven Controlled Crystal Oscillator (OCXO) unit and a GPS receiver, please refer to Figure 1 below for a better visualization.

Basically the GITC VME module interacts with three different sub-systems via VME bus independent lines and with the CPU via the VME bus.

The GITC VME module interacts with the OCXO from where it receives a 10Mhz signal and phase compares it with the GPS or external 1 Pulse Per Second (PPS), the resultant error signal is filtered by a digital Proportional Integral (PI) controller with an adjustable time constant of several hours and the output is fed to a 20 bit Digital to Analogue (D/A) converter to obtain the OCXO control voltage. While the GPS_OK signal is asserted the OCXO control loop remains closed and the control voltage updated once every 10 seconds, if the GPS_OK signal fail the control voltage is frozen with an average value. The phase measuring and control voltage resolutions are 25nS and 10uV respectively.

The GITC VME module interacts with the EconoGPS from where it receives three different signals, a serial string containing the UTC hours, minutes, seconds and modified Julian date, a 1 PPS reference pulse and the GPS_OK flag. The UTC information string is manipulated by the software in the CPU and loaded into the serializing Electrically Programmable Logic Device (EPLD) using interrupts for synchronisation. Since the TIM signal is a serial 1 Mhz carrier that contains all the UTC information in PWM encoded format, it is necessary a dedicated hardware for this function. Inside the EPLD a group of counters, latches, flip-flops, shift registers and gates are responsible for this time critical task. This EPLD is seen by the microprocessor as a standard peripheral circuit very much like a standard Universal Synchronous Asynchronous Receiver Transmitter (USART) normally used for standard RS-232 interfaces.

The GITC VME module interacts with the Time Bus Distribution Box (TBDB-TX) ESO standard module. This is a simple converter from balanced differential to four ST optical outputs. For further details please refer to [RE5].

The GITC VME module interacts with the VME bus for communication with the MVME167 CPU.

