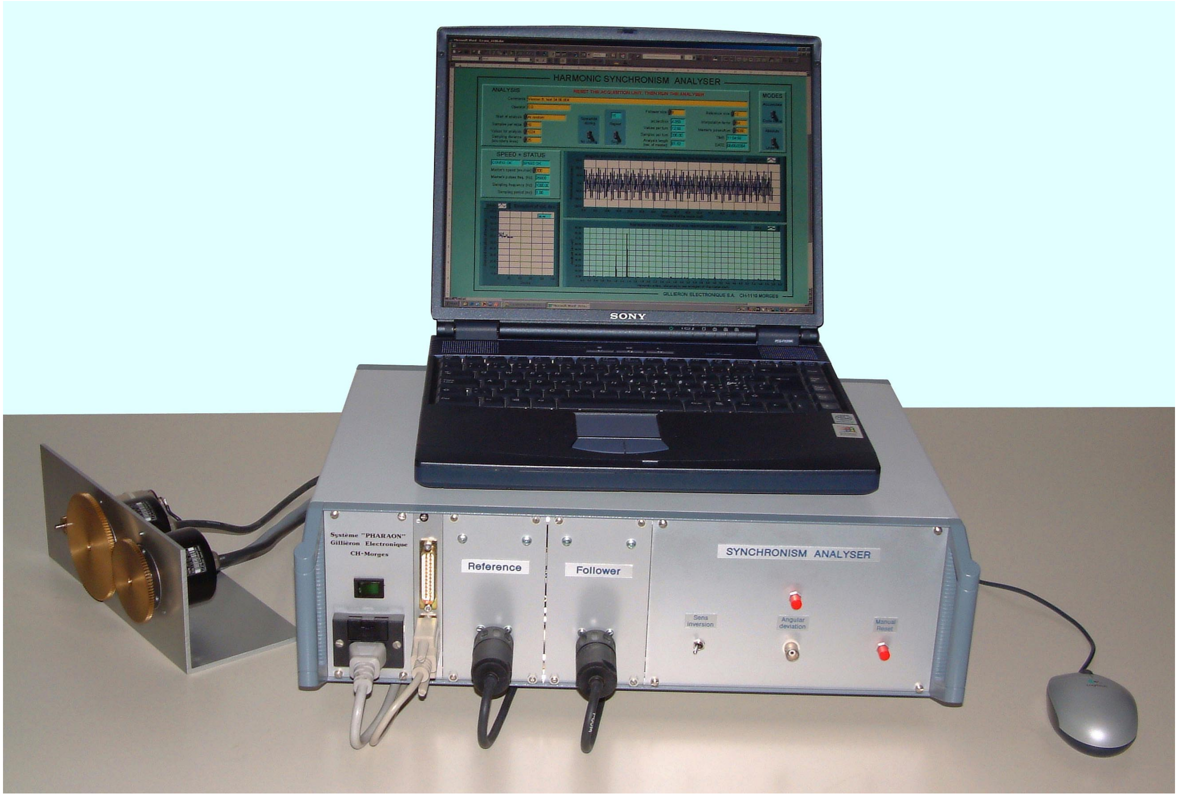
Synchronism analyser.

Technical documentation and user's guide.



The synchronism analyser with the test and demonstration equipment

Note.

This is the technical documentation and the characteristics of our standard synchronism analyser.

As a small engineering company, we always try to fit our products to your needs. Don't hesitate to propose us modifications or adaptations for your application.

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1 PRESENTATION

1.1 Introduction

Two questions are frequently asked in the field of the motion control:

- how good is the **speed stability** of an axis ?
- what is the **synchronism error** between two axis drived by a mechanical or electrical device ?

The speed stability can be calculated by observing the jitter of the frequency issued from a shaft encoder. The Fourier transformations will provide a more subtle analysis of the speed variation.

The error of synchronism is defined as the variation of the relative position between the concerned elements.

The frequency spectrum of the relative position provides also very useful informations to find the origin of the errors :

1.2 Short presentation of some real cases

We present here some typical cases. More information and details are given on the following pages.

Problem 1) On a new printing press, equiped with classical mechanical drives, it has been found some misajustment of the colors.
Diagnostic of the analysis : mechanical excentricity and pitch errors on the pinions of a right angle gearhead.

Problem 2) Poor accuracy on a packaging machine, also equiped with classical mechanical drives.
Diagnostic of the analysis : the tension of a notched driving belt was too loose. The mechanical tension of the belt was corrected using the "standard deviation graph" of the stability analyser.

Problem 3) Indexing errors on a machine generating identification hologramms . The machine is quite complex, with mechanical and electrical synchronous drives.
Diagnostic of the analysis : The spectrum shows an important spectral line : is it the sign of a mechanical or an electrical problem ?
We decide to increase the speed of the machine of 2 percent. The spectral line shifts of 2 %, indicating that this oscillation has a constant frequency. The trouble was eliminated by re-ajusting the parameters of a PID loop.

1.2.1 Remark

The synchronism analyser, is a relatively simple but very powerful tool. Like the stethoscope for the doctor, the synchronism analyser will give to the engineer valuable informations to locate the source of a malfunction or inaccuracies.

1.2.2 Structure of the analyser.

The accurate measurement of the synchronism of two movements is a little bit tricky: in theory, the comparison of the speed of the two axis could be the basis for calculating the synchronism error.
In practice, the measurement errors are so critical that this method doesn't gives useful results. So, the tacho-generators are not adapted to this application.

We must measure, record and analyse the relative position of the two axis during the rotation. The analysis should not be made in function of the time but in function of the movement of one axis that is defined as the reference.

By this method, the measurements are also independent of the speed of the machine.

The sensors used in the synchronism analyser are the shaft encoders (incremental encoders) with sinusoidal outputs. The resolution of the encoders is enhanced with the interpolation process of our **PHARAON**® system.

