

GEMINI

INTERFEROMETER

COMPLETE OPERATIONAL EXAMPLE (LABVIEW AND NI-DAQ)



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This manual is continuously updated by our staff to help our customers to use the GEMINI interferometer at the top of its potential. You can always find the latest version of this manual at www.nireos.com/downloads

We made our best to assure that the manual is clearly written and does not contain errors, but we are aware of possible imperfections. Please contact us at info@nireos.com in case you spot an error or in case you find hard to understand some parts of the manual.

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1. Introduction

The aim of this manual is to show a step by step example on how to properly acquire spectra with NIREOS GEMINI Interferometer using LabView programming language. This manual is based and tested on LabVIEW 2017 (32 bit/64 bit), although similar code can be written with any previous and future LabView versions with slightly variations. This software controls the positioner inside the interferometer, and it is based on Smaract GmbH Sub-VIs (For further details see Smaract MCS programmers Guide manual). The **MCS_Installer_3.8.9** must be correctly installed to use this software.

As an example, the acquisition part is done using a National Instrument Data Acquisition (DAQ) Card (USB-6002) and the software uses DAQmx software. The DAQ card and the DAQmx software are not included in the GEMINI Interferometer.

This example contains all the steps needed to acquire successfully an input light interferogram and then compute its correspondent spectrum. This manual is intended for user with a previous knowledge of the principle of Fourier transform spectroscopy and on the GEMINI interferometer operating principle. See the *Theoretical Manual* for a detailed explanation. A basic knowledge of the LabVIEW programming language is required. All the processing codes to retrieve the light spectral information are the results of year of research in the Fourier Transform spectroscopy field and have been tested and applied to a great variety of scientific applications. Please have a look on www.nireos.com to see the wide applicability of this device.

2. Front Panel

2.1 FRONT PANEL SECTIONS

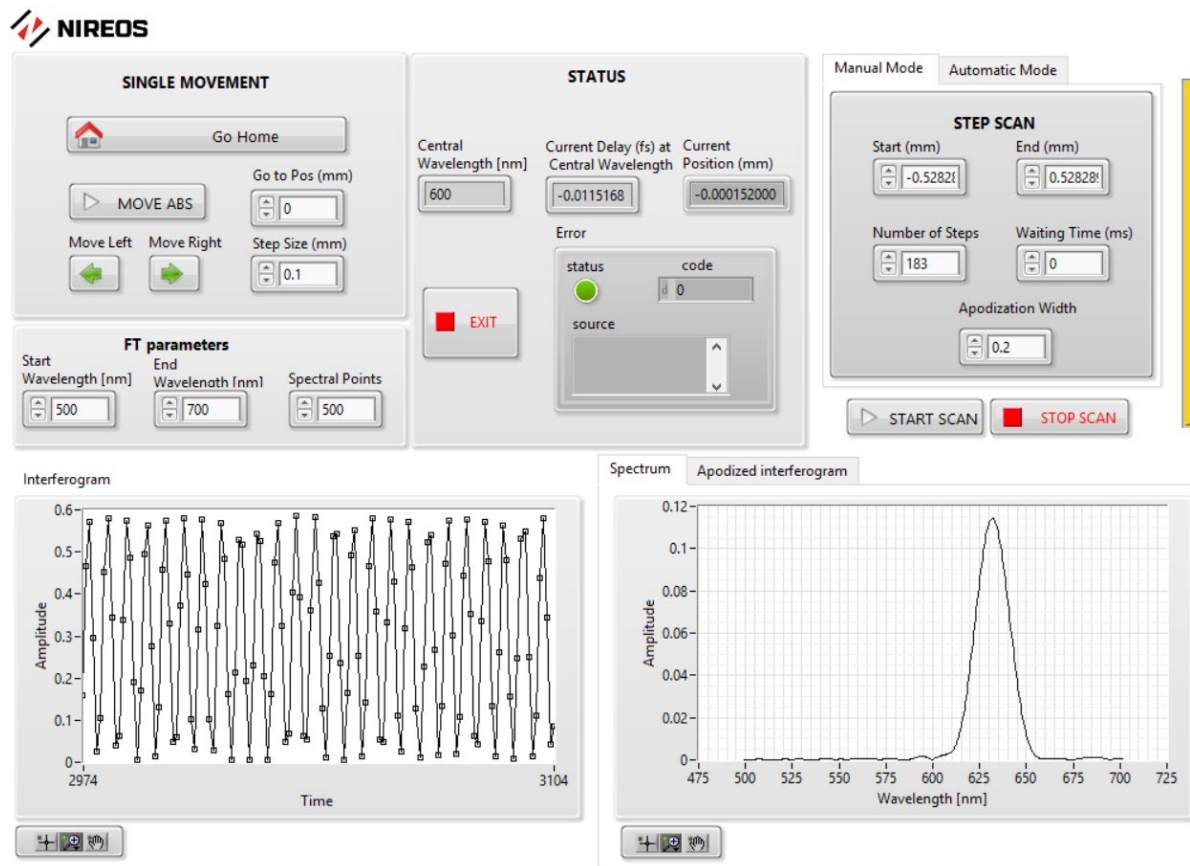


Figure 1. Front panel of the LabVIEW software example (with Manual Mode selected).

2.1.1 SINGLE MOVEMENT panel

By using the control buttons in this panel, it is possible to move the positioner to the desired positions.

- “Go Home” moves the positioner to the defined “home position”. Each time you run the software; the positioner always moves to the defined “home position” first. *NB. The ‘home position’ is the position of the interferometer where the interferometric delay is set to zero. The GEMINI interferometer is shipped with the right “Home position” and in general there is no need to manually change its value.*
- “MOVE ABS” performs an absolute movement to the desired position indicated in the Go to Pos (mm) numeric control. The absolute movement is performed with respect to the “Home position”.

- “Move Left” performs a negative relative movement with respect to the actual current position of the positioner. The amount of movement is selected in the Step Size (mm) numeric control.
- “Move Right” performs a positive relative movement with respect to the actual current position of the positioner. The amount of movement is selected in the Step Size (mm) numeric control.

NB. The total travel range of the positioner is:

| S version | M version | L version |
|-----------|-----------|-----------|
| 12 mm | 21 mm | 31 mm |

2.1.2 FT Parameters panel

In this section the user can select the spectral parameter of the measured light spectra as computed by a Fourier Transform (FT) of the measured signal.

- In the “Start Wavelength” numeric control the user can select the shortest wavelength of interest of the measured light.
- “End Wavelength” select the longest wavelength of interest.
- “Spectral Points” select the number of spectral points of the output spectra.

NB. *Start Wavelength* and *End Wavelength* parameters do not affect the spectral transmission of the GEMINI interferometer. The settings above set only the computed output spectra parameters.

2.1.3 STATUS panel

This section shows the actual status of the interferometer.

- The “Central Wavelength” indicator shows the current middle wavelength of the spectral range defined in the FT parameters panel.
- The “Actual delay (fs) at Central Wavelength” indicator displays the current delay of the GEMINI interferometer as computed for the central wavelength. Differently from a Michelson’s interferometer, for each position of the GEMINI interferometer each wavelength of the input light experiences a different delay.
- The “Actual position (mm)” indicator shows the current position of the interferometer in millimeters. The current position is defined with respect to the “Home position” corresponding to position: 0 mm.
- The “STOP” button is used to disconnect the interferometer and stop the software.
- The “error” panel displays the possible motor errors with their identification codes.

2.1.4 STEP SCAN panel

STEP SCAN PANEL: This section is used to perform step scanning of the interferometer. For each step, the National Instrument data acquisition card (NOT INCLUDED) acquires a data-point (a scalar value). The user can choose between two modes of operation. In *manual mode* the user can define all the scan parameters; in *automatic mode* the scan parameters are defined based on the user selected spectral resolution at the central wavelength.

Manual Mode:

- “Start (mm)” and “End (mm)” define the travel range of the scan in millimeters with respect to the “home position”.
- “Number of Steps” defines the number of steps in which the travel range is divided in.
- “Waiting Time” defines the time (in milliseconds) during which the positioner does not move between one step and the other. This can be very useful when it is required to integrate the signal at the detector at each position of the interferometer.
- “Apodization Width” defines the standard deviation (normalized to the number of steps) of the gaussian apodization window. The apodization window is multiplied to the acquired signal before the FT is performed.

NB. In FT-spectroscopy the maximum scan length defines the spectral resolution (*see Theoretical Manual* for more details).

Automatic Mode: in this operation mode all the parameters are chosen automatically based on the user defined spectral resolution and on the selected spectral range parameters (see “Start Wavelength [nm]” and “End Wavelength [nm]”).

- The “Desired resolution at central wavelength [nm]” numeric control sets the resolution at the central wavelength of the spectral band defined by the user. This control sets automatically the scan range of the interferometer.
- The “Sampling Factor” defines the minimum number of points per period of the interferogram. This control sets automatically the number of steps of the scan. The sampling factor is defined with respect to the shortest wavelength of the input signal. The shortest wavelength is defined by the user with the “Start Wavelength” numeric control.
- The “START SCAN” button starts the step scan and point by point NI-DAQ acquisition.
- The “STOP SCAN” button stops the scan.

