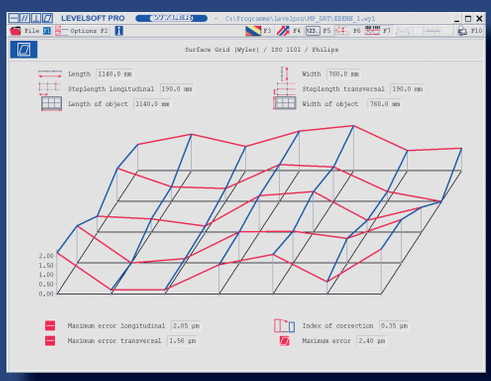
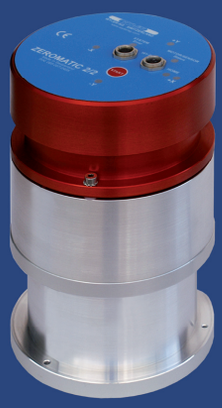
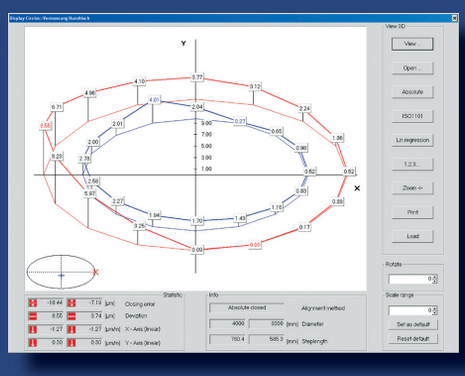
WYLER

QUALITY INCREASING BY USING HIGH PRECISION INCLINATION MEASUREMENT

In the focus: BlueSYSTEM - ZEROMATIC - MT-SOFT







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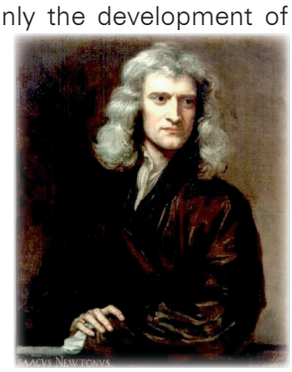
ilac-MRA SWISS CALIBRATION

Swiss Quality

QUALITY INCREASING BY USING HIGH PRECISION INCLINATION MEASUREMENT

WYLER AG has a tradition of more than 75 Years in the field of inclination measurement. Grace to the use of most modern technologies and the consequent development of new products WYLER AG has an international reputation as a leading company for inclination measuring equipment and systems. The product range starts from simple spirit levels to complex electronic measuring systems.

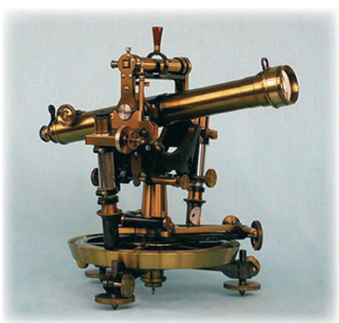
In ancient times angular measurement was used for construction of buildings, the layout of maps and naturally for navigation purposes at sea. The instruments were rather insufficient and only the development of new materials and manufacturing processes allowed to build more precise instruments. The manufacturing of the first Sextant in the Year 1727 according to ideas of Isaac Newton, the English physic and astronomer, and the production of the first Theodolyte by the physic Dollond in the Year 1760 are milestones in the history of angular measurements.



Sir Isaac NEWTON
1642 - 1727

Even today the technical life is unthinkable without the angular measurement. Especially in the quality assurance the inclination measurement, a special field of the angular measurement, is applied in all kind of different variations. An inclination measuring instrument is used for measuring angles as well as for measuring flatness of lines and surfaces. Also long term monitoring of angular deviation is a large field of applications.

The classic spirit level used for many Years by the engineers when constructing buildings, bridges or large machines is continuously replaced by electronic instruments. The main reason is, that these are more precise and reliable in different surroundings, supply more resolution, shorter reaction time and data for protocols and transfers.



Theodolyte von
W. & S. Jones / 1890

The latest development clearly tends toward inclination sensors used in a network of all kind of sensors where the measured data can be transmitted over short or long distance and supplied to a data collecting device such as a computer or a manual read out instrument (Levelmeter).

Milestones WYLER AG

1970 / The development of the first electronic inclination measuring instrument NIVELTRONIC was done in close co-operation with the company TESA in Renens, Switzerland. Still today this instrument is highly esteemed by a number of metrologists.

1977 / Development and introduction of the handheld instrument MINILEVEL "classic" A10 and the LEVELTRONIC "classic" A40, based on the capacitive measuring principle.

1995 / Presentation of the first inclination measuring sensor ZEROTRONIC, working completely on the digital principle together with the corresponding software DYNAM.

1996 / Development and introduction of the new generation of handheld precision measuring instruments MINILEVEL "NT" A11 and LEVELTRONIC "NT" A41 as successors of the classic series instruments.

1997 / Development and launching of the new type of handheld instrument named CLINO 2000 with integrated calibration possibility.

1998 / New development and marketing of the spirit level series "SPIRIT" with a completely new revolutionary adjustment system.

2000 / Development and introduction to the market of the Software LEVELSOFT PRO.

2005 / Development and introduction to the market of the new Software MT-SOFT for definition of machine tool geometry.

2005 / Development and introduction to the market of the electronic inclination measuring instruments BlueSYSTEM, with BlueLEVEL, BlueMETER and BlueTC.

2009 / Redesign of the two–dimensional precision inclination sensors with automatic reversal measurement ZEROMATIC 2/1 and 2/2

2010/11 / Development and introduction of BlueCLINO und BlueCLINO High Presision with wireless data transmission.