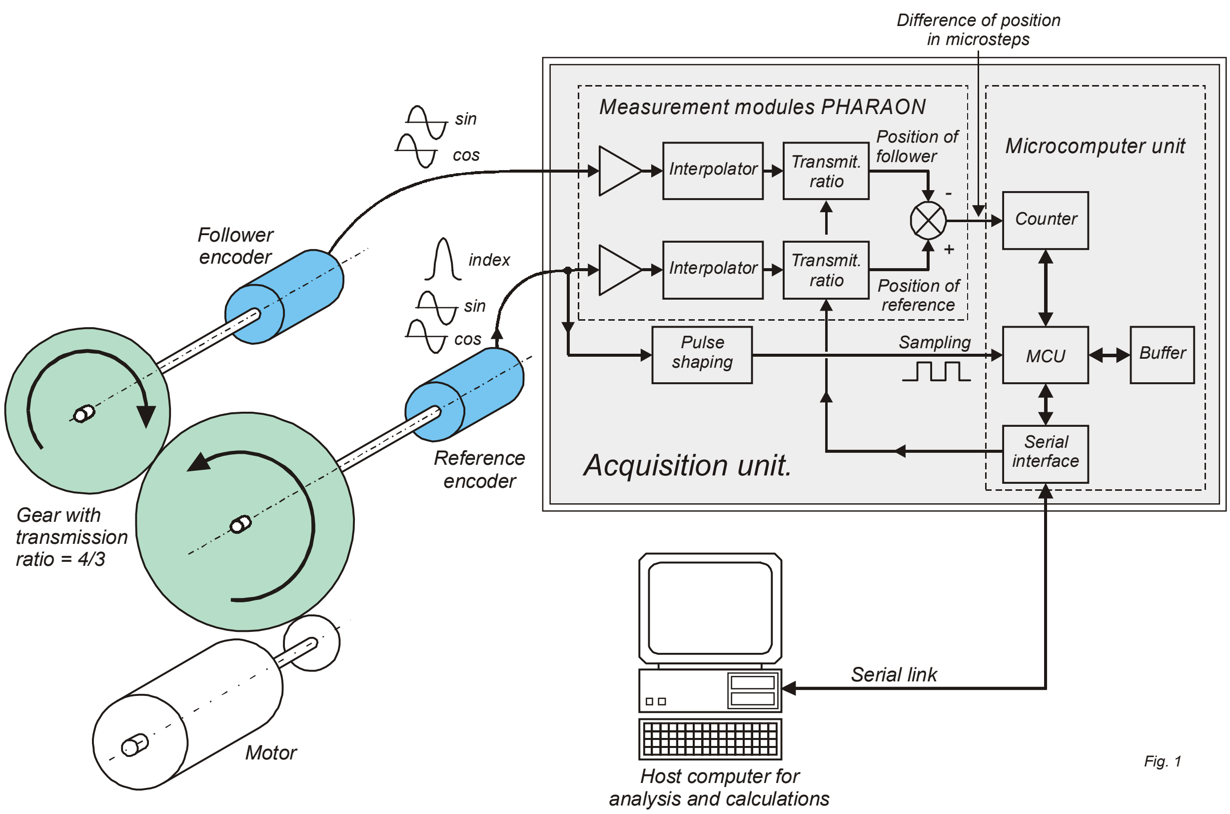


Fig. 1

Principle of the synchronism analyser with the test and demonstration equipment

1.3 Working principle.

As said before, the measurement and the analysis is not made in function of the time but in function of the movement of one axis that is defined as the **reference**. The other axis is defined as the **follower**.

The unit of the sampling is the "step". A step is simply the distance of a line of the reference encoder.

The unit of the measurement is the "microstep". A microstep is the value of a step divided by the interpolation factor.

See fig. 4 below.

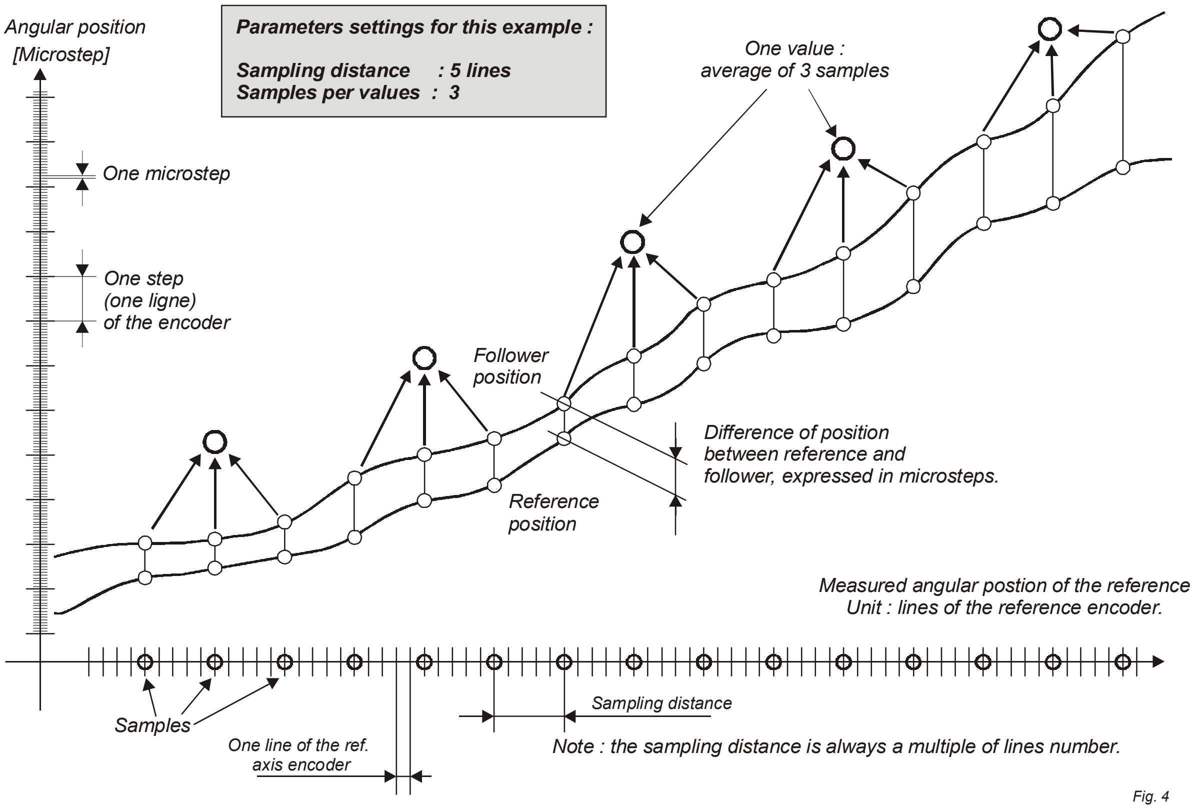


Fig. 4

Measurement and analysis of the synchronism : principle and definitions.