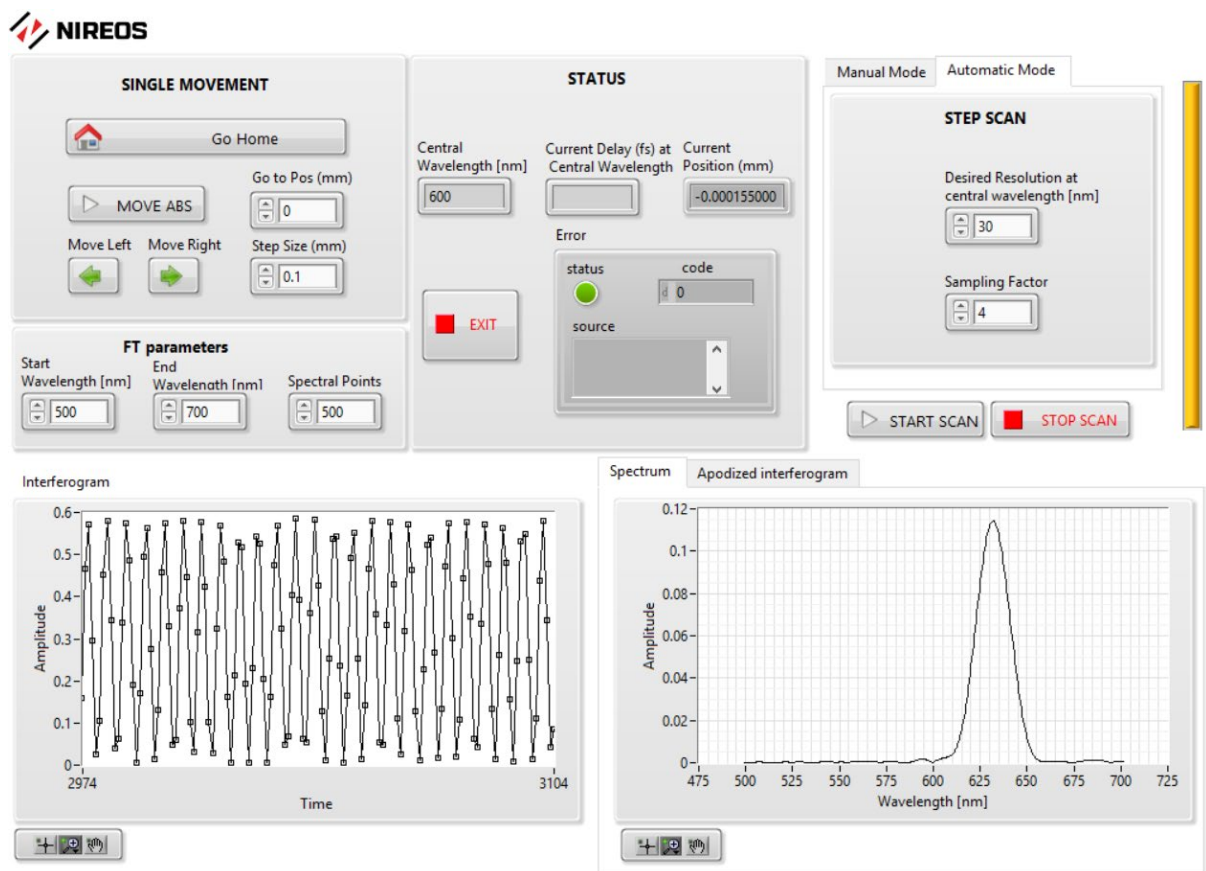


Figure 2. Front panel of the LabVIEW software example (with Automatic Mode selected).

The bottom part of the software is devoted to the plot of the interferogram (left) and to the correspondent spectrum (right).

3. Block Diagram

The block diagram of the code has been designed in order to be the most compact and simple as possible. For this reason, the code makes extensive use of stacked frames and SubVIs.

The code frame structure is:

0. INITIALIZATION FRAME
1. OPERATING FRAME:
 0. Event handler for the single movement panel
 1. Status panel and automatic mode codes
 2. Code used to perform the interferometer scan
 0. Go to the start position of the scan
 1. Loop through the scan positions
 0. Wait for the movement to stop
 1. ACQUISITION CODE
 2. Get current position, calculates the current delay at the central wavelength, waits for the specified waiting time
 3. Performs a relative step
 2. Calculates the spectrum
2. DISCONNECTING FRAME

The detailed SubVI descriptions can be found in the appendix.

3.1 Initializing the GEMINI interferometer - Frame 0

This frame shows the procedure to initialize the motor inside the interferometer and move the interferometer to the “Home position”. The “Home position” is calibrated in factory and saved in the non-volatile memory of the motor driver. The home is the position where the two replicas have zero relative delay.

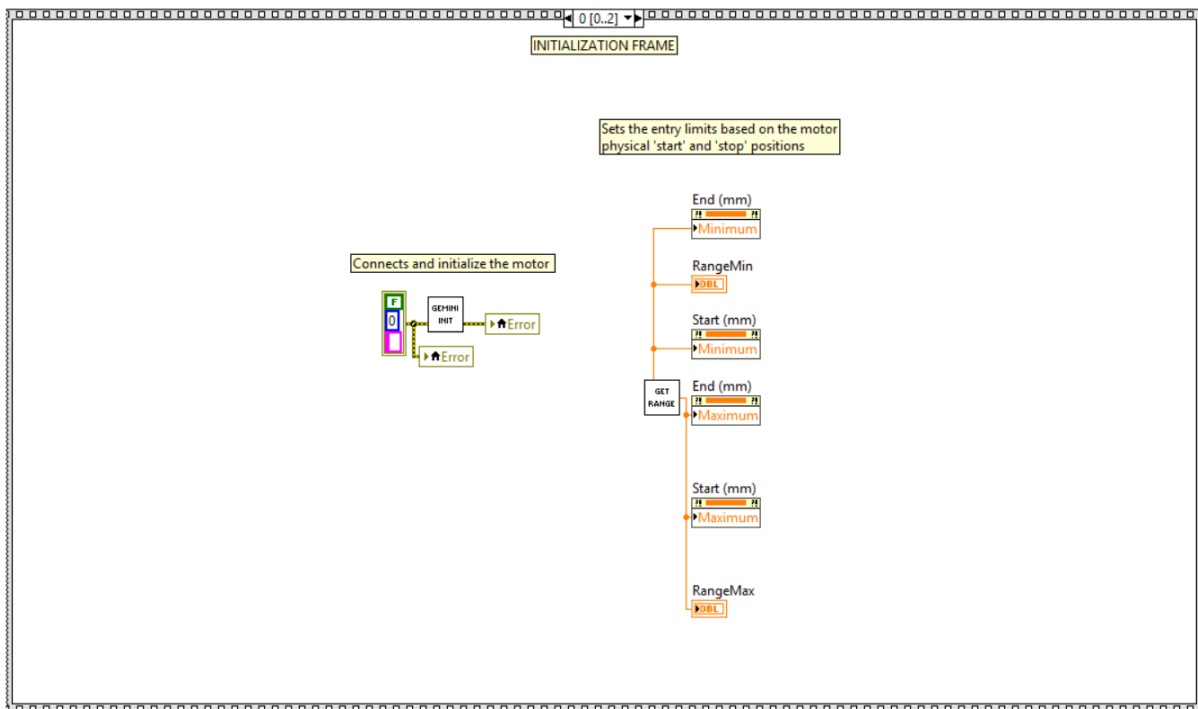


Figure 3. The block diagram frame 0 is devoted to the initialization of the motor of the GEMINI interferometer and to set the default motor range limits.

3.2 Main Frame - frame 1

The frame 1 contains the program while loop with all the main codes of the program. The *while loop* ending condition is wired to the “STOP” button situated in the front panel.

3.2.1 SINGLE MOVEMENT PANEL code.

Inside the frame 0 of the sequence structure contained in the *while loop*, an event structure handles the **SINGLE MOVEMENT PANEL** button behaviors. The event structure waits for one of the buttons in this section to be pressed (“Go Home”, “MOVE ABS”, “Move Left”, “Move Right”) and performs the correspondent action.