2011 / Development and introduction of BlueMETER SIGMA with wireless data transmission

WYLER AG combines sensors, precision measuring technology and system solutions in the field of inclination measurement. We produce added value through proven advanced technology and well-founded application know how.

1. INTRODUCTION

On all products, the requirements regarding quality and cost effectiveness and therefore on the manufacturing processes, are constantly increasing. In order to keep up with these requirements, new production methods and machines must be developed. At the same time the development of test methods and test equipment must be accelerated.

Since the foundation of the company in 1928, WYLER AG in Winterthur, Switzerland was eager to fulfill the demand of the market and to satisfy the worldwide clientele with the supply of high quality inclination measuring equipment.

The field of angular detection and measurement is extensive and complex. A great number of different instruments and processes have been developed to produce suitable results to fulfill the requirements, for instance; sine-bars, sine tables, theodolytes, autocollimators, laser interferometers etc. This brochure concentrates on the inclination measuring instruments and systems of WYLER AG.

This document is intended to give an overview of the development in the area of the inclination measurement of the past decades. The emphasis is on the newest products, requiring the most modern manufacturing technology, by using high tech materials and the application of microelectronics.

What is the resolution range of the WYLER inclination measuring instruments?

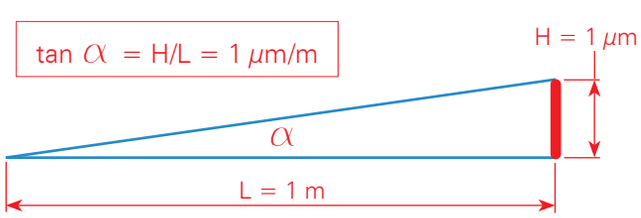
Besides the commonly used units, such as e.g.

- Degrees / Arcminutes / Arcseconds
- Radiant, mRadiant, μRadiant
- etc

Arcseconds and μm/m are used for very small inclinations. The latest generation of inclination measuring instruments and sensors has the ability to produce a resolution of <1 μm/m.

It is difficult to visualize an angle of <1 μm/m. By multiplying the length „L“ and the height „H“ with the factor 1000 the relations of the triangle remain intact. This means

1 μm/m is corresponding to 1 mm/km



2. APPLICATIONS AND OPERATIONAL AREAS OF INCLINATION MEASURING TECHNIQUES

The inclination measuring instruments and systems are widely used for „MEASURING / ADJUSTING / MONITORING“ (Overview see next page):

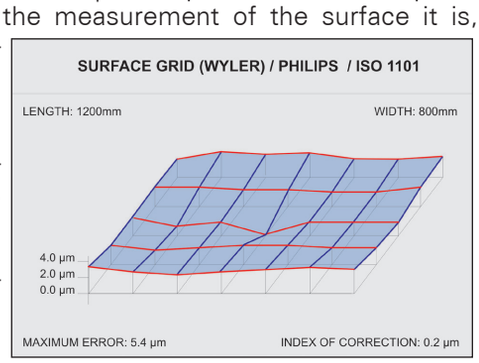
- Measurement of straightness and flatness of objects, e.g. surface plates and straight edges made of granite
- Measurement of machine tools; comparison of different measurements performed e.g. comparison between a horizontal guide way and a vertical spindle
- Measurement of printing machines and lineup support
- Calibration of industry robots
- Calibration of large radar stations
- Monitoring of objects such as bridges, dams, buildings etc.

The measuring instruments and system are getting more and more accurate. Despite the user friendly design and the well documented user guide the demands on the user are increasing. Considering this, it is quite clear that the training of the user in handling the instruments and systems is getting increasingly important. What's the use of an excellent instrument when this is not suited for the task?

Looking from the application's point of view three different options are basically available:

a. RELATIVE MEASUREMENT

Measuring the flatness of an object, such as e.g. a granite surface plate, it is quite important to set the plate horizontally. For the measurement of the surface it is, however, important to look only at the difference between the individual measurement steps. In other words it is for such a particular measurement of now importance to receive the result in an absolute value (deviation from centre of the earth). These measurements may be done comfortably with the software LEVELSOFT PRO. After the measurement the results may be analyzed and aligned according to different methods such as:



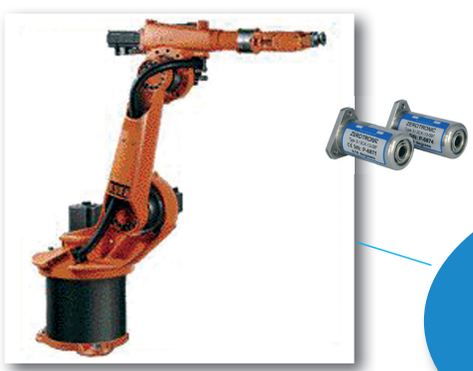
I. Alignment according to the method “Endpoints”
II. Alignment according to the method “ISO 1101”
III. Alignment according to the method “linear Regression”

APPLICATIONS WITH WYLER INCLINATION MEASURING INSTRUMENTS

Calibration

Monitoring dams

Monitoring of bridges



Measuring and calibrating
of industrial robots

Measuring and calibrating
of radar stations

MEASUREMENT
ADJUSTMENT
MONITORING

Measurement of high speed printing machines

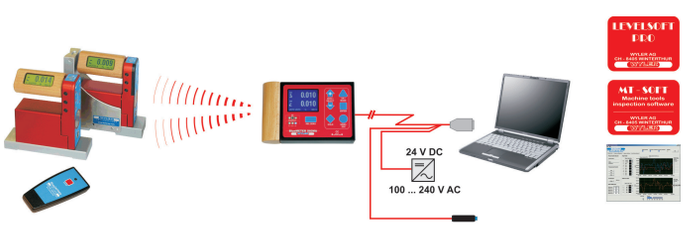
Measuring and adjustment of
machine tools

Measurement
of flatness

Monitoring of buildings

Especially well suited for such measurements are the WYLER handheld instruments MINILEVEL NT and LEVELTRONIC NT or the latest instrument's generation called BlueSYSTEM.