1.4 Architecture of the synchronism analyser.

Refering to the fig.1, the system is shared in two parts:

- the acquisition unit, mounted in a 19 inches cabinet.
- the computation unit. (PC)

The **acquisition unit** performs the critical real-time operations. It is built with the modules of the **PHARAON**® system and the **MICROFLEX** microcomputer.

The heart of the acquisition unit is formed by a special interpolation circuit that divides the distance between two lines of the encoder in 32, 64, 128 or 256 divisions, named "microstep". The high degree of resolution plus its high computational speed allows high performances in accuracy and velocity.

The measurement values are stored in the acquisition unit and sent to the PC for the analysis.

The **computation unit** (PC) executes the following functions:

- operator interface for parameters setting.
- calculations and analysis.
- presentation of results on the screen or to the printer.

The programm is written in "G" langage (Labview).

1.5 General properties.

- processing the signals of incremental encoders with analog output (sine and cosine).
- analysis of linear or rotational movements.
- measuring resolution up to the second of angle. (Depending on the incremental encoders).
- the transmission ratio between the two axis can have any value.
- Incremental speed :
  Guaranteed : 5 MHz.
  Can reach 15 MHz in most of the conditions.

2 MOUNTING OF THE ENCODERS.

If the system under test is equipped with the proper incremental encoders, we can use these encoders by derivation of their electrical signals.

If we have to add the measuring encoders, they should be tightly coupled to the axis under test. This rule is however not mandatory. We have made good experience with the apparatus described in fig 2, where the encoders are mounted on a tripod.

The magnetic adapter is aligned by a centering spike introduced into the conical hole which exists normally at both ends of the shafts.

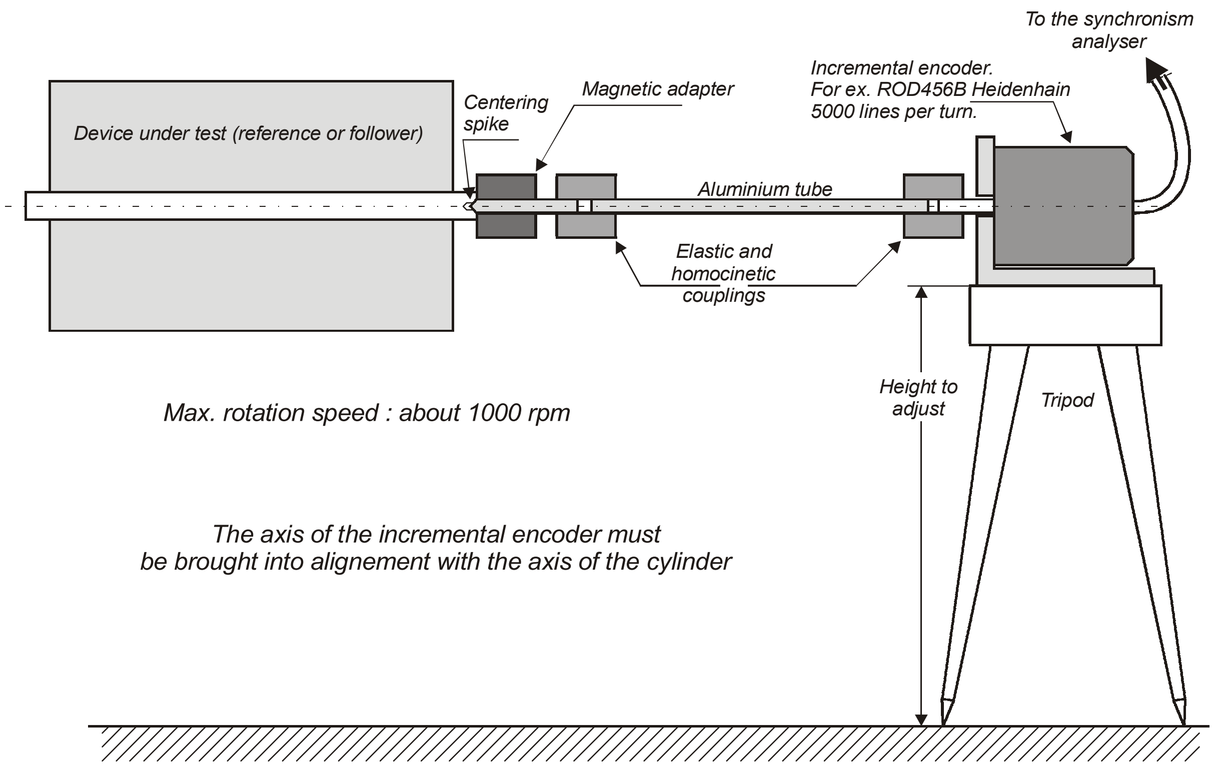
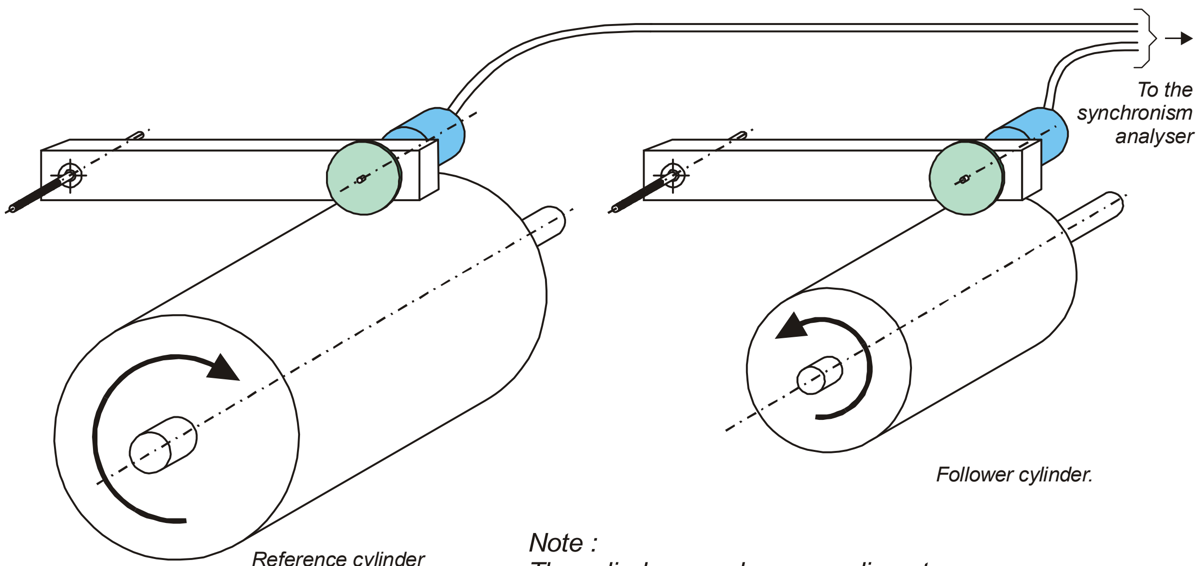