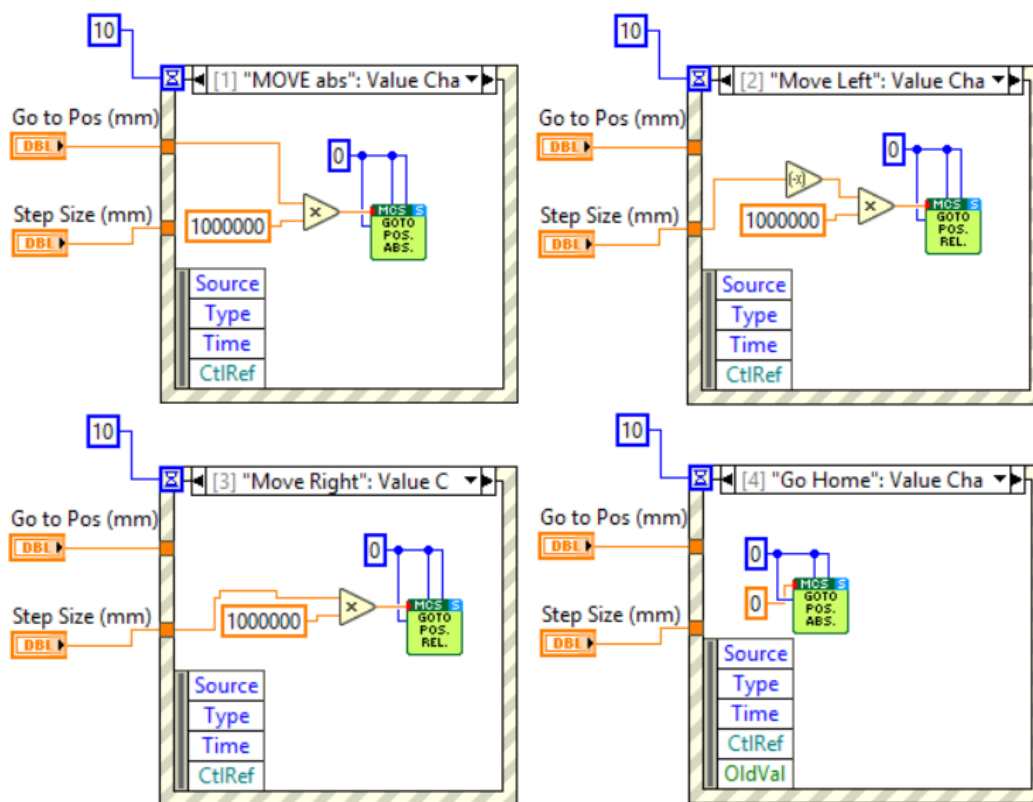


Figure 4. Events and the correspondent triggered actions.

3.2.2 Automatic Mode and status panel code.

In the frame 1 a case structure sets the scan parameters when the “automatic mode” tab is selected and the current position and delay are measured and shown in the status panel of the front panel. The sub-VI **Find Scan Range** (see appendix) calculates the maximum excursion in mm to be performed in order to have the “Desired resolution at central wavelength”. The start and end positions of the motor are calculated as *minus* and *plus* this maximum excursion. These are constrained to be inside the motor scan range. The number of steps to be performed are calculated in order to sample the interferogram with at least a number of times per period equal to the “sampling factor” numeric control. To calculate the number of steps needed to fulfill this condition, the interference period at the “start wavelength” is calculated by using the **Wavelength Calib** SubVI (see appendix). This SubVI contains the polynomial coefficients of the calibration function of the interferometer that converts from 1/wavelength (nm⁻¹) to frequency (mm⁻¹). In automatic mode, the number of steps is calculated dividing the scan range (“end (mm)”- “start (mm)”) by the interference period at “start wavelength” divided by the “sampling factor”.

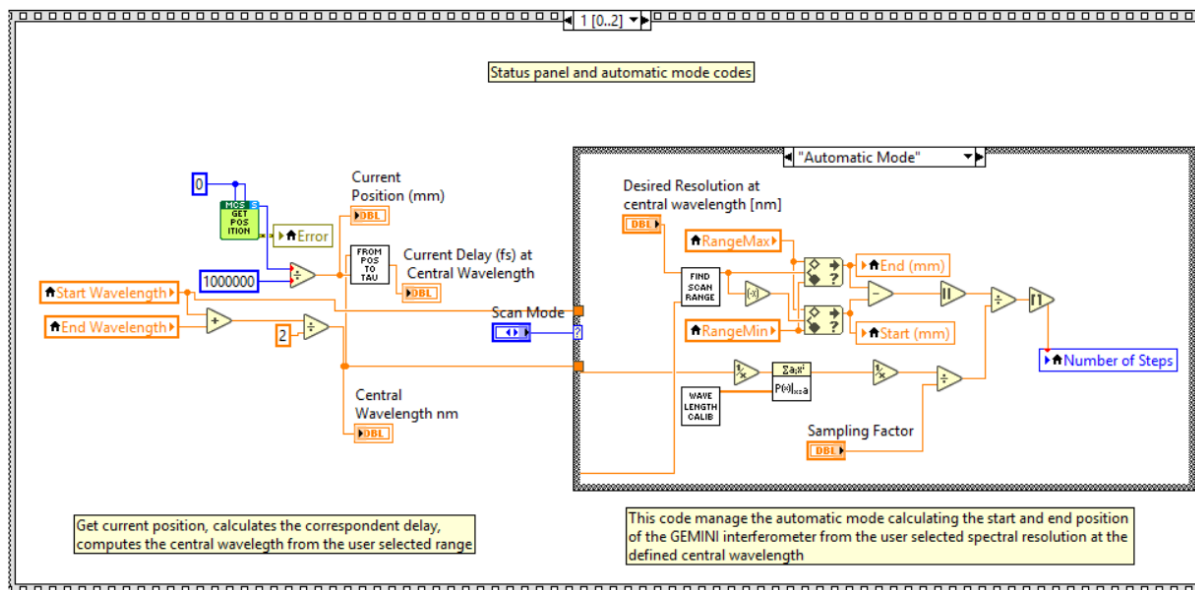


Figure 5. Automatic mode case structure. The code computes the Number of steps and the end and start position from the desired resolution at central wavelength and the sampling factor.

3.2.3 STEP SCAN code.

The start scan case structure is placed in the frame 2. This is the central part of the code and the aim is to move the interferometer step by step and to measure a voltage value from the NI-DAQ card for each position of the GEMINI interferometer. The code is divided in three frames:

- The motor is moved to the start position of the scan.
- A *for loop* move the motor in steps till the end of the scan.
- The acquired signal is processed to obtain the spectrum from the input light interferogram.

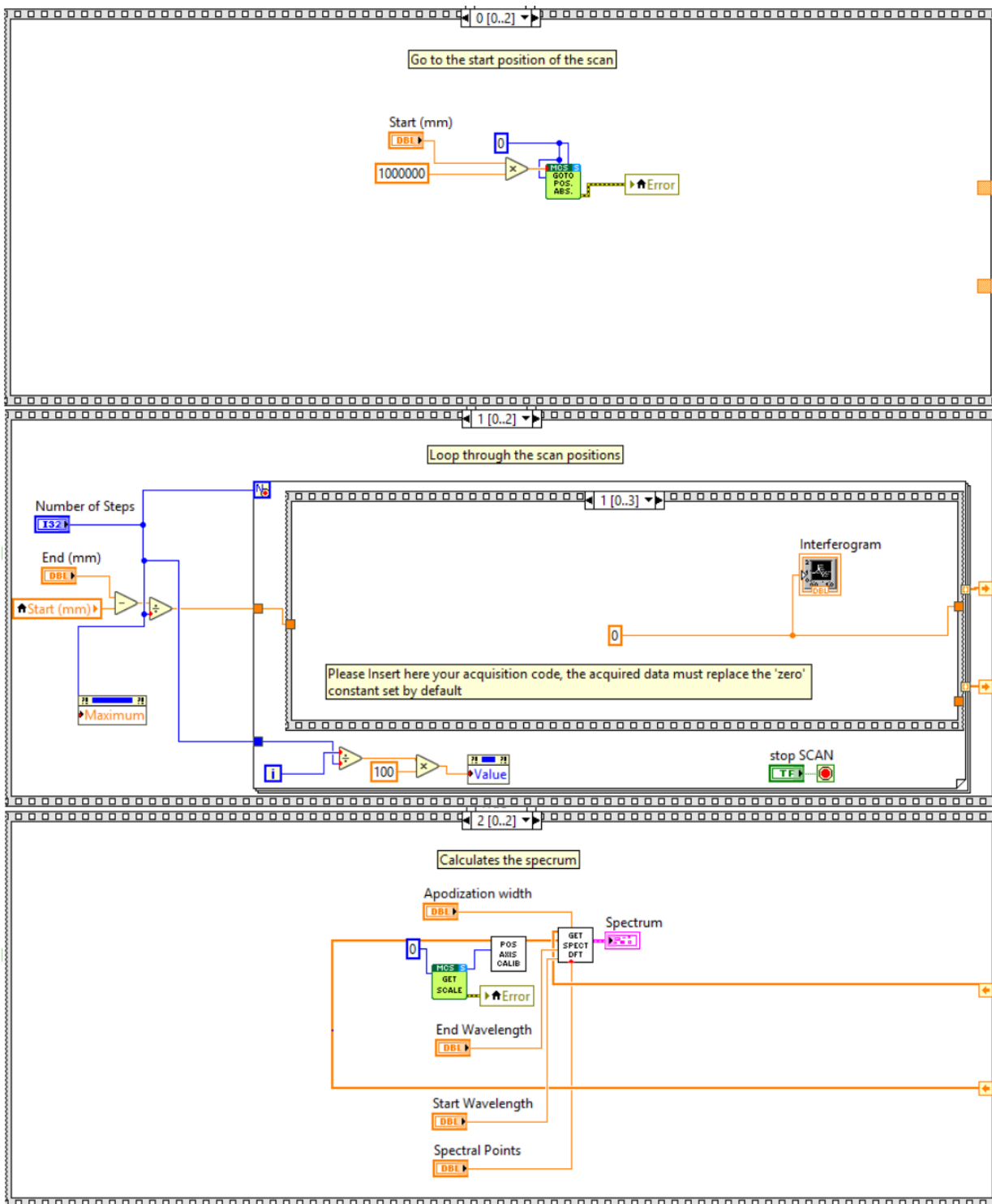
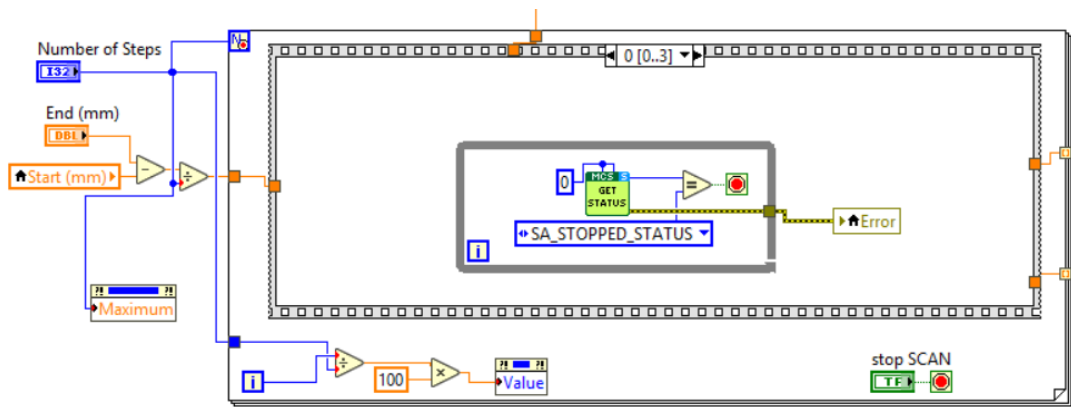