Here after you find a schematic view of a measuring set-up with two BlueLEVELs and a BlueMETER SIGMA linked to a PC or Laptop. Le software LEVELSOFT PRO is very suitable for the anylysis of the measuring results.

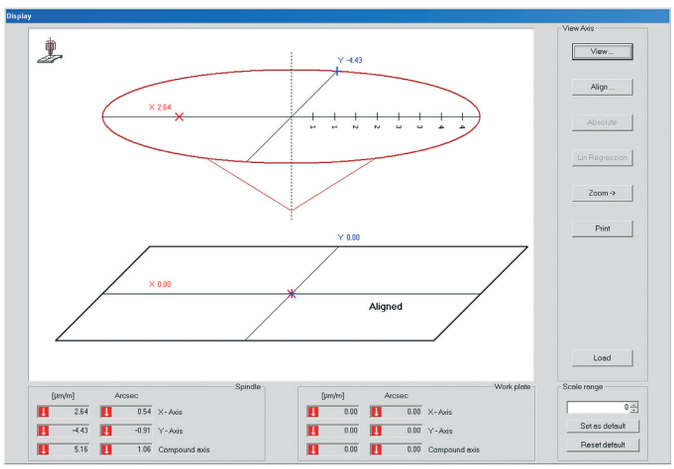


The measured data may be transferred wireless to a PC or Laptop. The data transmission is wireless from the instruments to the BlueMETER by using the Bluetooth™ wireless technology.

b. ABSOLUTE MEASUREMENT

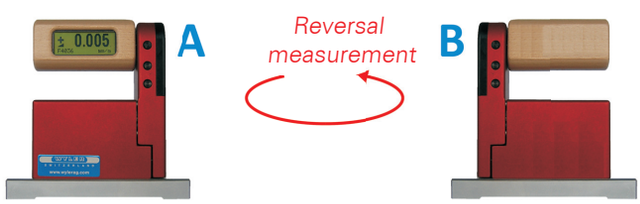
The monitoring of buildings, bridges and dams requires to measure the values in absolute mode.

Machine tool inspection is usually done by measuring in the absolute mode and best done with the software MT SOFT. By doing so the true position of the objects to be measured is determined. This measurement in the absolute mode is inevitable when e.g. a horizontal guide way must be compared with a vertical spindle of the same machine.



For measurements in the absolute mode a number of different inclination instruments and sensors are available.

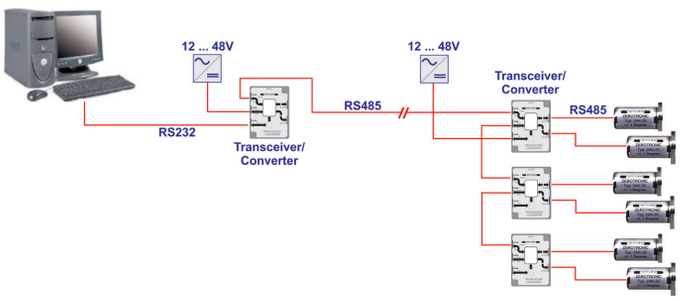
I. Handheld instruments MINILEVEL NT and LEVELTRONIC NT or the latest instrument's generation called BlueSYSTEM with wireless data transmission as described under "Relative measurements" are well suited for the measurements on machine tool elements. Due to the so called "reversal measurement" an integral part of the software LEVELSOFT PRO as well as MT SOFT, a possible zero point deviation of the measuring instruments may be determined and eliminated



before starting the measurement.

II. Also very well suited for the measurement in the absolute mode are the completely digitalized inclination measuring sensors ZEROTRONIC. An excellent linearity as well as a very good long term stability are the assets of these sensors. Because the sensors may be calibrated over a larger temperature range by applying up to 5 calibration curves, the sensors are also well suited for the use in a greater temperature range. The design of the sensor is in such a way that no permanent deformation or damage is done to the sensor cell even when heavy shock loads occur.

The sensors may be connected through a network to a PC or a Laptop for data collecting.



c. LONG-TERM MONITORING OF OBJECTS

Long-term monitoring with all kind of sensors also with inclination measuring sensors is generally influenced by various facts such as e.g.:

- Changing of temperature and humidity
- Vibrations and shocks
- Mechanical drift caused by stress in the materials and electronic components used
- Users manipulation

The long term stability is often named long term drift. For long term monitoring of machines, buildings, bridges etc. it is essential to use inclination measuring instruments with minimal zero point drift.

A number of possibilities exist today to reduce long-term drift respectively to increase the long term stability.

1. Aging

During the various production stages all the used electronic and mechanical components are subject to an aging process. Alternating mechanical and thermal treatment accelerate the natural aging process.

2. Use of material with similar expansion / temperature coefficient

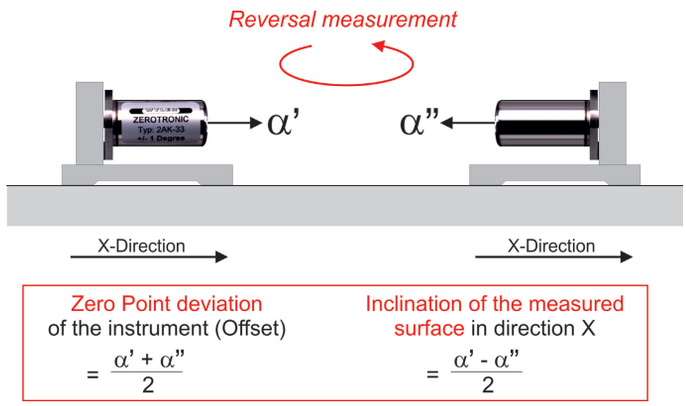
In order to reduce material stress caused mainly by temperature differences it is required to use materials with identical or similar expansion coefficient. In case this is not possible it is required to design the system in such a way that possible mechanical tensions do not have an impact on the quality of the measurement.