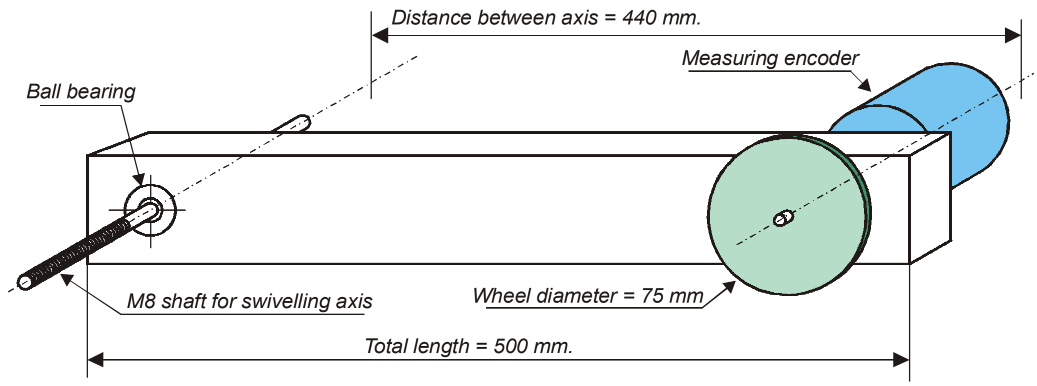
Fig. 2

Overview of the magnetic driving mechanism for encoders.

An another method is to mount disks on the shaft of each encoder and to drive them simply by the friction against the cylinder. Refer to fig 3, with disks in green and encoders in blue. These disks must be carefully machined in order to have a good concentricity.

In order to compensate the small amount of slipping between the cylinders and the disk, a special algorithm is incorporated in the analysis programm. This feature gives very good results in most of cases.





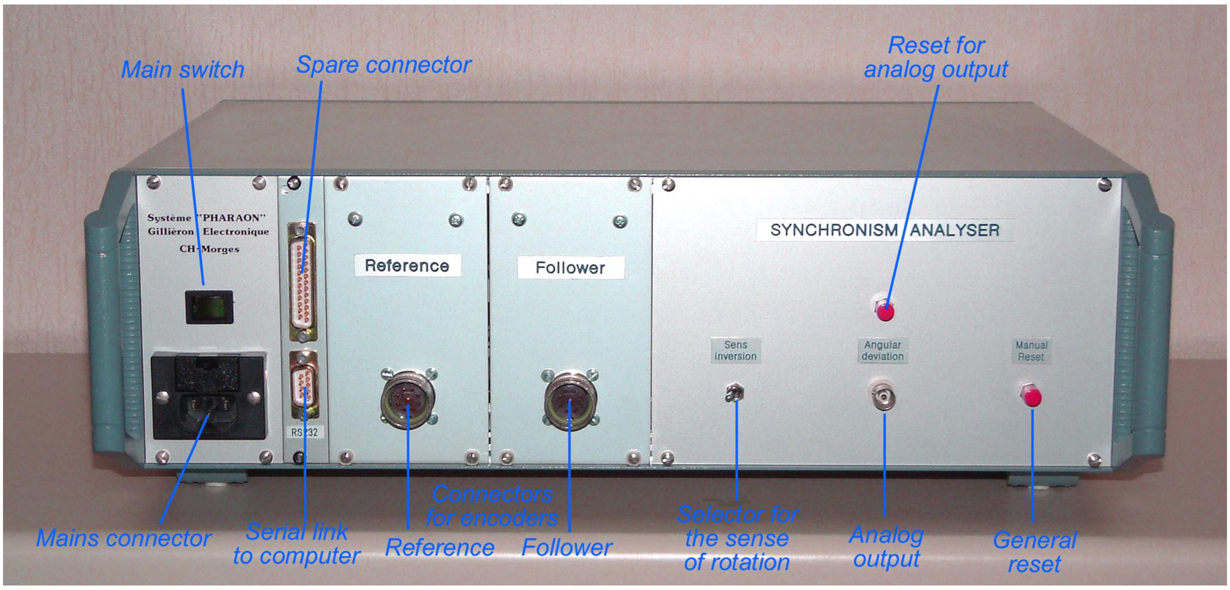
Dimensions of the arm

Fig. 3

Overview of the “friction” measurement system.