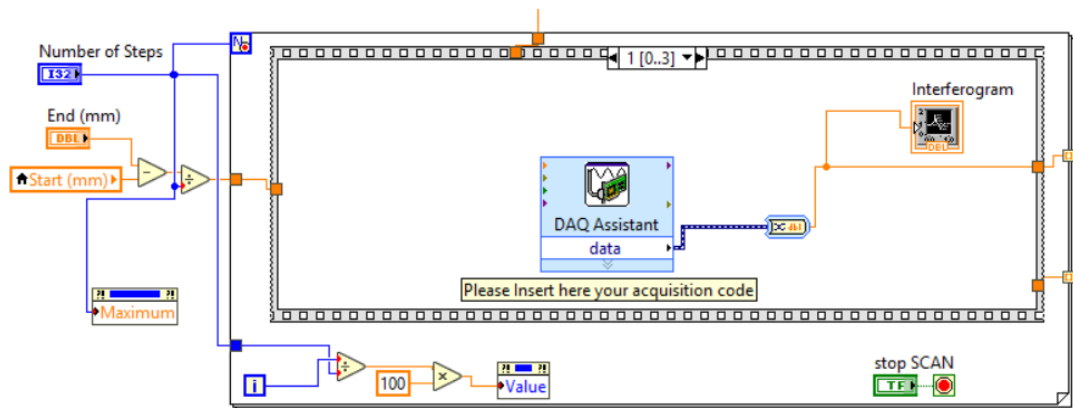
Figure 6. The three frames of the step scan part of the code.

In the second frame, the step size is computed as the ratio between scan range and the number of steps, then the movement code is based on a *for loop* ordered with a frame structure comprising 4 frames:

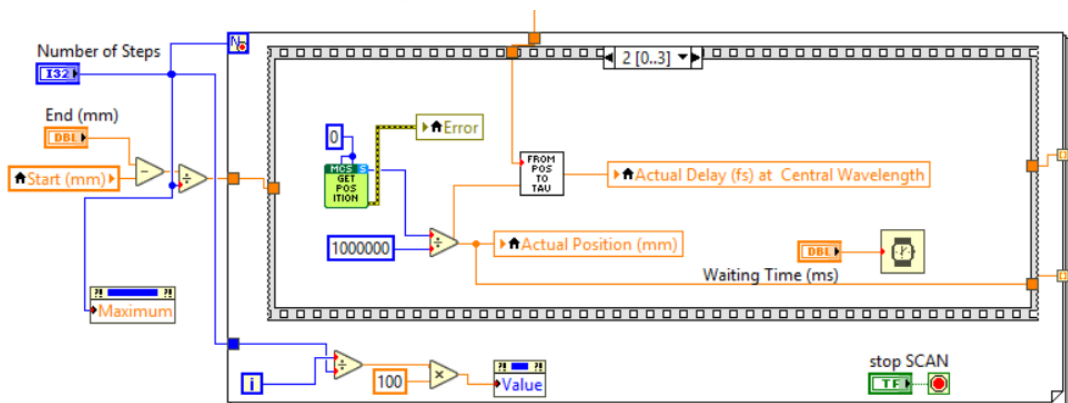
- Frame 0: a *while loop* waits for the motor to be in the stopped status.



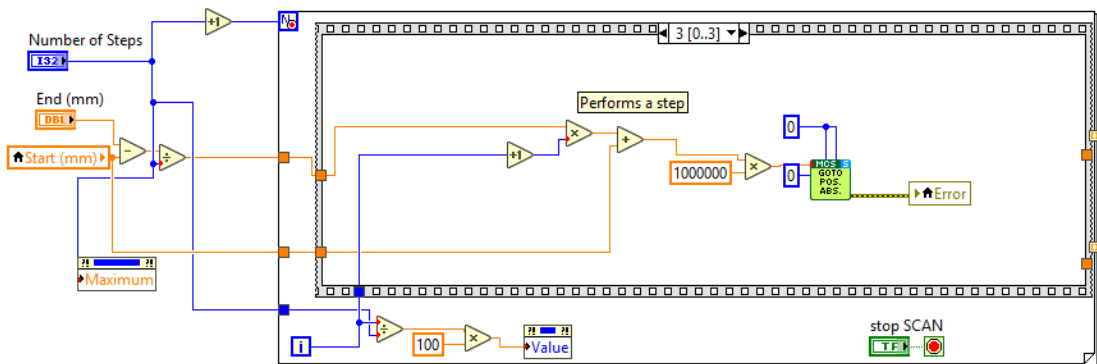
- Frame 1: the DAQ assistant measure a single voltage from the NI-DAQ and the value is plotted in the interferogram graph. **This is the frame where every acquisition code should be written.**



- Frame 2: the get position SubVI measure the position of the interferometer and is visualized in the “Actual Position” indicator in the front panel. The **from pos to tau** SubVI (refer to appendix 1f) displays the “actual delay (fs) at central wavelength”. The Waiting Time (ms) set the time to wait before the next step starts.



- Frame 3: The motor performs a step, moving to the next delay of the scan.



The *for* loop cycles through all these frames a “Number of Steps” times completing the scan.

The third frame performs all the calculations needed to retrieve the spectrum from the measured interferogram. This is accomplished through the **pos axis calib** and the **get spect dft** SubVI (see appendix). The first one returns a position calibrated axis from the position axis measured by the encoder. The second one comprises all the processing steps from the interferogram and the calibrated position axis to the actual wavelength dependent spectrum. Finally, the wavelength calibrated spectrum is plotted in the spectrum graph in the front panel.

3.3 Releasing GEMINI Interferometer - Frame 2



The last frame releases the COM port used by the GEMINI interferometer. The interferometer is ready to be switched off or reinitialized by another program session.

Appendix - NIREOS SUBVI

1. SubVIs

In order to improve readability of the code, the example software makes extensive use of SubVIs. In this section a detailed explanation of the working principle and a complete list of the inputs and outputs is provided for each SubVI.

a) FIND SCAN RANGE

DESCRIPTION:

The *find scan range* SubVI returns the maximum excursion needed to achieve a specific spectral resolution at a certain wavelength. To compute the maximum excursion the SubVI uses the formula:

$$Excursion_{max} = \frac{\lambda^2}{\Delta n(\lambda)\Delta\lambda \sin \alpha}$$

Where λ is the wavelength, $\Delta n(\lambda)$ is the wavelength dependent birefringence and α is the wedge apex angle (see *Theoretical Manual*).

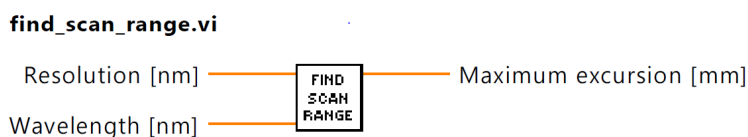


Figure 7. SubVI Diagram showing inputs (left) and outputs (right).