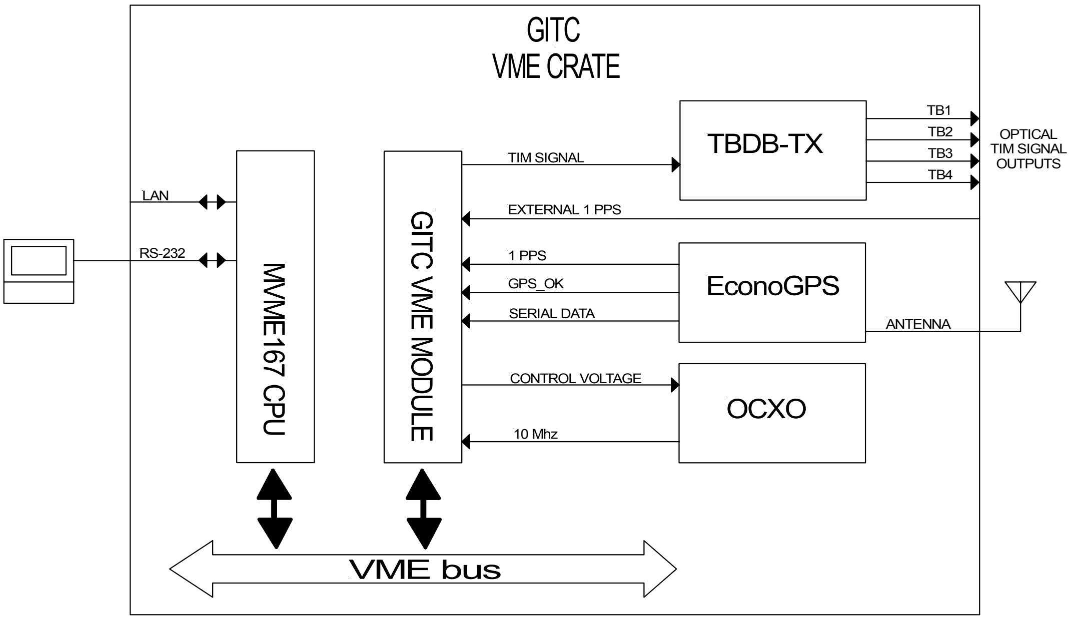

Figure 1: GITC Block Diagram

Although the system exploits a GPS both for disciplining the built in high stability quartz OCXO and obtain the UTC and modified Julian date, the GPS can be dropped at any time and operated as a high quality stand alone quartz clock keeping the latest average control voltage for the OCXO.
As a GPS independent system it is possible, when required, to discipline the oscillator using any high quality1 PPS source such as a Rubidium or Cesium oscillator to correct for the long-term drift and aging of the quartz, as well as manually set the UTC, modified Julian date and increase or decrease the time by +/-1 second in steps of 1mS.

3.2. CONTROL MICROPROCESSOR

The microprocessor is responsible for the execution of the various control tasks and acting, via the software, as an interface with the operator. Since all the high speed and time critical operations are done inside an EPLD and by dedicated hardware, the election of the microprocessor is not particularly critical. Of course it was convenient to use a well-known and supported microprocessor system. Therefore the whole system for the prototype was built around a VME module used together with a MVME167 CPU and C programmed under the vxWorks operating system.

3.3. EconoGPS

The EconoGPS prototype contains a 12-channel GPS core, a PIC CPU with high-level language support, a backlit alphanumeric liquid-crystal display, and a few drivers. It shows UTC time and date on the display, sends time advanced data as BCD-coded string at RS-232 levels, and provides GPS status and highly accurate pulse per second output at differential Transistor Transistor Logic (TTL) levels. For further information please refer to [RE4] and [AP3].

3.4. PROTOTYPE SYSTEM PERFORMANCE

Our prototype system uses an old Oscilloquartz model B-5400 OCXO with a specified aging rate of <10E-10 per day after 90 days of continuous operation and a short-term stability of 10E-12 in 10 seconds. We have no long-term stability specification. The OCXO has been running continuously for more than a year. The tuning range is 1.5X10E-7 with an external voltage range of +1 to +10V. The output frequency is 10Mhz.

3.4.1. Disciplined OCXO

Every second an eight bits counter clocked at 40Mhz is started by the GPS 1 PPS and stopped by the raising edge of the 10Mhz OCXO's signal divided by 16. Together with stopping the counter an interrupt is generated instructing the CPU to read and reset the counter to zero. The Value in the counter represents the phase difference between the reference 1PPS and the 10Mhz oscillator. The measuring range is 1.6uS and the resolution is 25nS.
The difference between a reference phase value and the phase measurement is fed to a digital PI controller with a time constant of several hours. The typical range for the time constant is between 5 to 10 hours. The ultimate selection is a balance between reduction of the GPS jitter, which needs a long time constant, and the elimination of medium and long term OCXO drift, which requires a shorter time constant. The longest time constants are suitable only for very stable oscillators, such as high-quality oven-controlled quartz crystals and Rubidium (Rb) oscillators. Although Rb oscillators are very stable, even they can be improved by locking them to the GPS Cesium clocks.
The output of the PI controller is fed to a 20 bits D/A converter with an output voltage range of 0 to 10V (1.4E-13 tuning resolution or 10uV). Great care was exercised with the circuit layout and the election of the critical components such as the I/V converter associated to the D/A.
In Figure 2 below a twelve hours run of the disciplined oscillator system is shown. The graph represents the phase variations, in nanoseconds, from the zero phase reference value set for this experiment. For the same run Figure 3 represents the input values to the D/A converter whose output voltage feeds the OCXO (1 Least Significant Bit (LSB) equals 10uV).