3. Temperature compensation

Most of today's inclination measuring sensors allow to compensate for temperature changes. Mostly the sensors are calibrated throughout the whole measuring range in a climate chamber under different temperature ranges such as e.g. -40°C, 0°C, +20°C, +40°C, +80°C. For a correct output signal the measured angular signal is interpolated by using different temperature curves saved in the sensor.

Today's requirements are such that the above mentioned provisions are in many cases not sufficient enough. The inclination sensors available with a measuring range of ±1Deg. can reach over a period of one year a limit of error of 5 Arcsec. +1.4 Arcsec/°C. This is usually for long term monitoring of outside objects exposed to large temperature changes definitely not good enough.

The inclination instruments and sensors are based on the principle of Newton's law of gravitation. Grace to the properties of this law it is easy to define the absolute zero point by applying a so called reversal measurement.



With such a reversal measurement the exact zero point deviation can be defined when ever needed and the instrument can be „calibrated" from new based on that. With this principle the so called automatic reversal measurement system ZEROMATIC was developed. With this system a detected zero point deviation will automatically be corrected and the future measurements will consider this correction.

The biggest challenge in the development was to solve the task of mechanical repetition reliability. The heart of the system are two inclination sensors positioned in the two axis X and Y which are delivering continuously the correct angle values. The system with a measuring range of ±1° has a limit of error, over a period of several month, of less than 2 µm/m!

This new measuring device has been tested intensively under all kind of conditions and has proven it's excellent performance.

The two dimensional inclination measuring sensors ZEROMATIC 2/1 and 2/2 was especially developed for high precision, long term monitoring of dams, bridges and building. The sensors are based on an automatic reversal measurement for determining and eliminating a possible zero point deviation as described before. The point of time, when such a reversal measurement should take place can be set by the user.

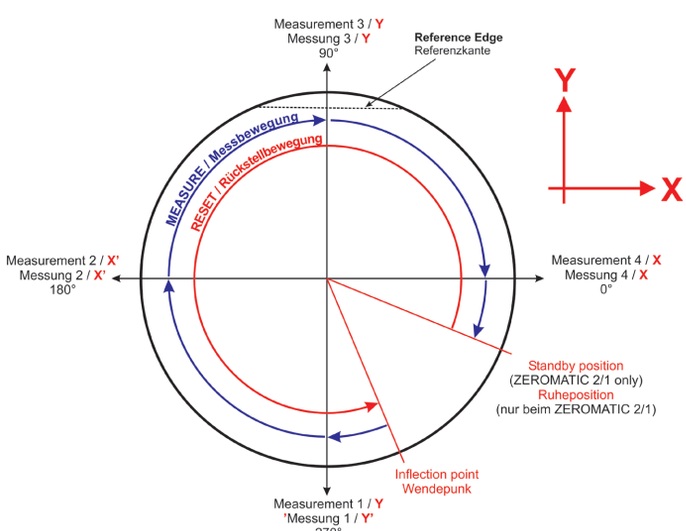
The difference between the two instruments are as follows:

ZEROMATIC 2/1 is equipped with one inclination sensor. Every reversal measurement results in a set of values in the X and the Y direction.

ZEROMATIC 2/2 is equipped with two inclination sensors. This allows to receive continuously values in the X and the Y direction. After a pre-set time an automatic reversal measurement is done in order to compensate a possible zero point offset.

ZEROMATIC 2/1 with one inclination sensor,
ZEROMATIC 2/2 with two inclination sensor

The graph below illustrates the procedure of the periodically performed reversal measurement. The time for such a reversal measurement takes maximum 2 minutes. The point of time, when such a reversal measurement should take place can be set individually.



Monitoring and analysis of the measured values by means of LabEXCEL WyBus

Typical applications are:

- Monitoring of critical machinery (Synchrotrons)
- Monitoring of Buildings, bridges, dams
- Defining an absolute zero angle reference value e.g. for a radar

The instruments have the following features:

- LED's showing the actual status of the instrument
- LED's showing the position of the sensors during the reversal measurement
- Rugged, precisely machined aluminum housing to avoid any outside influences
- The Instrument can be connected directly to a PC
- Optional connection to an Levelmeter 2000
- Optional connection via a network using TCP/IP protocol

Monitoring of Synchrotrons

3. HOW DO THE DIFFERENT INCLINATION MEASURING INSTRUMENTS FUNCTION?

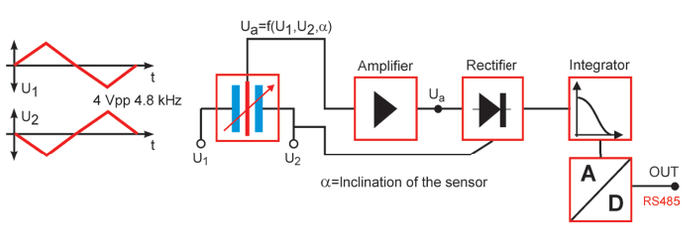
Besides the field of application a difference can be made in the principle of measuring. Two measuring principles are used, the analogue and the digital principle.

I. The analogue measuring principle

In the family of the handheld instruments MINILEVEL, and LEVELTRONIC NT as well as in the new generation „BlueSYSTEM" the capacitive measuring principle with an analogue signal and partially a digital signal treatment is applied.