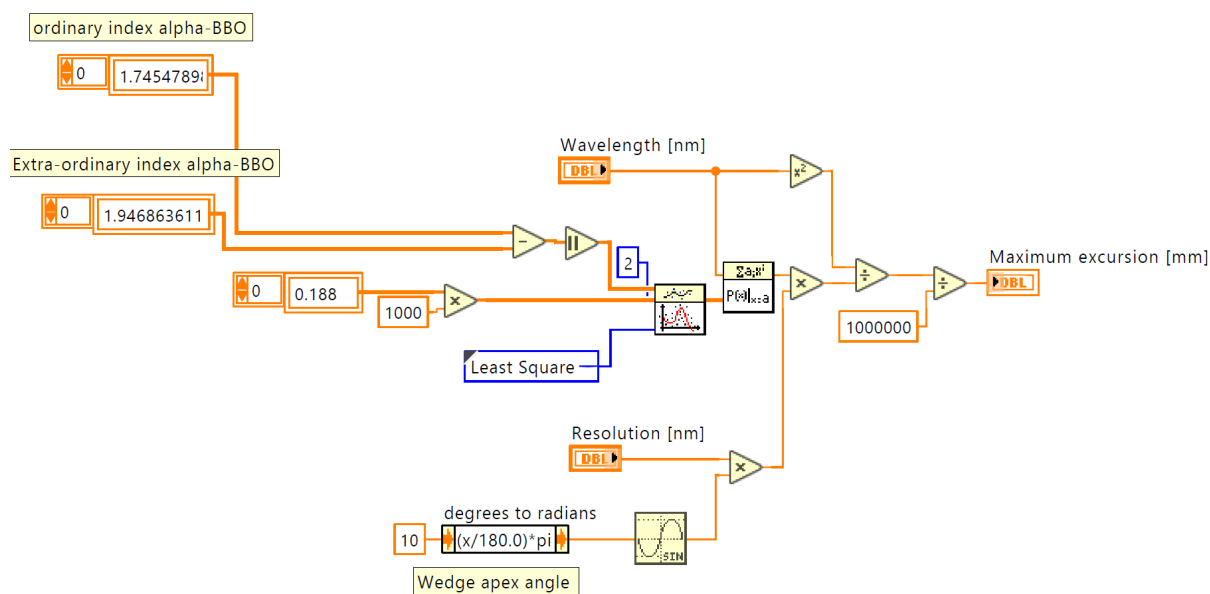


Figure 8. Find Scan Range Block diagram

INPUTS:

- Resolution [nm] (double): Desired resolution at the selected wavelength in nanometers.
- Wavelength [nm] (double): Wavelength at which the resolution is associated.

OUTPUTS:

- Maximum excursion [mm] (double): Excursion to be done to achieve the desired Resolution [nm] at the selected Wavelength [nm]

b) WAVELENGTH CALIBRATION

DESCRIPTION:

The *Wavelength Calibration* SubVI returns the polynomial coefficients of the fitting function that converts from 1/wavelength [nm^{-1}] to frequencies [mm^{-1}] and vice-versa. It is possible to modify the calibration by editing the lookup table inside the file *Initialize_parameters_cal.txt*. In the lookup table each wavelength in nanometers is associated univocally to a frequency in mm^{-1} . Please note that the GEMINI interferometer is already calibrated when shipped. The GEMINI interferometer is designed to be an ultra-stable device; therefore, the calibration remains stable over long periods of time. Please see the *Theoretical Manual* for more details on the calibration procedure of the interferometer.

Spectral_calibration.vi

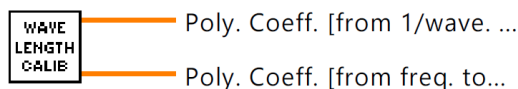


Figure 9. SubVI Diagram showing inputs (left) and outputs (right).

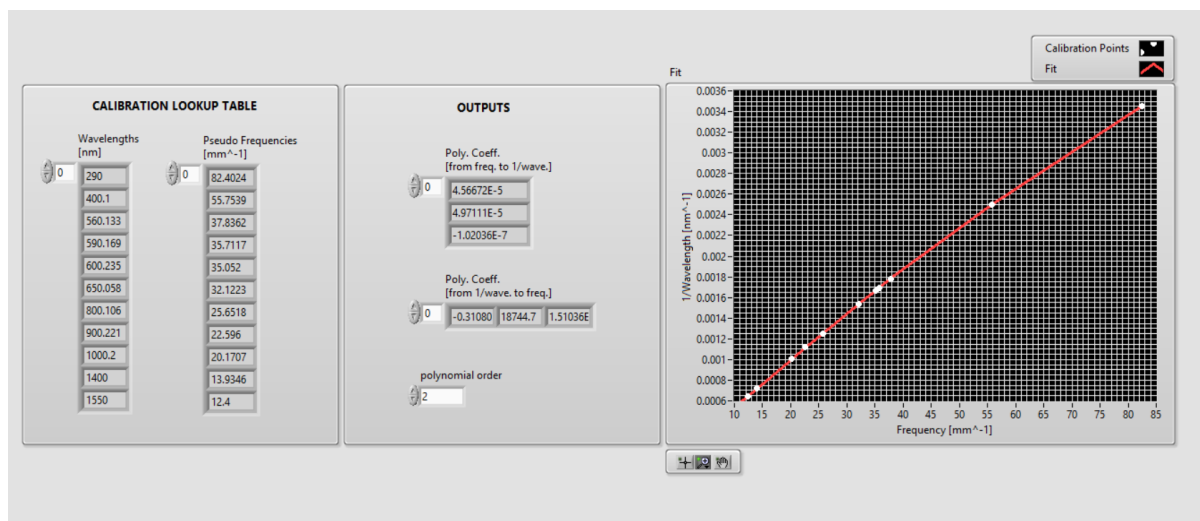


Figure 10. SubVI scheme showing inputs (left) and outputs (right). Front panel of the wavelength calib SubVI.

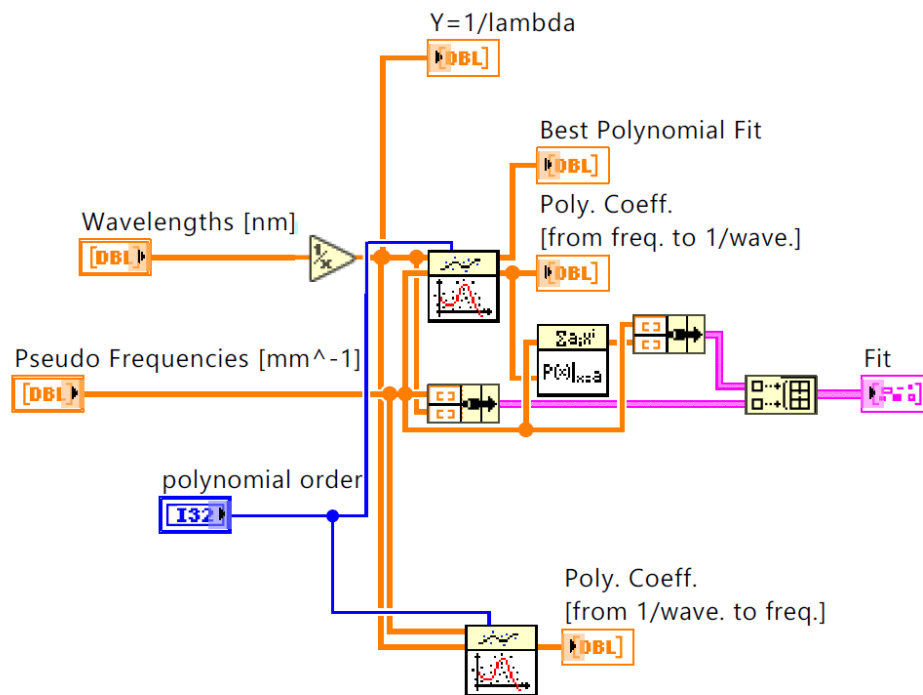


Figure 11. Block Diagram of the wavelength calibration SubVI. The code computes two sets of polynomial coefficients in order to convert from 1/wavelength [nm⁻¹] to frequency [mm⁻¹] and vice versa.

INPUTS:

- [NONE]

OUTPUTS:

- Poly. Coeff. [from freq. to 1/wave.] (1D array of double): This array contains a set of polynomial coefficients in ascending order of power. These are the polynomial coefficients of the function that converts from frequencies in mm⁻¹ to 1/wavelength in nm⁻¹. Mathematically, using the set of polynomial coefficients to convert from a specific frequency f_0 to the correspondent wavelength in nm one obtains:

$$\frac{1}{\text{Wavelength}(f_0)} = P_2 f_0^2 + P_1 f_0 + P_0$$

- Poly. Coeff. [from 1/wave. to freq.] (1D array of double): This array contains a set of polynomial coefficients in ascending order of power. These are the polynomial coefficients of the function that converts from 1/wavelength in nm⁻¹ to frequencies in mm⁻¹. Mathematically, using the set of polynomial coefficients to convert from a specific wavelength Wavelength_0 to the correspondent frequency in mm⁻¹ one obtains:

$$f = P_2 \frac{1}{\text{Wavelength}_0}^2 + P_1 \frac{1}{\text{Wavelength}_0} + P_0$$

c) POSITION AXIS CALIBRATION

DESCRIPTION:

This SubVI receives the encoder position array and the motor current scale value and returns the interferometric calibrated position axis in millimeters. This SubVI eliminates artifacts due to motor linear slide imperfections. This SubVI contains NIREOS proprietary algorithms and the block diagram is not accessible. To measure the actual scale of the motor inside GEMINI interferometer use the Smaract *SA_GetScale_S.vi* as in the software example.

