Compendium

THE SECRETS OF INCLINATION MEASUREMENT

WYLER AG, Inclination measuring systems

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Preface

There are already a great number of reference books on the topic of measuring techniques – so why the need for a book on inclination measuring technology?

The title of this book "The Secrets of Inclination Measurement" addresses the essential point: Inclination measurement holds a niche position within the field of metrology. The potential of this measuring technology remains largely unmet since it – and the implementation and interpretation of measurements for quality improvement – continue to be areas about which far too little is known. This remains the case despite the fact that inclination measurement has recently been employed in an expanding range of new applications. These range from high-precision measurement of machine tools through to the precise alignment of high performance machine components during assembly, and the long-term monitoring of dams.

At the same time, the requirements of machine tools, industrial robots, aircraft, and dams in terms of quality, precision, safety, and efficiency are continuously increasing. This requires ever better and more modern fabrication machines and processes, as well as more reliable inspection processes and monitoring systems. In order to keep pace with this development, measurement and inspection instruments need to be continuously improved.

Since 1928, Winterthur-based WYLER AG has dedicated itself to meeting these requirements and supporting its clients in their measuring duties through user-friendly, high-precision inclination measurement devices and systems.

The aim of this book is thus to provide readers with a better understanding of the principles and terminology of inclination measurement, and to therefore assist them in the use of inclination measurement tools so that they can carry out their measurement tasks in an optimal manner.

Who is this book intended for?

This book is intended as:

- an accompanying document for training in inclination measurement
- a reference guide for the user
- a compendium for students of metrology

This primer is dedicated to the employees of WYLER AG, its partner firms around the world, its clients and product users, as well as those studying metrology.

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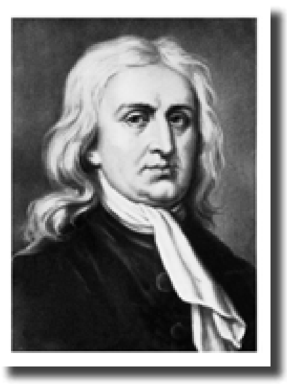
1. General introduction to inclination measurement

1.1 History of inclination measurement

Inclination measurement was used already in ancient times
- for the construction of buildings
- for the creation of simple city maps
- for navigation at sea

Sextant

The use of new materials and working methods allowed the development of new and more accurate inclination measuring instruments
- 1727 the first sextant was built according to Isaac Newton's designs
- 1760 the first theodolite was made by the physicist Dollond

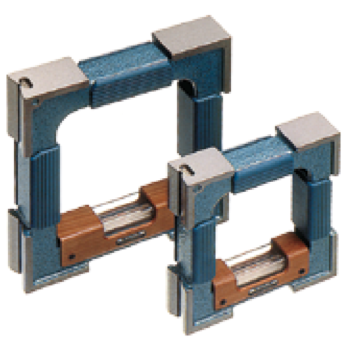


Sir Isaac NEWTON
1642 - 1727

Especially in the field of quality assurance, inclination measurement is applied in various different forms
An inclination measuring instrument is used for:
- measuring an inclination
- measuring the straightness of a line, e.g. of a machine guideway
- measuring the flatness of a surface
- long-term monitoring of objects

The classic spirit level is increasingly being replaced by electronic inclination measuring instruments due to higher requirements of precision, resolution, sampling time, reliability, data storage, and documenting.

The latest development clearly tends towards inclination measuring sensors bound in networks with the possibility of data transmission over short and long distances and collected in appropriate units such as computers and display units (Levelmeter, BlueMETER, BlueMETER SIGMA).



Classic precision spirit levels are increasingly being replaced by modern electronic inclination measuring instruments and sensors.

Classic precision spirit levels and Clinometers

Modern electronic inclination measuring instruments and sensors

1.2 What is inclination?

The expression "ANGLE" is defined as the divergence between two straight lines g_1 and g_2 in a flat plane. The angle δ is created at the cross section between the two lines g_1 and g_2.