3 Description

3.1 The acquisition unit.



3.1.1 Description of the elements of the acquisition unit

Mains connector	230V, 50/60 Hz. Power about 40VA Connector with 2 fuses T 1A.
Main switch	No comment.
Spare connector	For special customisation.
Serial link to computer	RS 232 connection 9600 bds.
Connectors for encoders	Standard Heidenhain connector, for encoders with voltage symmetrical output, 1V pp.
Switch for the sense of rotation.	Left position : encoders rotating in CCW sense Right position : encoders rotating in CW sense.
Analog output	For direct monitoring purposes. 12 bits +/- 10 V range One microstep corresponds to one increment of the DAC. One analog increment of the DAC corresponds to 4,88 mV.
Reset button for analog output	Reset button only for the analog output. Without any action on the other functions of the analyser.
General reset	Hardware, cold reset for the acquisition unit.

3.2 The software running on the host computer .

The software programm is an autonomous executable module (.exe). The source is written in the G-langage LABVIEW.

When started, an operator panel with controls and indicators is displayed on the screen of the computer. (See example on the next page.)

Handlings are made with the mouse.

There are 3 categories of controls and indicators.

- The graphs and charts indicators.
- Digital **indicators**, in light **blue**. Show some useful data.
- Digital **controls**, in **yellow**. Used to set the working parameters.

The graph of the position represents the synchronism error of the follower in function of the angular movement of the reference axis. The scale is in seconds of arc.

The graph of harmonics is the FFT of the graph of position. The scale is also in seconds of angle.

The 3rd graph is the standard deviation of successive measurements. It represents the standard deviation of all the measured values relatively to the mean value of the reference-follower position. This graph is very useful for adjustment and optimization purposes, for example on electrical synchronous drives.

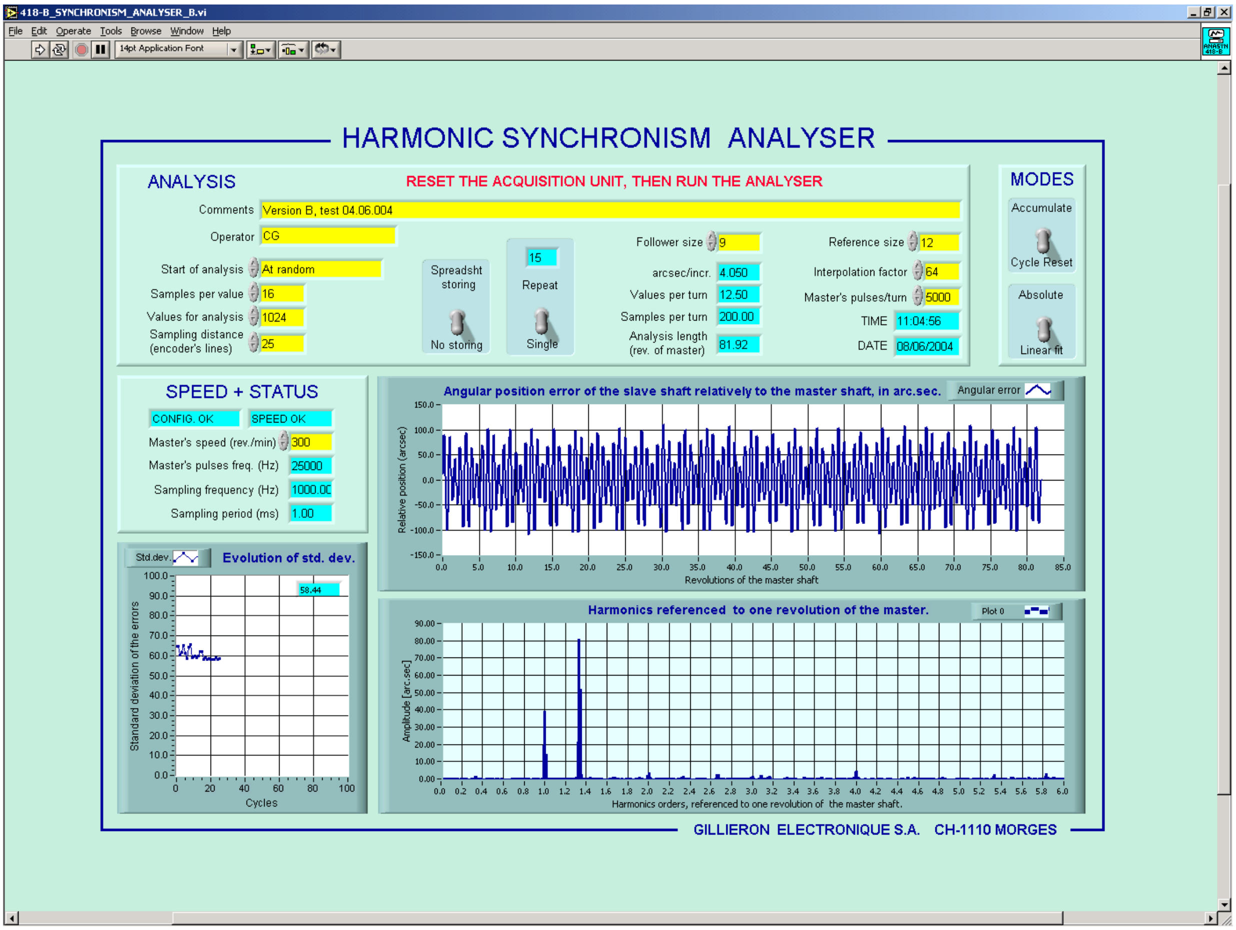
For that operating mode, the operator should run the synchronism analyser in continuous mode. For each measurement/analysis cycle, the screen refreshes the graphs of position and spectrum.

A new point of the standard deviation is added on the graph at each new measurement/analysis cycle.

By this way you can easily record a change of the quality of the synchronism, consecutively to a modification of the regulation parameters or mechanical adjustments.

An HELP function is provided with the software. It is activated by the "Help" command on the top of the screen.