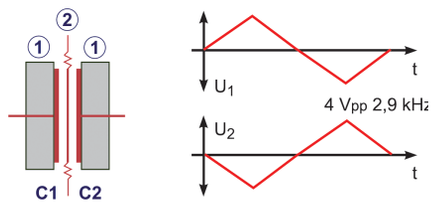
These levels base on the measuring values on the pendulum properties of a friction free supported disc of mass weighing less than 1 gram. A two-phase frequency (2.9 kHz) is supplied to two electrodes, which together with the pendulum disc supported in the shielded and dust proof gap between them, build a differential capacitor. The inclination signal is created at the pendulum. Due to the perfect rotational symmetry of the sensor, inclinations perpendicular to the measuring axis are of insignificant influence to the measurement, even overhead measurements are possible. The shielded sensor and the capacitive measuring principle make the system insensitive to magnetic and electric fields.

With this pendulum system extremely accurate results regarding repetition and hysteresis combined with very short reaction times has been achieved.



Schematic of an analogue measuring principle

Depending on the inclination of the measuring instrument the voltage of the output signal changes accordingly in a range of ±2000mV. As an alternative the output signal is also available in the format RS485 at a Rate of 9600 Baud.



II. The digital measuring principle

The digital measuring principle is incorporated in the ZEROTRONIC sensors and in the instruments +CLINOTRONIC PLUS+ as well as in the CLINO2000.

Similar to the analogue measuring principle the pendulum, suspended by the Archimedes helical spring, is mounted between two electrodes. Depending on the inclined position of the system, the pendulum will swing out of the zero-position and by that, changing the capacity between the pendulum and the two electrodes. These capacities will be transformed into different frequencies through the RC-oscillator. The ratio of the two frequencies available will be used as the primary signal for detecting the required angle. (The system is patent protected in most countries)

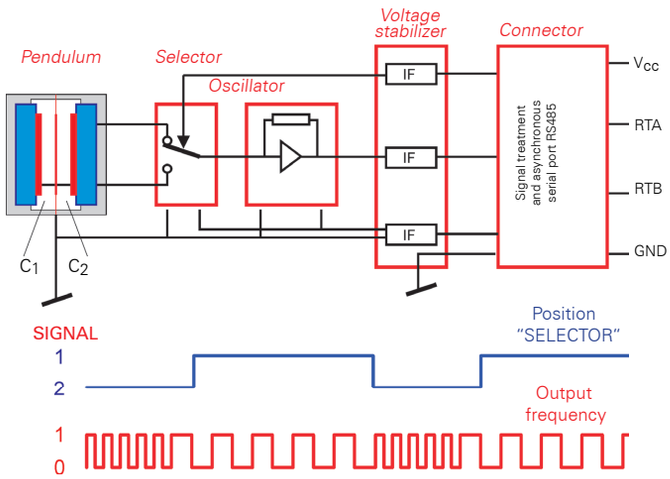
Ideally the mechanical dampening of the pendulums movements is done by gases. The viscosity changing of gases in the temperature range between -40°C and +70°C are marginal. Therefore the dampening with gases is superior to dampening with other substances like e.g. liquids. The best possible results in dampening are achieved in the optimized ratio between the surface of the pendulum to the aperture of the Archimedes helical spring. In addition mathematical smoothing can be done by integrating the results over a period of time. This is possible in a great variety by adjusting the individual parameters.

Sensors ZEROTRONIC

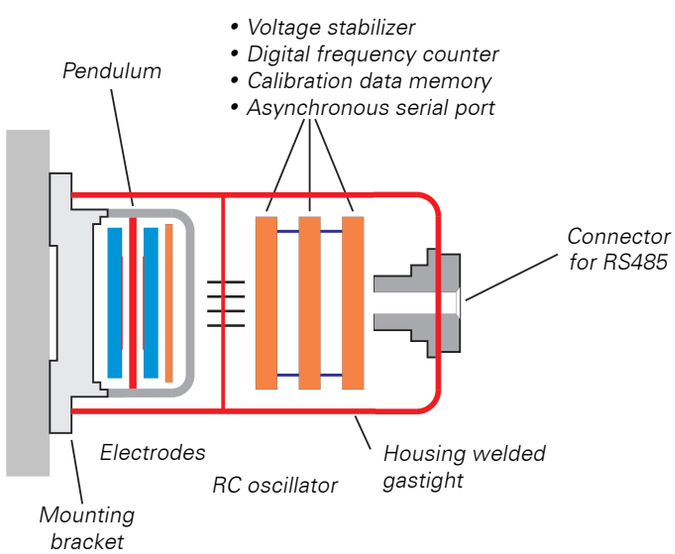
CLINOTRONIC PLUS

CLINO 2000

Measuring instruments with a digital measuring principle



Schematic of an digital measuring principle



Axial section of the ZEROTRONIC sensor

4. ANALYZING THE MEASURING RESULTS

A number of special software are available to properly analyze the measuring results.

- **LEVELSOFT PRO**
  The following measurements can be performed with the Software LEVELSOFT PRO for Flatness and Geometry Measurements:

  - Lines (Straightness)
  - Parallelism
  - Measuring the Flatness of surfaces
  - Squareness

- **MT-SOFT** / Machine Tool Inspection Software
  With this software it is possible to measure, protocol and compare various elements, components and assemblies of a machine tool.

  - All kinds of horizontal and vertical guide ways
  - Rotating axis e.g. Definition of the rectangularity between the surface of a machine table and the vertical spindle.
  - Rotation of machine elements: Measurement of geometry error PITCH and ROLL
  - Circles: Flatness and position of a circular area. Deviation from the true vertical X and Y-axis.
  - Surfaces: Flatness measurement of surfaces and comparison of the position of various surfaces (co-planarity)
  - LEVELSOFT PRO
  - Comparison measurements

- **DYNAM** / The measuring software for ZEROTRONIC sensors
  The software DYNAM was developed for the computing and the graphical display of measured inclinations of static as well as slightly moving objects. With DYNAM all sensors and instruments of the ZEROTRONIC family can be operated.

