Automatic Phase Comparison with the Legal Colombian Standard Clock Frequency Signal

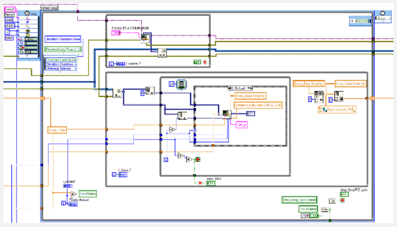

Figure 1: A Modular Schematic of the Data Acquisition Process

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- Ing. Carlos Andrés Quevedo Fernández, Time and Frequency Laboratory

The Challenge:

Developing an automatic measurement system synchronized to Legal Colombian Time to obtain phase differences, stability, and uncertainty when calibrating standard oscillators for nominal frequency values up to 10 MHz.

The Solution:

Deploying an application developed using the NI LabVIEW Real-Time Module, the NI PXI-8195 controller, and the NI PXI-5105 digitizer to acquire real-time data and calculate the phase difference (time) between each oscillator and the reference signal (standard frequency of an cesium oscillator).

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The “Laboratorio de Tiempo y Frecuencia del Grupo de Trabajo de Metrología” (time and frequency laboratory of the work group of metrology) of the “Superintendencia de Industria y Comercio” maintains, coordinates, and disseminates Legal Colombian Time and provides calibration services on time and frequency magnitudes. Currently, the laboratory maintains the legal time using a time server commanded by a primary standard cesium oscillator. The laboratory has another cesium standard and some reference standards such as rubidium oscillators and GPS. These standards are used to help disseminate legal time and provide calibration services.

We can calibrate frequency equipment such as oscillators, counters, and generators by measuring time intervals (phase comparison—time domain). This requires a time interval counter or a phase comparator to determine the phase difference in seconds between the standard frequency signal (reference) and the signal that needs to be calibrated. Therefore, the laboratory uses an NI PXI-8195 controller and an 8-channel NI PXI-5105 digitizer with a 60 MS/s sampling rate. We use LabVIEW Real-Time and these PXI modules to perform simultaneous phase comparisons of up to eight frequency signals of equal nominal values at up to 10 MHz at different time intervals. As a result, it is possible to identify the three key characteristics of the frequency sources (oscillators): stability, reproducibility, and frequency offset.

Application Description

The application is divided into three specific tasks: simultaneously acquiring the frequency signals of the oscillators connected to the digitizer in real time; synchronizing this acquisition with Colombian Legal Time; and processing and comparing the frequency signals to obtain the phase difference before doing a mathematical calculation to obtain the frequency offset and stability of each signal compared. The data is recorded and presented in a report for different purposes such as calibration certificates.

Because we use a PXI embedded controller and LabVIEW Real-Time, we based the program on a Timed Loop structure (Figure 1). This structure is helpful for multitasking, developing an application that runs over a specific time period, and providing exact time and feedback in each iteration cycle. Most importantly, combining the Timed Loop structure with this hardware and software made it possible to design a deterministic, rugged system. The main part of the application operates in the PXI embedded controller, and the interface between application and user is executed from a PC to monitor the significant variables and generate the mathematical processing mentioned above.

The programming for the frequency signal acquisition and synchronization is performed under a master/slave design scheme (Figure 1). Each task is implemented using a master/slave design within an independent Timed Loop structure. The Timed Loops are always synchronized at the beginning of the application execution. The advantage of programming with a master/slave structure is that immediately after acquiring the frequency signals and the legal time, the notification to start processing this data is sent, the synchronized phase comparison begins (Figure 2), and the shared variables are constructed. These variables contain the information that needs to be mathematically processed in the computer. Finally, the value of the characteristics of the standard oscillators, such as frequency offsets and stability, are worked out (Figure 3).

The frequency signal behavior on the phase difference between each oscillator with the reference standard is monitored in real time (Figure 2). The variable values shown on the front panel (# Dato Actual, Diferencia de Fase)[1] are updated synchronously with the legal time (Hora de Adquisición)[1]. The data is configured as shared variables, which are an option from the LabVIEW Real-Time targets. The phase comparison and timestamp are shared so they can be read and written between the embedded program VIs and so they can be entirely read and processed by the monitoring PC connected to the PXI via Ethernet. It is important to mention that the values obtained with the phase comparator usually correspond to very small times—on the order of nanoseconds or even picoseconds if the frequency signals come from primary standard oscillators.