When the HELP function is active, a description of the element pointed by the mouse is displayed on the screen.



On this example, the conditions of the measurements are as following :

- Incremental encoder : 5'000 lines.
- Interpolation factor : 64 -> 320'000 pulses per revolution of the reference.
- Sampling each 25 lines of the encoder -> 200 samples per turn.
- One value for display and FFT calculation is defined as the mean value of 16 samples. So, the sampling length of one value is : 16 * 25 lines = 400 lines of the encoder.
- Number of values : = 1024 values. (81.92 revolutions)

3.2.1 Measurement of a right angle gearhead.

To close this presentation, we show bellow the results of the analysis of a real case: the test of a right angle gearhead, mounted in a rotary printing press. This gearhead is formed of two conical toothed wheels, diam. of about 300 mm. and 33 teeth for each wheel.

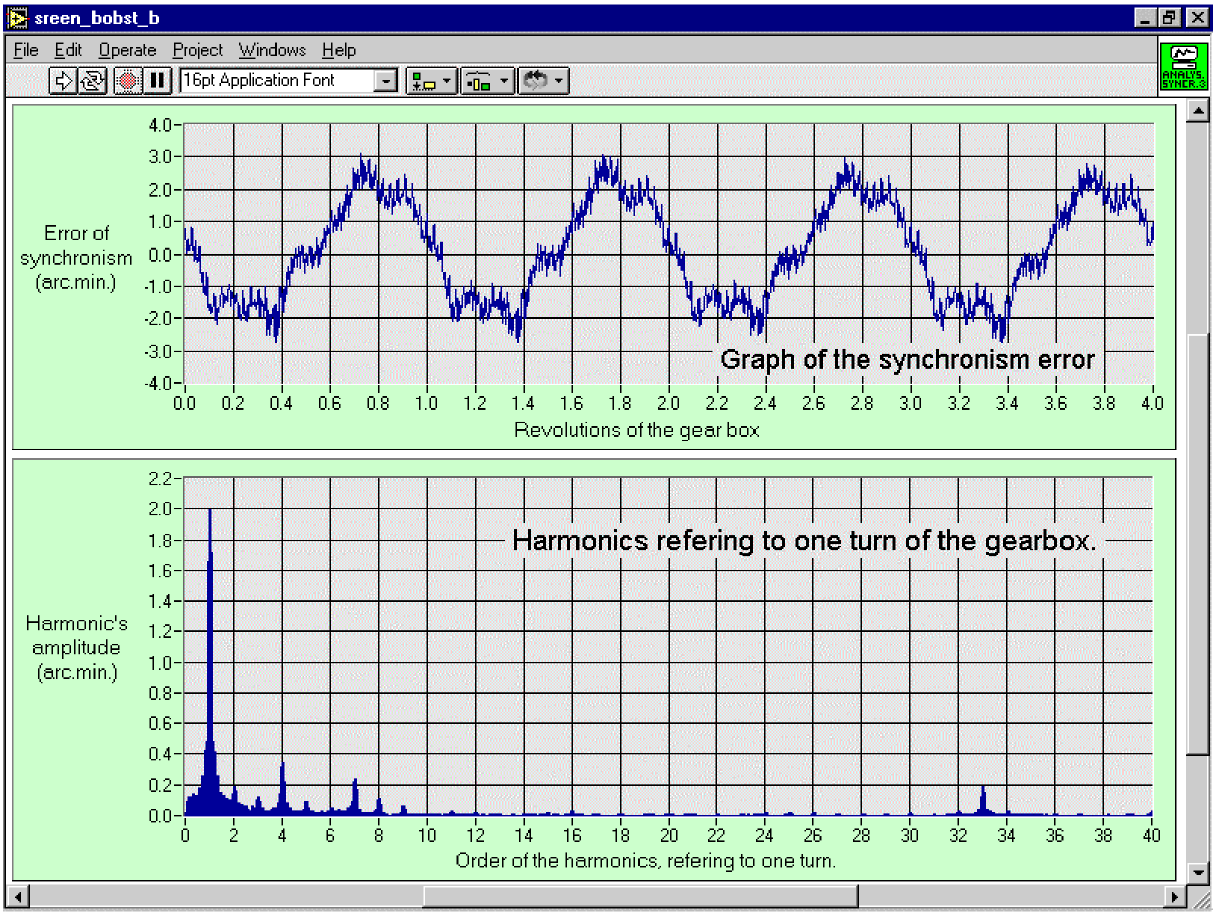
The screen is different of the present screen and was recorded with an ancient version of the analyser.

The total error is about +/- 3 minute of angle.

The main cyclic error is at "n = 1" : +/- 2.0 minute of angle.

The next important error is at "n = 4" : +/- 0,4 minute of angle.

Note the presence of the 33th harmonic corresponding to the number of teeth.



4 USER'S GUIDE

4.1 HARDWARE INSTALLATION OF THE ACQUISITION UNIT.

4.1.1 Connections of the encoder to the interpolator.

The acquisition unit is fitted for the Heidenhain encoders having an output voltage of 1 Vpp. The proper connectors are mounted on the front pannel. An adaptation cable makes the interface between the Heidenhain connector and the interpolator connector Dsub 15p.

For the details of this cable, see dwg 531-005A.SCH

	(8)	(7)	(6)	(5)	(4)	(3)	(2)	(1)	
O									**O**
	(15)	(14)	(13)	(12)	(11)	(10)	(9)		

Connector of the interpolator seen from front side.

Pin	Mnemo.	Function
1	GNDA	Analog ground.
2	SIN-	Input signal "sinus neg"
3	SIN+	Input signal "sinus pos"
4	COS-	Input signal "cosinus neg"
5	COS+	Input signal "cosinus pos"
6	IND-	Input signal "index neg"
7	IND+	Input signal "index pos"
8	GNDA	Screen.
9	Spare	
10	-15V	Power output -15 V / 100 mA.
11	GNDA	Analog ground.
12	+15V	Power output +15 V / 100 mA.
13	Spare	
14	+5V	Power output +5 V / 300 mA.
15	GNDD	Digital ground.