- **LabVIEW** of National Instruments
  For all the WYLER measuring instruments and interfaces the basic VI's (Virtual Instruments) will be provided to the customers free of charge.

POWERED BY NATIONAL INSTRUMENTS LabVIEW

Details of MT-SOFT im Detail

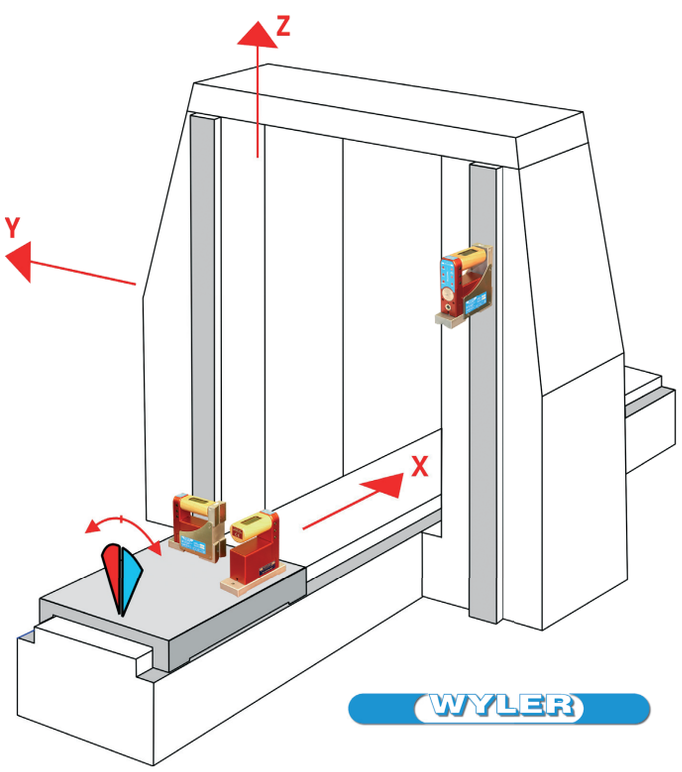
MT-SOFT
(Machine Tools Inspection Software)

Software for the definition of machine tool geometry

For a highly skilled, specialized mechanic with a long time experience it was quite clear how and where he was supposed to measure a machine tool in order to take the necessary corrective action, mostly by mechanical adjustment and by scraping. The objects machined today are getting more and more complex and the quality requirements are increasing constantly. This situation has called for larger, more powerful and more complex machine tools with the respective requirements for higher accuracy. The geometry checking of a machine as a fundamental pre-condition for a high quality machine tool brings the test personal and the classically used instrumentation to their limitation.

A number of methods are presently available for the determination of the total system error of a machine. It is, however, very demanding to find the existing source of the possible errors in order to make the necessary corrections.

The major goal for developing the software MT-Soft was exactly to fill this gap and supply the engineer with a tool with which he can take the necessary measurements and actions not only in the early stage of the manufacturing process of a new machine tool but also during the final assembly and the maintenance and repair phase.

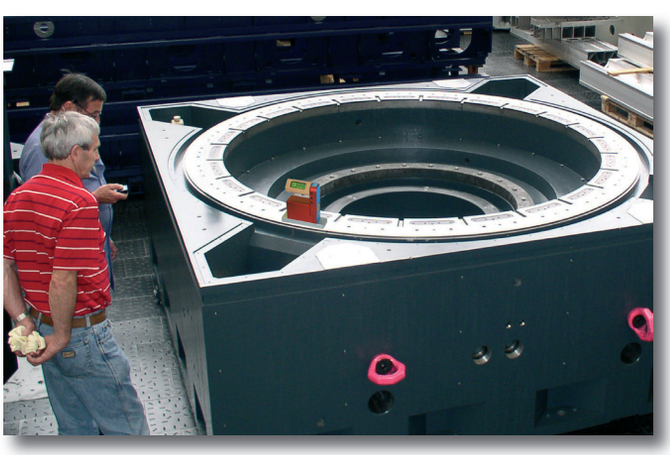


The newly developed software MT-Soft allows to measure independently various geometrical elements of a machine with standard inclination measuring instruments. The individual measuring results can be saved and consolidated spatial on demand for the conclusion of the total error of the machine. A simple example of the great variety of the possibilities of the software is e.g. the measurement of the vertical spindle in relation to a horizontal guide way of a machine tool.

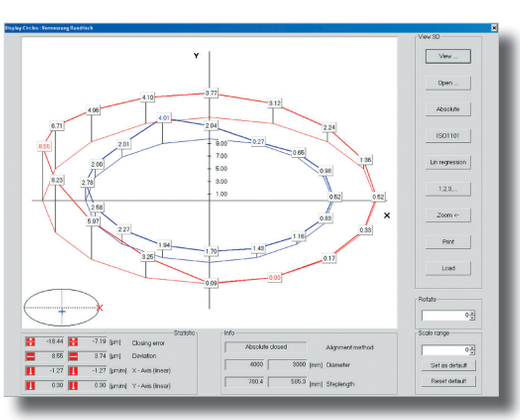
The logical layout and the clear structure of the software allows to dare to go to more complex and demanding measuring tasks.

Who is to benefit from this software?