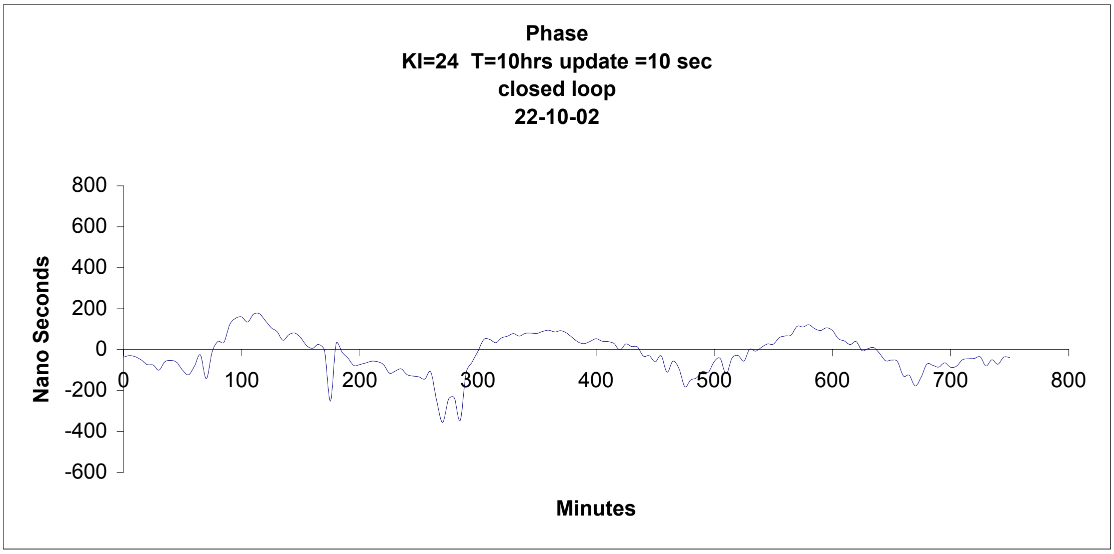

Figure 2: 12 hour disciplined OCXO run, phase deviation from the GPS 1 PPS

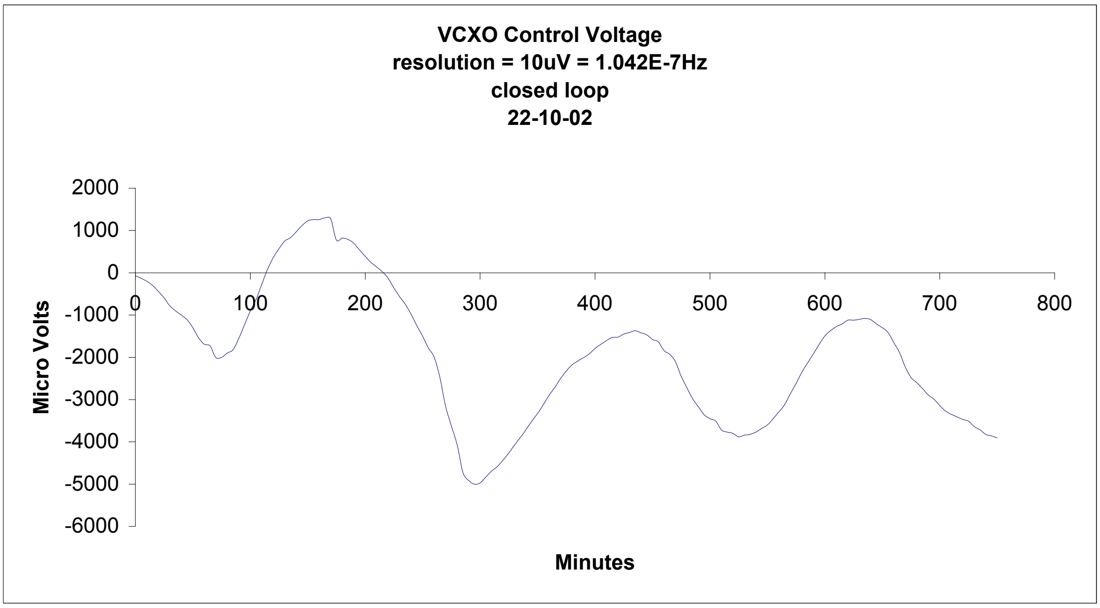

Figure 3: 12 hour disciplined OCXO run, control voltage

3.4.2. Free Running OCXO

Using the average control voltage from Figure 3 we did a medium term stability test of our OCXO. This is a 15 hours open loop run, still of course comparing our phase with the GPS 1 PPS. The result of the experiment is shown below in Figure 4. Doing some simplistic extrapolation and assuming that this drift will persist in 100 days we get a departure of 0.128E-3 seconds from the absolute reference this is well within the requirement of 50E-3 seconds for 100 days [RE1]. Another open loop run was done, this time during 6 days. The measured drift was of 10us giving 0.166E-3 seconds in 100 days.