4.1.2 Replacement of an encoder.

If you replace an encoder, place the interpolator on a card extender and verify the following points :

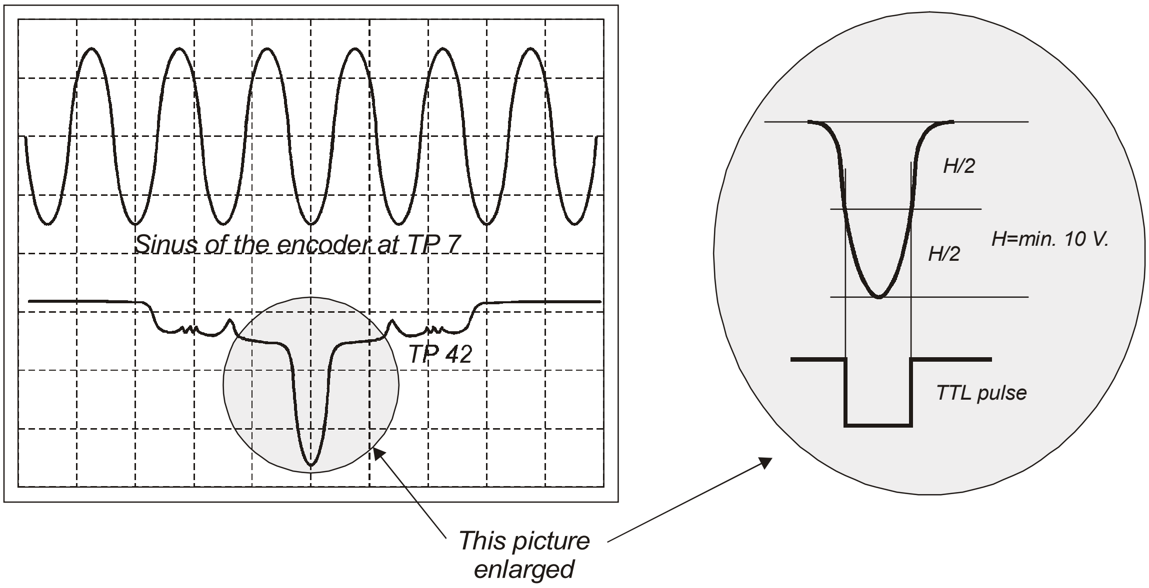
SINUS signal on TP7 and COSINUS signal on TP8. When the encoder is running, you must see 2 sinus signals in quadrature on TP7 and TP8. Both amplitude must be equal within 10 % tolerance.

See dwg : 531-009A, layout and schematics

Nominal range +/- 4 V. to +/- 9 V. (Peak to peak values).

4.1.3 Adjustement of the index (FOR REFERENCE SHAFT ONLY).

- For the REFERENCE only, adjust GAIN and OFFSET of the index to obtain at TP42 the figure as indicated on fig. 5 below. Check the digital pulse on the pin 24a of the 41612 connector.
(LED also flashing).



FOR THE INDEX OF THE REFERENCE INTERPOLATOR
Adjust the gain with P3 in order to have the proper amplitude
Adjust the offset with P2 in order to have the proper width of the TTL pulse

Fig. 5

Adjustment of the index pulse on the reference axis

4.1.4 Check of correct relative rotation.

- Connect the 2 shaft encoders..
- Connect the computation unit (PC) with a 9p Dsub cable. Non inverting.
- Adjust the transmission ratios of REFERENCE and FOLLOWER at the control screen of the analysis programm.
- Set the RELATIVE ROTATION selector to the left side
- Connect an oscilloscope with a BNC cable to the ANALOG OUTPUT. Sensitivity 5V/div. DC. Trigger mode AUTO. To obtain the best result, you sould add a small RC lowpass filter just at the input of the oscilloscope. Fq = 50 kHz.
  For instance : first order low pass with 1 kohms/3300 pF.
- Run the analysis programm
- Press the RESET button on the front pannel of the acquisition unit. The voltage of the analog output should be less than 0.1 V DC.
- Run the mechanism at low speed. The voltage of the analog output must remain about zero, with variations that indicates the deviation of the follower relatively to the reference.
- If not, reverse the RELATIVE ROTATION selector. Check again. Now, the voltage of the analog output must remain about zero.
- If not, verify the transmissions ratio of REFERENCE and FOLLOWER. Check again. Now, the voltage of the analog output must remain about zero.
- The hardware is ready for function.

4.2 WORKING WITH THE ANALYSER.

4.2.1 Normal mode versus mean mode.

We have 2 working modes : NORMAL and MEAN.

The basis unit for the analysis is the VALUE.

In NORMAL mode, a VALUE is just the sampled measurement of the mechanical deviation between REFERENCE and FOLLOWER. In MEAN mode, a value is the mean value of "n" samples.

The SAMPLING distance is the angular distance between 2 samples. The sampling unit is the "encoder's line number" of the REFERENCE. The sampling distance is specified by a control and is the same for all the sampling values during an analysis.

Largest sampling distance : 255.

The analysis length is calculated as :

Analysis length = (Sampling dist.)*(Number of values)*(number of samples per value).

The unit for the analysis length is the "revolution of the reference axis".

4.3 NORMAL MODE. Preparation for analysis.

In the NORMAL working mode, the system performs the analysis with "s" values of measurement, that are "s" samples equally spaced at a distance of "d" lines of the reference encoder.

Specify :

- **sampling distance "d".** This is the number of lines between samples. For example, if the encoder has 5000 lines per turn and if the distance of sampling is fixed to 25, you will obtain 5000/25 = 200 samples per turn.
- **Speed of the machine "n"**. This parameter is not used by the analyser for calculation, but just to display some useful informations for the operator.
- **Number of values "s".** Max. number of values is 4096. The number of samples is always a power of 2 (necessary for the FFT).
  In the normal mode, one value is also one sample.
- **Start of measurement.** Random or indexed.
  In the indexed mode, the measurement starts when the acquisition unit meets the index pulse of the reference axis.
  In the random mode, the measurement starts anywhere.