- Machine Tool manufacturers of complex and precise machines
- Engineers who have to install and adjust machine tools at the customers premises
- Users of machine tools who have to check and correct periodically the geometry of the machines



Flatness and angular deviations of circular horizontal paths



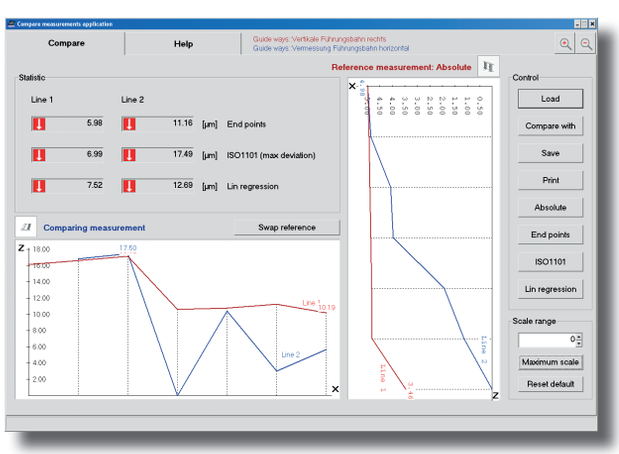
User friendliness

- Measuring templates with the exact definition of the measurement layout, the instruments used and the jigs applied have to be defined only once and can be re-used for future measurements
- Clear and easily understandable graphical presentation allowing the assessment of errors on individual geometrical elements
- Corporate identity: Users or owners company logotypes can easily be added to the protocols
- Each measurement is documented and each document is clearly assigned to one specific geometrical element of the machine
- If required only a short report can be printed
- Operator guidance and print-outs in several languages are possible

Comparison of Measurements (Applications)

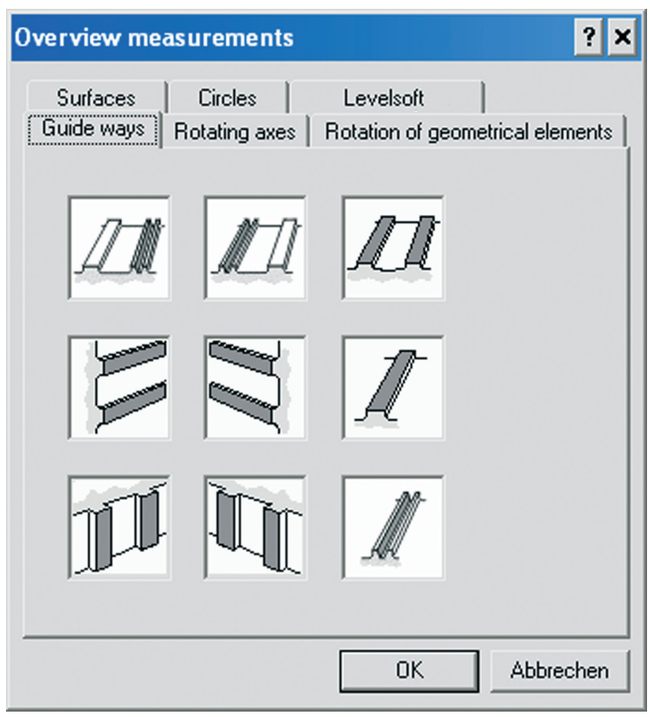
In order to allow a comparison of several individual measurements, e.g. a horizontal guide way in relation to a vertical spindle, each measurement has to be carried out in "absolute- mode". The software will guide the user to carry out a reversal measurement prior to each measuring task to determine the exact zero point of the instrument.

This procedure is part of the software and the measuring values are then calculated taking the offset into account.



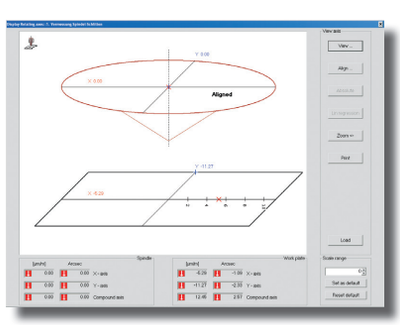
What can be measured with the software MT-SOFT?

- All types of horizontal and vertical guide ways



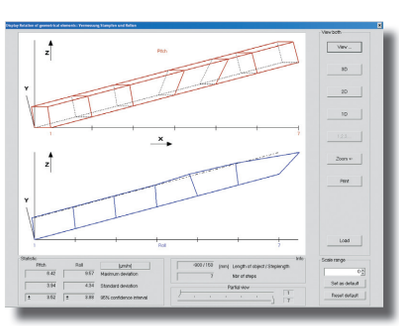
- Rotating axis, e.g. rectangularity between the horizontal surface of a working table and a vertical spindle

Rotating axis

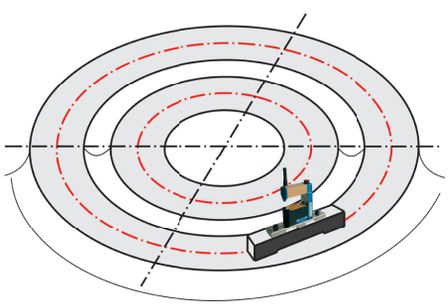


- Rotation of machine tool elements: PITCH and ROLL

Rotating machine elements

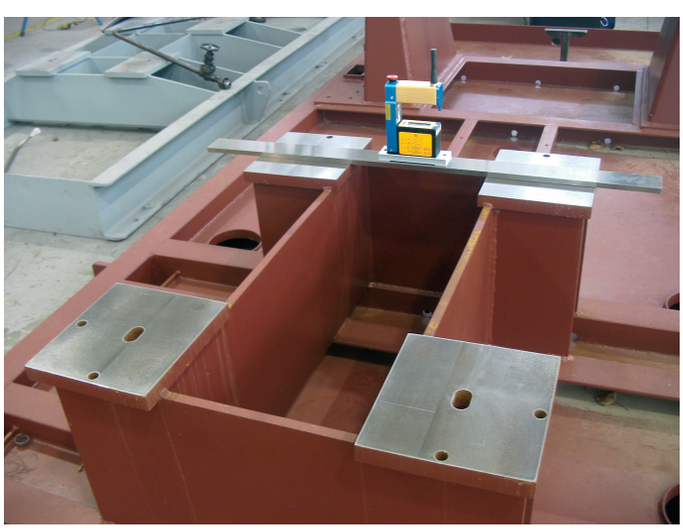


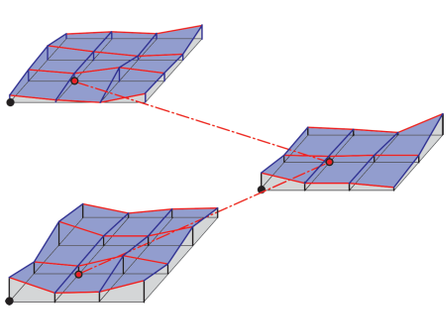
• Circles: Flatness and angular deviations of circular horizontal paths