Thanks to the GEMINI high reproducibility, to have an interferometric calibrated position axis, it is enough to measure the interferogram of a high temporal coherent source (e.g. Lasers) over the whole scan range of the motor. The measured interferogram together with the correspondent position array as recorded by the encoder should be saved in a file with the name: "Initialize_parameters_int.txt". This file must be placed in the same folder of the *Get_Calibrated_position_axis.vi* SubVI. Please note that the GEMINI interferometer is shipped already calibrated and there is in general no need to recalibrate the interferometer over a long period of time. Please Contact NIREOS customer service at info@nireos.com for hints on the calibration procedure.

Get_Calibrated_position_axis.vi

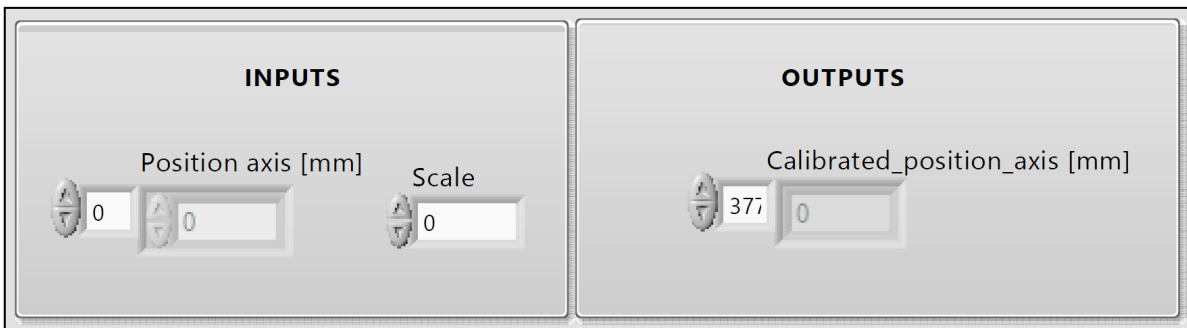


Figure 12. (top) SubVI scheme showing inputs (left) and outputs (right). (bottom) Front panel of the *Get_Calibrated_position_axis* SubVI.

INPUTS:

- Position axis [mm] (1D array of double): This array contains all the position values correspondent to each acquired interferogram point.
- Scale (Long Int): this is the motor scale value obtained through the Smaract *SA_GetScale_S.vi*. This value is needed to reference the motor position to the motor physical reference.

OUTPUTS:

- Calibrated_position_axis [mm] (1D array of double): This array contains the interferometrically calibrated position values.

d) GET SPECTRUM DFT

DESCRIPTION:

This SubVI contains all the steps to convert an interferogram into a wavelength dependent spectrum. The interferogram mean value is subtracted from the interferogram and the result is multiplied by a gaussian function (the so-called apodization window). The normalized standard deviation of the gaussian window with respect to the number of points of the interferogram is selected by the Apodization width numeric control. The result is given as an input to the *NIREOS dft* SubVI which calculates the Fourier transform of the interferogram as a function of the position axis. Finally, the output spectrum is plotted as a function of the wavelength axis obtained with the *wavelength calibration* SubVI.

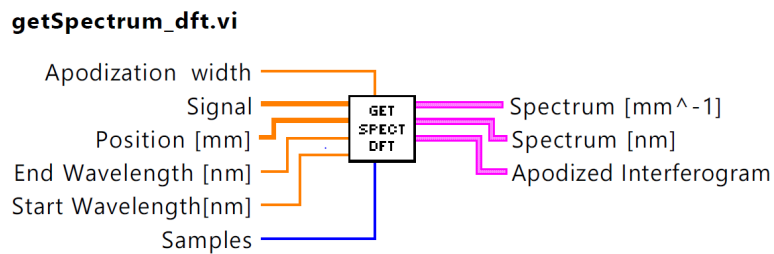


Figure 13. SubVI Diagram showing inputs (left) and outputs (right).

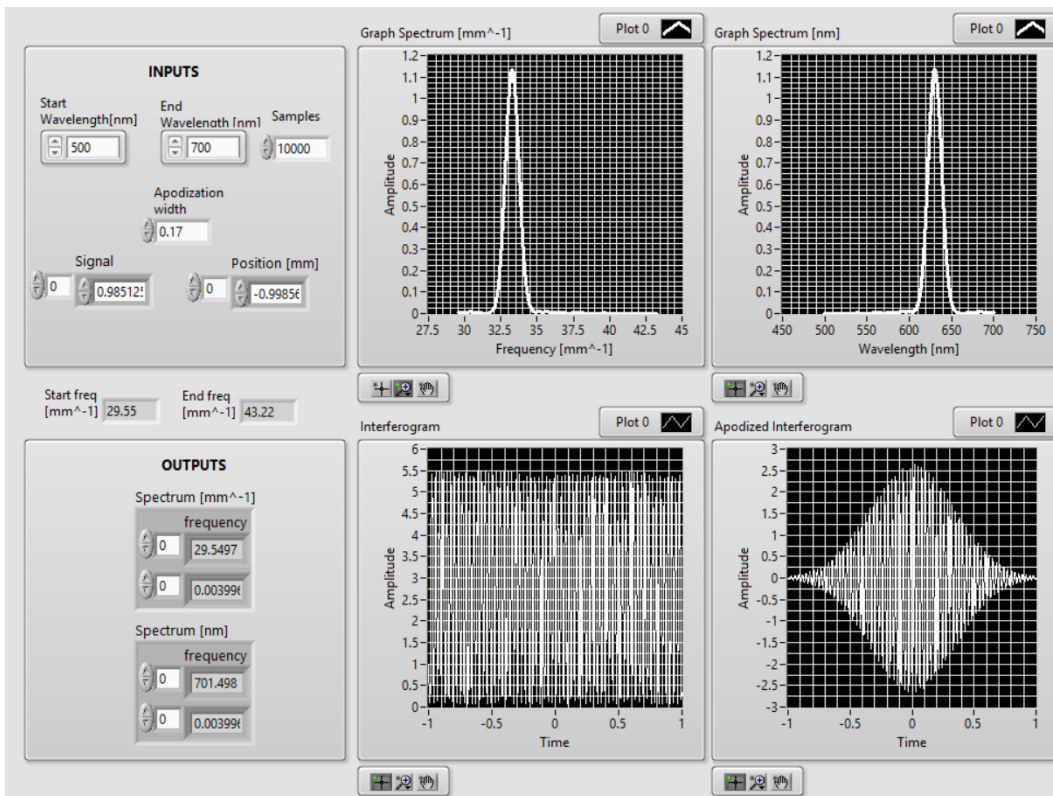


Figure 14. `Get_spectrum` SubVI Front Panel containing a real working example.

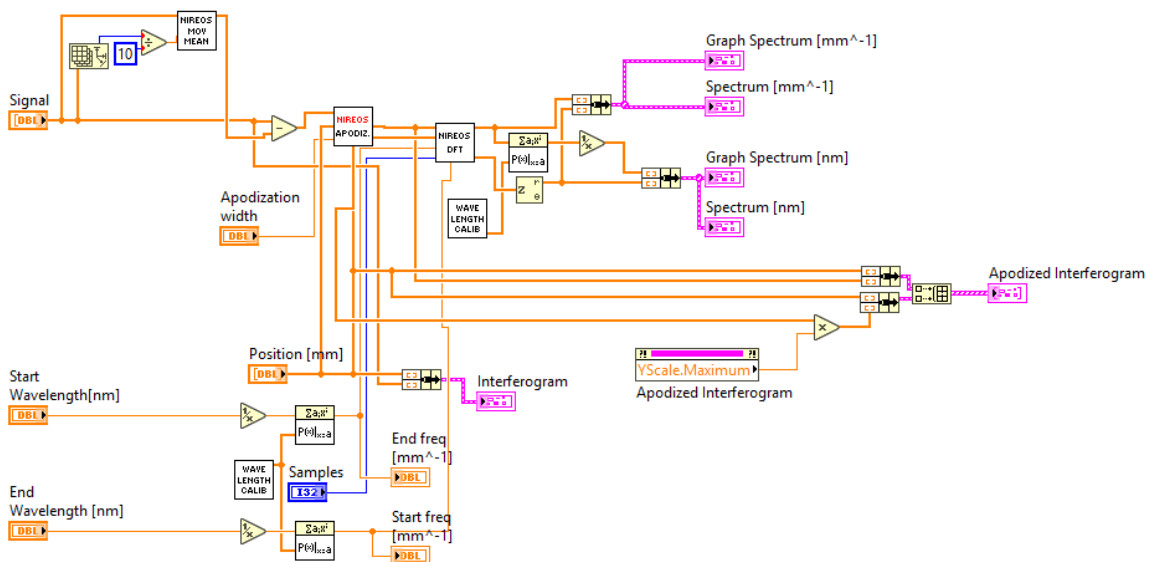


Figure 15. `Get_spectrum` block diagram containing all the steps to obtain the wavelength calibrated spectrum.

INPUTS:

- Apodization width (double): the normalized standard deviation with respect to the number of points of the interferometric signal.