4.4 MEAN MODE. Preparation for analysis.

In the MEAN working mode, the system performs the analysis with "s" measurement.
Each measurement is the mean value of "m" samples equally spaced at a distance of "d" lines of the reference encoder.

The max. value of "s" is 4096.

The max. value of "m" is 64.

Maximum samples number of an analysis = 4096*64 = 262'144 samples.

As the largest sampling distance is 255 lines of the encoder, the max. length of the analysis is :

262'144 * 255 = 66'846'720 lines.

If the reference encoder has 18'000 lines, the analysis can reach 3713 revolutions of the reference.

Specify :

- **sampling distance "d".** This is the number of lines between samples. For example, if the encoder has 5000 lines per turn and if the distance of sampling is fixed to 25, you will obtain 5000/25 = 200 samples per turn.
- **speed of the machine "n"**. This parameter is not used by the analyser for calculation, but just to display some useful informations for the operator.
- **Number of mean values "s".** Max. number of samples is 4096. The number of samples is always a power of 2 (necessary for the FFT).
- **Samples per value.** The max. number of samples per value is 64. It is always a power of 2.
- **Start of measurement.** Random or indexed.
- In the indexed mode, the measurement starts when the acquisition unit meets the index pulse of the reference axis.
  In the random mode, the measurement starts anywhere.

4.5 BEFORE STARTING THE ANALYSIS.

Each device on the front panel of the software analyser has an HELP text. To display this text :

- With the mouse : Help - show help.

  Then simply place the mouse cursor on the device.

To remove the Help function :

- With the mouse : Help - don't show help.

With Labview is included a data logging function. You can store copies of the front pannels only. This feature is controlled by the function : Operate - Data logging - ...

Caution : the chart of the STANDARD DEVIATION OF ERRORS is not fully stored.

We have added a STORE function. If activated, the programm saves on disk the measured values of the analysis in a text file.

See the example of next page.

Before the start of analysis, you must introduce the working parameters in the following "controls" :

- Operator name.
- Start of measurement (Random or From reference index.)
- Number of samples per value.
- Number of values for analysis.
- Sampling distance.
- Interpolation factor.
- Number of pulses of the reference encoder.
- Speed of the reference axis.
- Store/Non store measurement files (.txt)
- Repeat/single.
- Absolute/linear fit.

4.6 RUNNING AN ANALYSIS.

- Introduce the working parameters in the "controls".
- Run the machine at the analysis speed.
- Press the RESET button on the front pannel of the acquisition unit.
- With the mouse, press on the Start control. (Square button, on the front pannel tool bar).
- In repeat mode, to stop the analysis, place the switch from REPEAT to SINGLE and wait until the analysis stop.

4.6.1 Maximum speed.

It is quite difficult to calculate the maximum speed of the analyser. The sampling frequency is coming from the REFERENCE encoder. The frequency of this signal is "wobulated" by several factors : speed jitter of the axis, distorsion of the electrical signal of the encoders, etc.

With a machine in a good mechanical status, the maximum frequency of the microsteps should be about 6,4 MHz.

So, the maximum speed of the reference axis should be :

4.6.2 Interpolation factor = 64

6'400'000 / (5'000 * 64) = 20 rev./sec. = 1200 rev./min.

4.6.3 Interpolation factor = 32

6'400'000 / (5'000 * 32) = 40 rev./sec. = 2400 rev./min.

4.7 HOW TO FIX THE PROPER TRANSMISSION RATIO.

The REFERENCE axis is defined as the axis running at the slowest speed.

Example of a practical case :

- Motor with pulse encoder 2048 pulses, driving a gearbox.
- The ratio of the gearbox is 62/10.
- The output of the gearbox is driving a cylinder with a pulse encoder of 18000 pulses
- The speed of the motor is 62/10 time faster than the speed of the cylinder.
- The interpolation factor is the same for both encoders : 64

One turn of the cylinder gives :

For the cylinder encoder : 18'000 * 64 = 1'152'000 microsteps.

For the motor encoder : 2048 * 62/10 * 64 = 812'646,4 microsteps.

Note that the frequency of the cylinder encoder is greater than the frequency of the motor encoder.
The axis having the lowest frequency is defined as the REFERENCE, that is the motor axis.

4.8 Calculation.

4.8.1 1) Calculate the fractional integer electrical ratio.

```
                                        2’048 * 62 * 64
The « real electrical ratio » is : ----------------------
                                       18'000 * 10 * 64
```

4.8.2 2) Make the simplification.

You must simplify to make numerator and denominator prime numbers between them.

```
    2’048 * 62 * 64    2'048 * 31    128 * 31     3968
------------------- = ----------- = -------- =  -----
   18'000 * 10 * 64    18'000 * 5    1125 * 5     5625
```

As said before, the frequency of the cylinder encoder is greater than the frequency of the motor encoder.

So, set the ratio for the cylinder to the value of 3968 (FOLLOWER)

So, set the ratio for the motor to the value of 5625 (REFERENCE)

4.8.3 3) Calculate the constants relatively to the cylinder.

Ratio for the follower (cylinder) : 3968/5625

Initial conditions of the measurements:
(One turn = 360 deg. = 1'296'000 arcsec.)
- incremental encoder : 18'000 lines.
- interpolation factor : 64 -> 1'152'000 pulses per revolution.
-> One increment = 1'296'000/1'152'000 = 1.125 arcsec.

As the ratio for the cylinder is 3968/5625, we have less microsteps.

```
                                            3968
Number of microsteps per turn : 1'152'000 * ---- = 767'250
                                            5625
```

-> One increment = 1'296'000/767'250 = 1.689 arc.sec.

4.8.4 4) Calculation of the analog voltage.

One microstep corresponds to one increment of the DAC.

12 bits -> 4096 points -> 20 volts.

-> One increment corresponds to 20'000/4096 = 4,88 mV

Final analog ratio : 4,88 mV for 1,689 arcsec = 2,88 mV / arcsec.

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