Circles

• Partial surfaces: Flatness and relative position of several independent surfaces (co-planarity)





Partial surfaces

Example of a measuring result MT-SOFT

The lower left graphics shows the result of the measurement of the circular bearing support of a turning table. Besides the flatness of the inner and the outer circle there is an indication of perpendicular error of each circle to the z-axis as well. The number of numerical values shown can be chosen.

The lower right graphics shows the same measurement in a „cross section view".

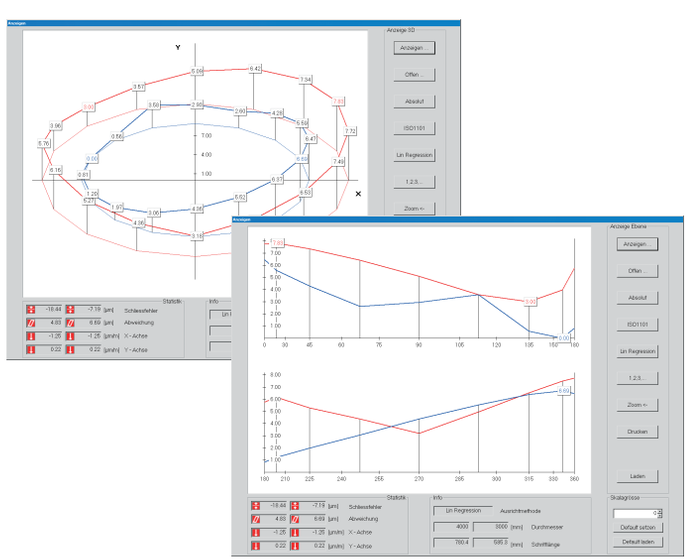
The results can be printed either as a short report with minimal information on measuring values and the perpendicular error or as a detailed complete report.

All measurements are saved in a data base. Due to this data base and due to the fact that all measurements are taken in the absolute measuring mode it is possible to compare different elements of a machine tool, even at a later stage. This means e.g. that the squareness between the X- and the Y-axis of a horizontal guide way and the vertical spindle can be compared.

The measurements can later be analyzed according to various points of view. Depending on the setup the following alignment methods are available:

- Alignment method ABSOLUTE
- Alignment method according to END POINTS
- Alignment method according to LINEAR REGRESSION
- Alignment method according to ISO 1101

All the above alignment methods are described in detail in the manual. All relevant WYLER measuring instruments are compatible with MT-Soft. Nevertheless for the measurement of machine elements the use of instruments with wireless transmission has proven to facilitate the task substantially, making them the instrument of choice!



SYSTEM REQUIREMENTS for MT-SOFT

- Microsoft Windows 98 / NT / 2000 / XP
- Pentium III
- Minimum 32 MB RAM
- Graphic card 800x600 pixel
- CD-ROM
- Hard disk with minimum free space of 50 MB
- Sound card is an advantage

SCOPE OF DELIVERY

Scope of delivery:	P/N / Art. Nr.
Software **MT-SOFT Full version** inclusive Levelsoft PRO	**024-MTSOFT-1**
Modules:	
Basic package including database, and the module for guide ways and rotating elements	*)
Circles	*)
Partial surfaces	*)
Rotation of machine elements	*)
Levelsoft as part of MT-SOFT	*)

*) MT Soft has a modular structure

When ordering MT-Soft the required modules have to be specified

Download Software and Upgrades / Updates

MT-SOFT Software can be downloaded from the page www.wylerag.com. Since the software is modular the assigned license key will only allow the use of the purchased modules. The procedure to install the license key is very well defined in the manual. Whereas updates are always free of charge and can be downloaded from the homepage, for upgrades to new modules a new license key has to be purchased and installed.

Test license

Through your local WYLER distributor you can apply for a time limited testing license of MT-Soft. When purchasing the software afterwards you just have to install the new license key and you can keep the values already measured.

SOFTWARE „LabEXCEL“

„LabExcel“ is a simple to use software to display measured values with the WYLER inclination measuring instruments and sensors. The software is based on the LabVIEW platform of National Instruments. The heart is the WYLER software module WyBus developed for the communication between the instruments respectively sensors and the software LabVIEW. The measured results can be transferred continuously to an Excel Spreadsheet for further treatment.

Up to 10 inclination measurements or sensors can be monitored simultaneously with „LabExcel“. In addition it is possible to measure the difference between any two different instruments or sensors.

Precondition for the software installation of “LabExcel” is:

- Windows XP or higher
- Microsoft EXCEL, minimum version 2003
- Framework 2.0 (Microsoft .NET Framework 2.0) Download via {Windows-Update} or from the enclosed CD_ROM
- 20 MB free harddisk space

As a new feature each instrument CLINOTRONIC PLUS will be delivered with the software „LabEXCEL Clino“. This software allows the reading of up to two instruments into a PC or Laptop.

The software „LabEXCEL Clino“ is based on the software „LabEXCEL WyBus“ described above.

For additional information on instruments, sensors, display units and software please refer to the homepage of WYLER AG

http://www.wylerag.com

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