Conclusion and Further Research

We solved this challenge satisfactorily using the NI PXI platform and the LabVIEW Real-Time Module. The simultaneous phase comparator program runs in real time using the tools, patterns, and structures offered by these products. From a study of the phase comparator with the hardware and software elements used, we found that the phase measurement system in some cases achieves a resolution of 10 fs, which is an extremely good value for laboratory measurements that can easily reach parts in 10^{-15}.

Based on our success acquiring and processing frequency signals in this application, we are initiating a project of metrological research to develop a national atomic time scale TA (SIC), which may contribute to the generation of a Coordinated Universal Time managed by the International Bureau des Poids et Mesures. This new project requires two stages to obtain the time scale mentioned. The first stage is developing a prediction algorithm, based on evolutionary clustering techniques, that can generate a virtual clock as a result of simultaneously comparing the frequency signals in real time of *n* highly accurate clocks (cesiums or hydrogen masers). This would make the frequency offset characteristics and stability of the time scale better than those of any individual clock that is part of the system.

The second stage is automatically controlling an auxiliary output generator (AOG). An AOG can correct both phase and frequency error up to 10^{-19} parts in a primary clock signal as a reference for the time scale. With this specification, and using the application described in this article, we may develop an atomic time scale TA (SIC) by comparing up to eight primary standards and translating the comparison values into the input variables of the prediction algorithm mentioned, and then using the AOG to correct the output value of the prediction. This shows the importance of this application as the starting point to achieve the goal of developing the time scale for Colombia TA (SIC).

[1] Text in Spanish as it appears in the application.

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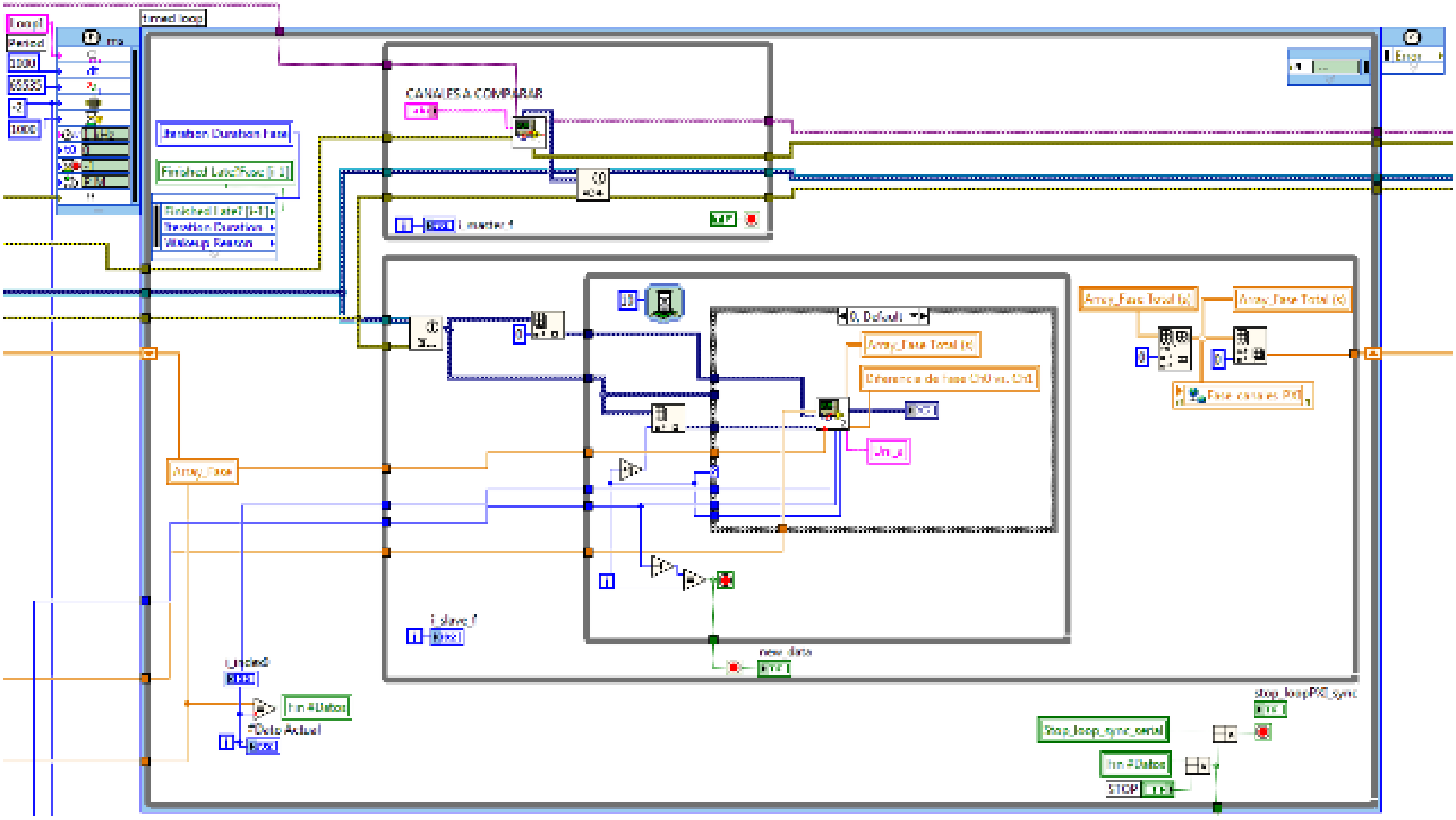