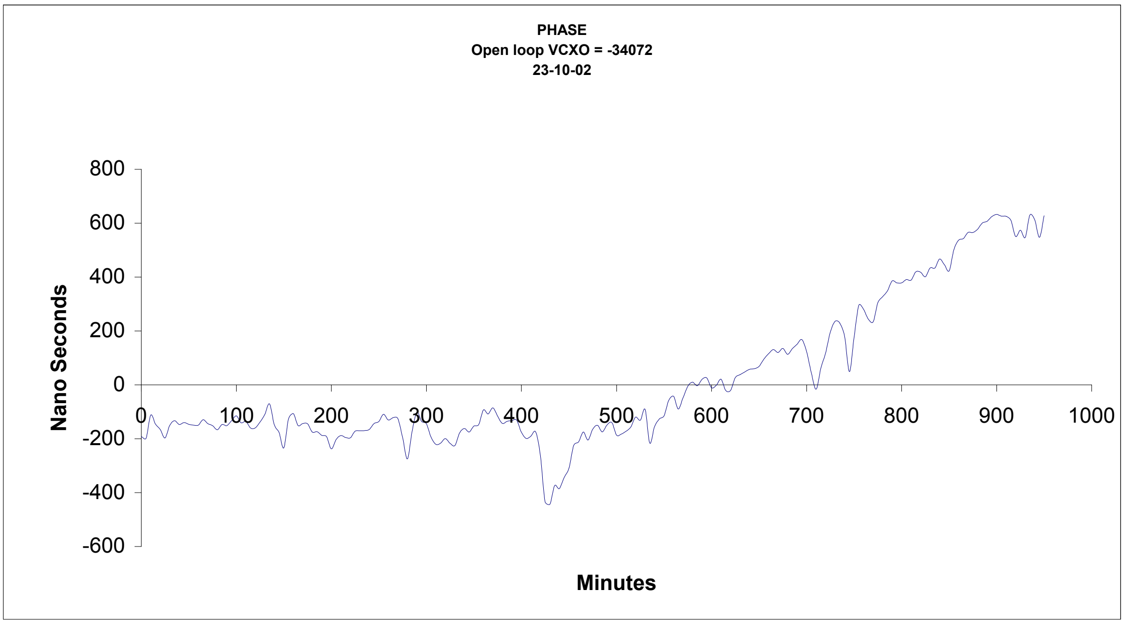

Figure 4: 15 hour open loop OCXO run, phase deviation from the GPS 1 PPS

3.4.3. TIM Signal Reliability

Initially the TIM signal output of our prototype was fed to the stand-alone time display of the NTT telescope, just to have a visual indication in the display of the correctness of the signal. After, a simple driver for the TIM module was written and a separate LCU with two TIM modules was set-up. Since more than a year we have transmitted the TIM signal to these modules. During this period both the UTC hours, minutes and seconds had incremented monotonically as well as the modified Julian date. Another good sign of the proper operation is that the PLLs of both TIMs had remained locked to the signal. Still pending to pull an optical fibre to the NTT or 3.6 and do a real test.