- Signal (1D Array of double): the interferometric signal, the so called interferogram to be Fourier transformed.
- Position [mm] (1D Array of double): The position array correspondent to the interferogram. Each point of the array should match in an ordered way to the correspondent point of the interferogram.
- Start Wavelength [nm] (double): Start Wavelength in nanometers from which the spectrum is computed.
- End Wavelength [nm] (double): End Wavelength in nanometers up to which the spectrum is computed.
- Samples (integer): Number of spectral points to be computed.

OUTPUTS:

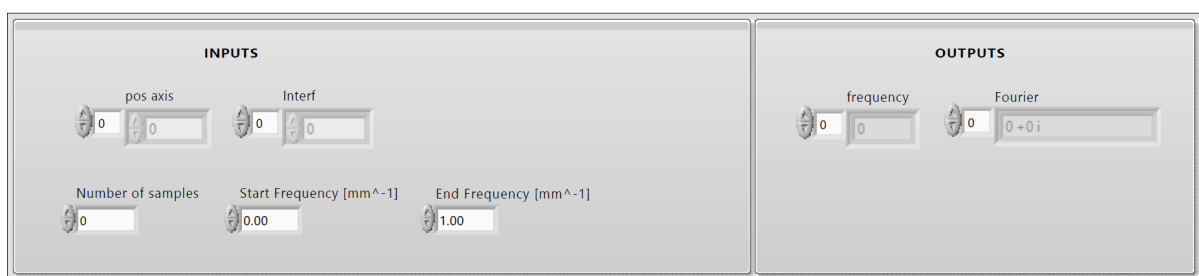
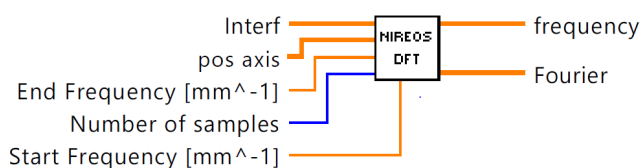
- Spectrum [mm⁻¹] (cluster of two 1D arrays of double): Output spectrum in mm⁻¹ with the selected number of points from start freq [mm⁻¹] to end freq [mm⁻¹]. The cluster comprises the correspondent frequency axis.
- Spectrum [nm] (cluster of two 1D arrays of double): Output spectrum converted in nanometers with the selected number of points. The cluster comprises the correspondent wavelength axis.
- Apodized Interf. (cluster of two 1D arrays of double): This cluster contains the apodized interferogram and its correspondent spatial axis. This signal is apodized with a Gaussian window having the selected apodization width.

e) NIREOS DFT

DESCRIPTION:

This SubVI calculates the discrete Fourier transform as a function of the frequency in mm⁻¹ from the interferogram as a function of the position array.

dft.vi



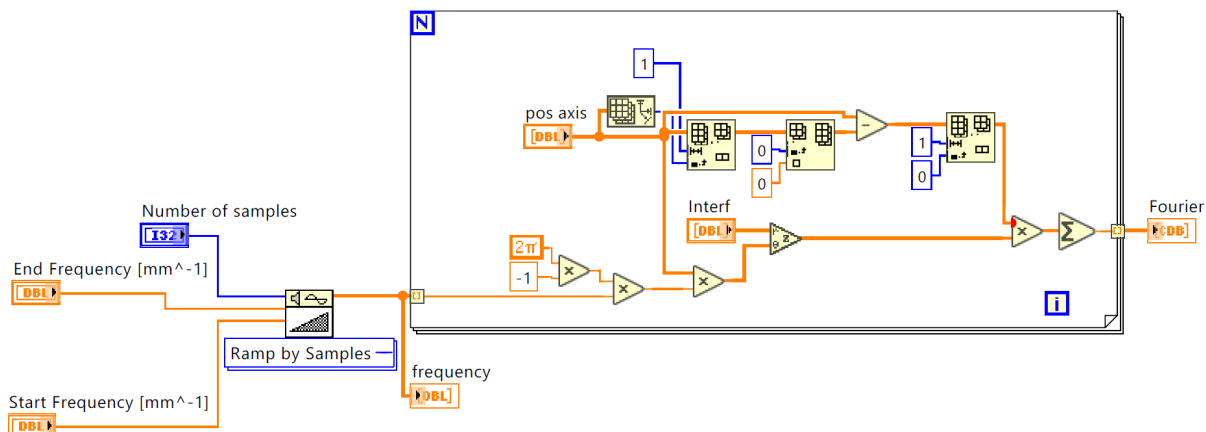


Figure 16. SubVI block diagram. This loop calculates the discrete Fourier transform of the signal in the selected frequency range.

INPUTS:

- Interf (1D array of double): this array contains the interferogram values.
- Pos axis (1D array of double): this array contains the position axis.
- Start Frequency [mm⁻¹] (double): Start Frequency in mm⁻¹ from which the spectrum is computed.
- End Frequency [mm⁻¹] (double): End Frequency in mm⁻¹ up to which the spectrum is computed.
- Number of samples (integer): Number of spectral points to be computed.

OUTPUTS:

- Frequency (1D array of double): Frequency axis of the complex discrete Fourier transformation.
- Fourier (1D array of double): complex discrete Fourier transform in the user selected spectral range.

f) FROM POS TO TAU

DESCRIPTION:

This SubVI returns the delay in femtoseconds at a specific wavelength from the relative position of the interferometer with respect to the “Home position”. Indeed, the interferometric delay is not constant for all the wavelengths (see *Theoretical Manual*). The delay is given by the following formula:

$$Delay = \frac{\Delta n(\lambda) Pos_{rel} \sin(\alpha)}{c}$$

Where $\Delta n(\lambda)$ is the wavelength dependent birefringence, Pos_{rel} is the relative position with respect to the “Home position” (zero interferometric delay), α is the wedge apex angle (see *Theoretical Manual*) and c is the speed of light in vacuum.

Calibration_position_delay.vi

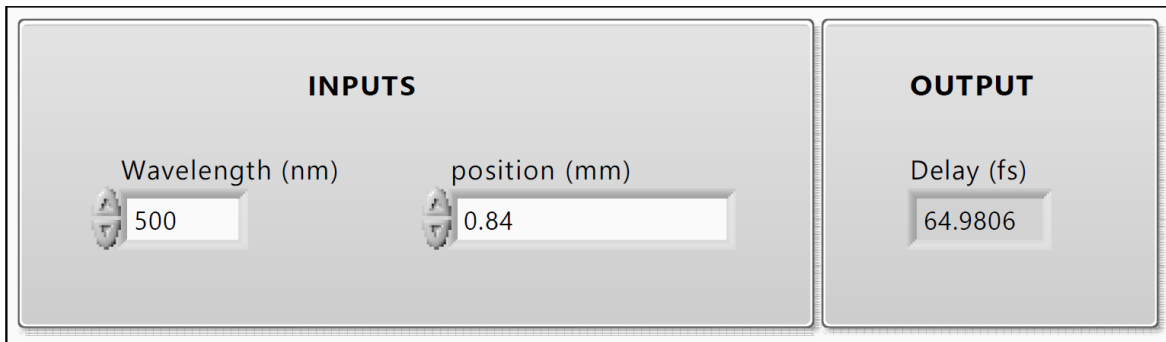


Figure 2 SubVI Front Panel

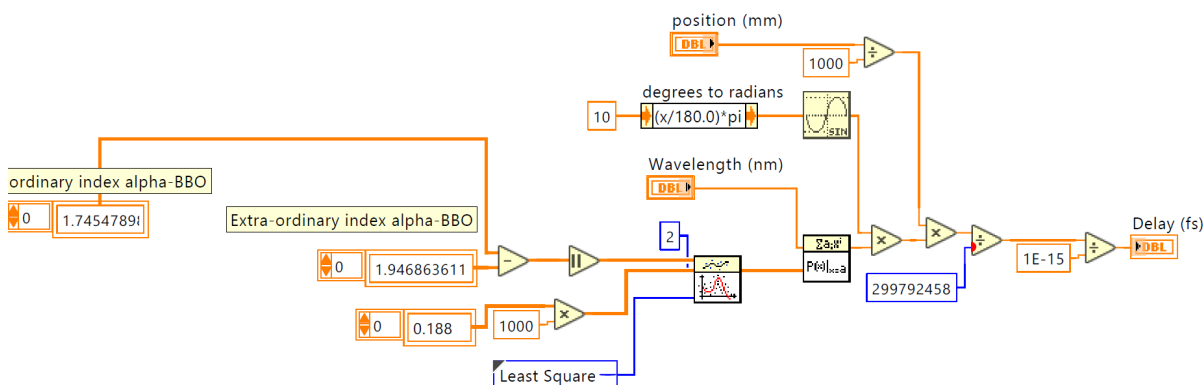


Figure 3 SubVI block diagram

INPUTS:

- Wavelength (nm) (double): the wavelength used to calculate the interferometric delay
- Position (nm) (double): the relative position with respect to the “Home position” in millimeters

OUTPUT:

- Delay (fs) (double): the interferometric delay in femtoseconds at the selected wavelength.

g) Gemini_init

This SubVI initialize the GEMINI and move the interferometer to the “Home position” where the delay is set to zero. The motor is initialized in synchronous communication. In the next step, the motor is asked to find the physical reference and the *while loop* waits for the referencing procedure to end. The motor moves to the “Home position” and the program waits for the movement to end.