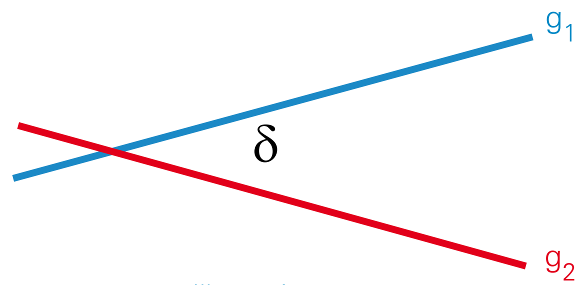


Illustration 1

INCLINATION is a specific, position-dependent angle whereas we distiguish between an absolute inclination and a relative inclination. The absolute inclination (illustration 2) corresponds to the angle α between the straight line g_3 and the horizontal straight line g_4, whereas the horizontal line g_4 lies in the intersection between a vertical plane E_1 and the horizontal (reference) plane E_2, which must be absolutely horizontal.

The relative inclination (illustration 3) corresponds to the angle β between the straight line g_5 and the straight line g_6, whereas both lines have to be in the vertical plane E_1.

The following illustrations 2 and 3 clarify the difference:

Illustration 2

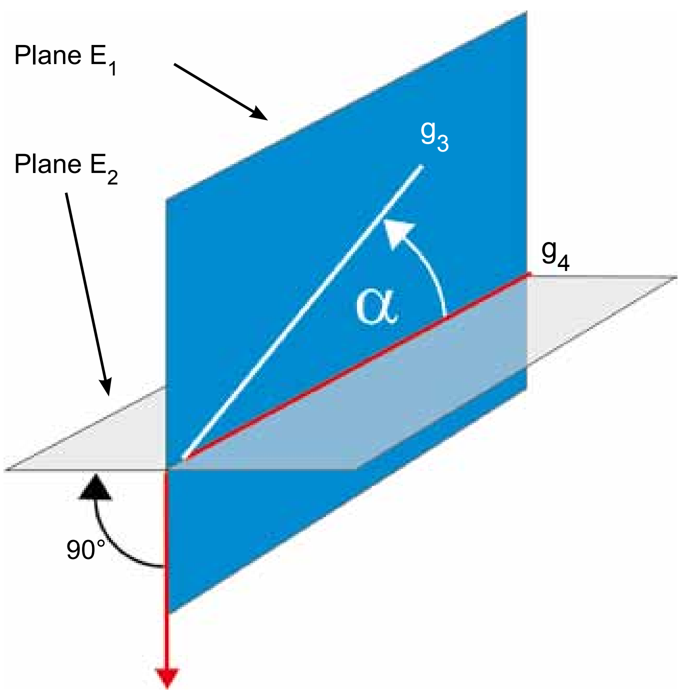
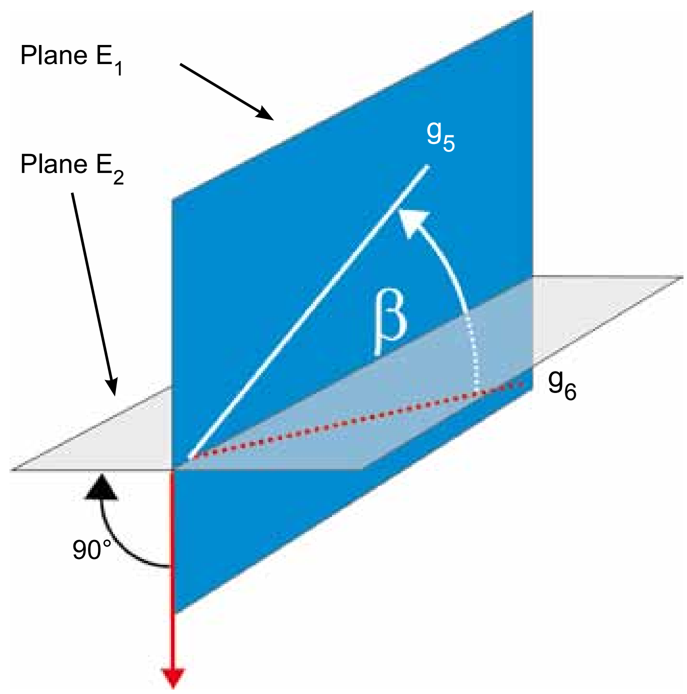