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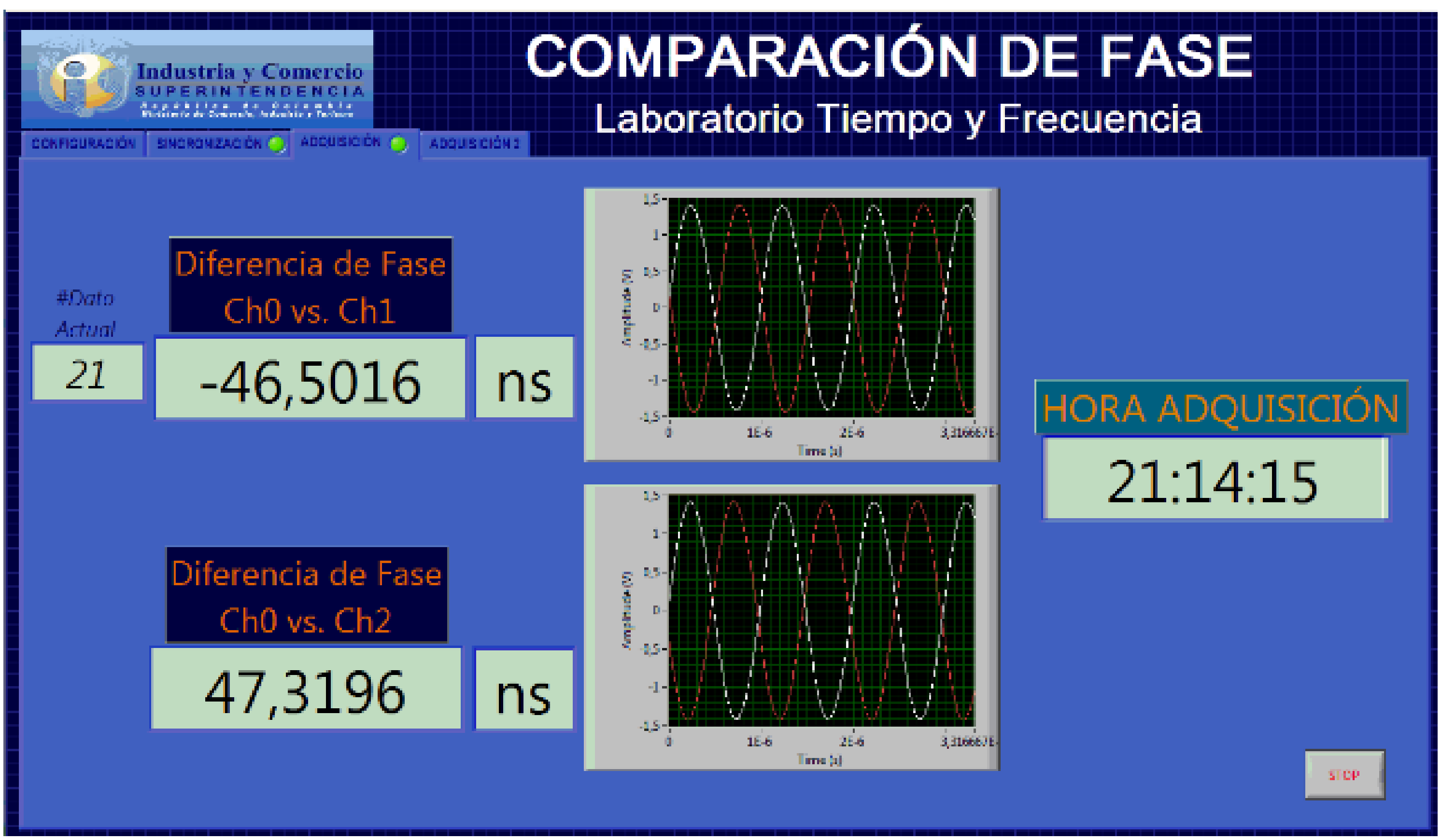