Figure 4 SubVI Diagram showing inputs (left) and outputs (right).

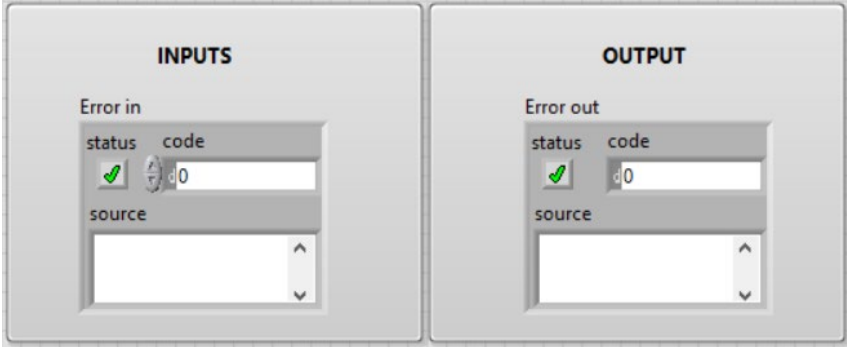


Figure 20. SubVI front panel

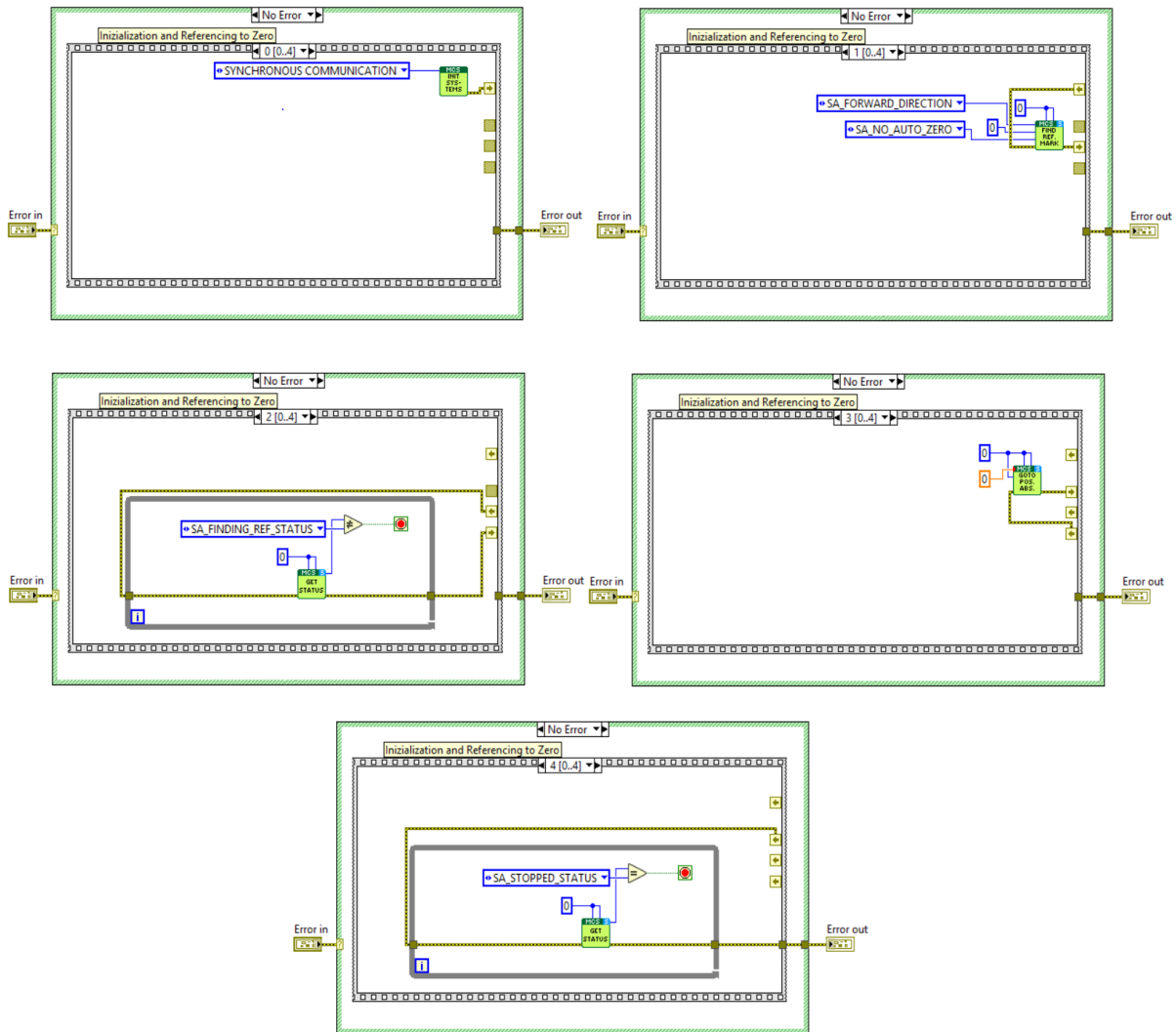


Figure 21. SubVI Block diagram showing the steps needed for the motor to find the physical reference and to move to the calibrated zero position.

INPUT:

- Error in (cluster of 3 elements): Input Error.

OUTPUT:

- Error out (cluster of 3 elements): Output Error.

h) Find_scan_range

This SubVI find the limit positions of the interferometer based on the *Initialize_parameters_int.txt* file. The limits are the first and last positions stored in the text file

(see appendix section 2 for more details). These limits are used to constrain the minimum and maximum values of the Start (mm) and End (mm) controls in the front panel.

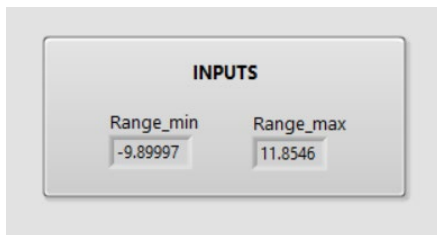


Figure 22. SubVI Front panel

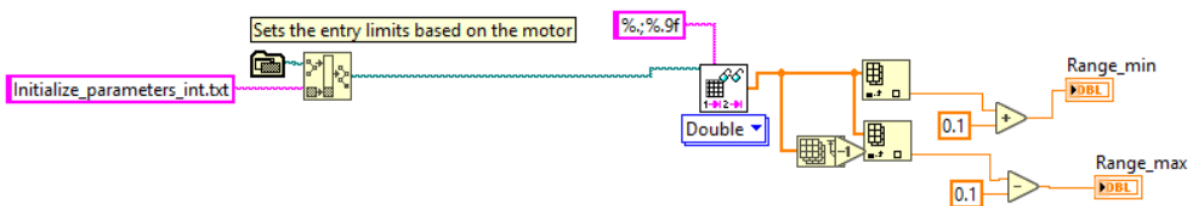


Figure 23. SubVI Block Diagram.

INPUTS:

[NONE]

OUTPUTS:

- Range_min (double): minimum position of the interferometer with respect to the calibrated “Home position”.
- Range_max (double): maximum position of the interferometer with respect to the calibrated “Home position”.

2. Configuration Files

The GEMINI interferometer is shipped already calibrated and configured. In order to work properly, this example software needs three configuration files that must be present in the operational example working folder together with all its SubVI.

a) *Initialize_parameters_int.txt*

This file contains the interferogram of a highly temporal coherent source such as HeNe laser sampled over the whole scan range of the GEMINI interferometer. The file is composed of two rows. The first one contains the position axis and the second one the interferogram values at the correspondent positions. This file is used to calibrate the position axis of the interferometer with an extremely high precision. The file is used inside the *Get Calibrated position axis.vi* to calculate the position axis with interferometric accuracy, therefore it is always recommended to use this file. The position axis calibration procedure is simply an interferogram acquisition of a highly temporally coherent source such as HeNe laser over the whole scan range of the motor. The Acquired interferogram should be saved together with its correspondent position axis inside the Initialize_parameters_int.txt file. The first row of the file must contain the position axis in millimeters and the second row must contain the correspondent interferogram values. If you need further information on how to perform the position axis calibration procedure, please contact us at info@nireos.com.

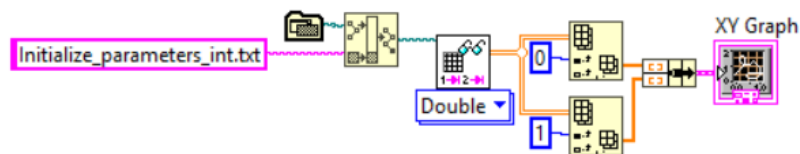


Figure 24. LabView block diagram used to visualize the configuration file.

b) *Initialize_parameters_scale.txt*

This file contains the scale parameter of the positioning system and it is used to find the physical zero position of the interferometer. Warning: Do not modify this file! Changing the value contained in this file require invalidate the position axis calibration procedure performed in factory.

c) *Initialize_parameters_cal.txt*

This file contains the conversion table from mm^{-1} to wavelength and it is used to calibrate the spectral axis. The user can add or modify any of the entry and the software will automatically take into account the change to compute the spectral axis.