Figure 2: Detail of the Front Panel for Real-Time Monitoring of the Application

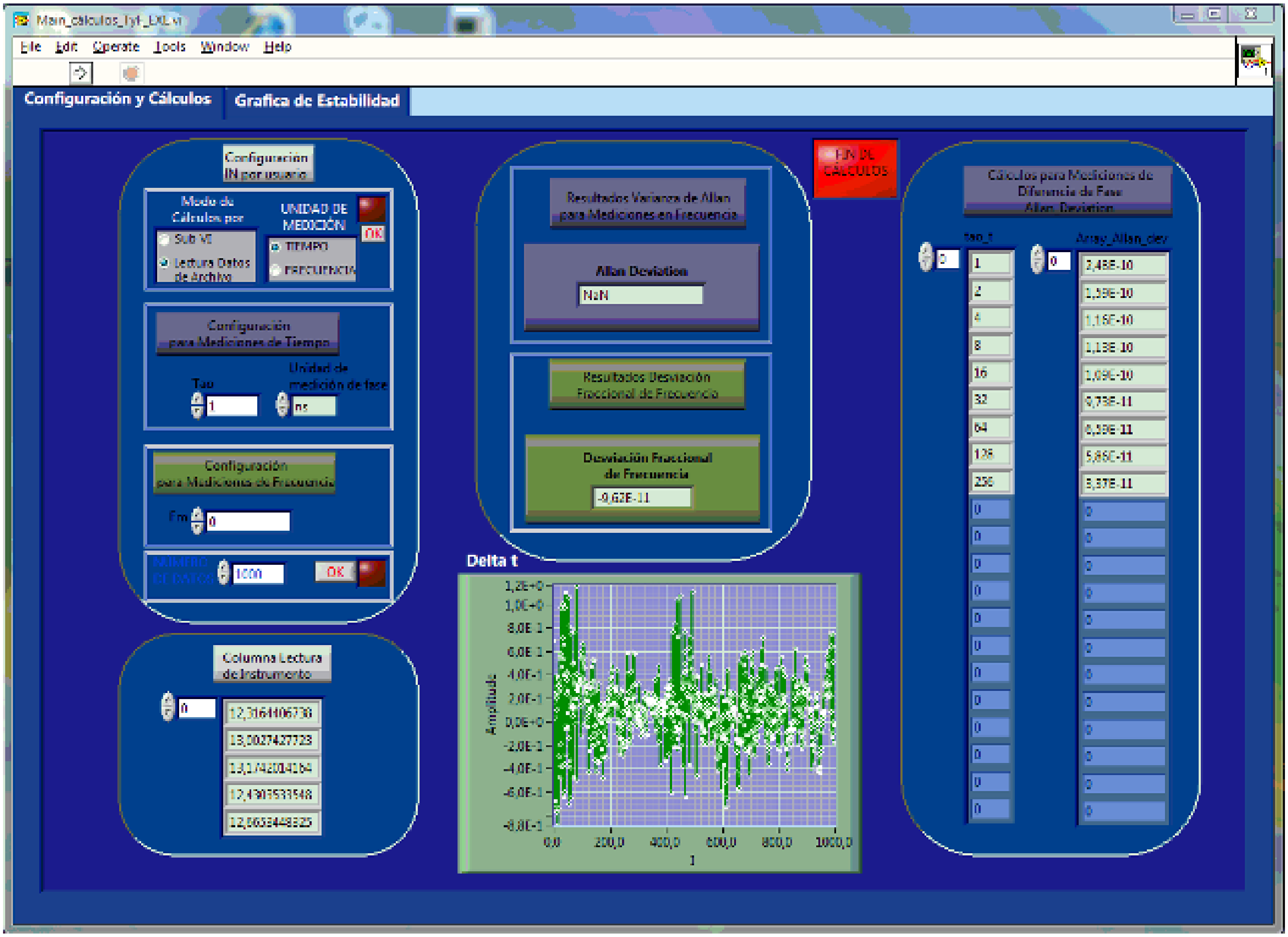

Figure 3: Design of the Subsequent Mathematical Processing Application