Illustration 3



Absolute inclination

An absolute inclination corresponds to the angle α between two straight lines, whereas one of these lines lies in the intersection between a vertical and the horizontal (reference) plane that must be absolutely horizontal.

ABSOLUTE INCLINATION α between the line g_3 and the horizontal zero baseline g_4.

- [Degrees / arcmin / arcsec]
- [Rad], [mRad], [μRad],
- [mm/m], [μm/m]

Relative inclination

A relative inclination corresponds to the angle β between two straight lines, whereas both lines have to be in a vertical plane.

RELATIVE INCLINATION β between the line g_5 and the line g_6.

- [Degrees / arcmin / arcsec]
- [Rad], [mRad], [μRad],
- [mm/m], [μm/m]

1.3 Units in inclination measurement

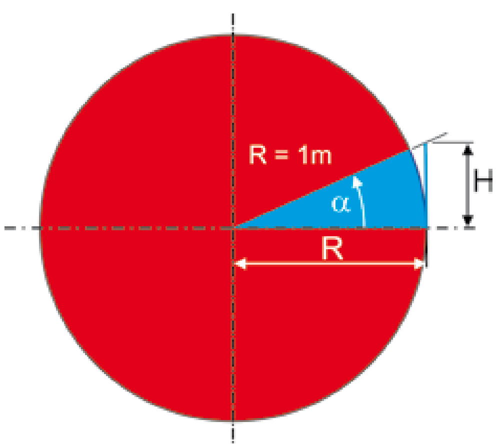
For large inclinations from 5...10 degrees the following units are normally used:

• x.xx Rad	radian
• xxxx.xx mRad	milliradian
• xxx.xxx° DEG	degree
• xxx° xx' DEG	degree / minutes
• xx° xx' xx" DEG	degree / minutes / seconds
• xxx.xxx GON	gon
• xxxx.xx A‰	artillerie-permille

For smaller inclinations up to 5...10 degrees the following units are normally used:

• xxx.xxx mm/m	mm per m (μm/m)
• xx.xxxx "/10"	inch per 10 inch
• xx.xxxx "/12"	inch per 12 inch
• xxxx.xx mRad	milliradian
• xxxx.xx μRad	microradian
• xxx.xxx mm/REL	mm in relation to the relative base
• xx.xxxx "/REL	inch in relation to the relative base
• xxxx.xx ‰	permille
• xxxx' xx" DEG	minutes / seconds
• xxxxx.x" DEG	seconds
• xxx.xxx GON	gon

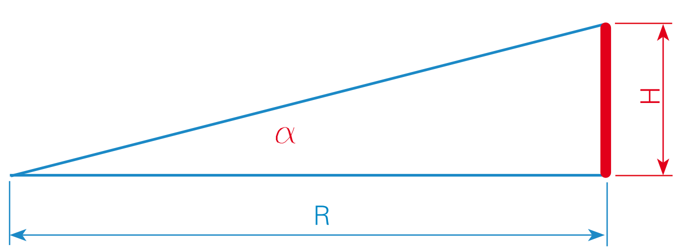
1.4 Relationship between Degrees/Arcmin and μm/m



With an inclination measuring instrument not only an inclination can be determined but also, related to the base length of e.g. 1 m, the heights of a point (topography of a surface) may be defined. This fact and the simple use of an electronic inclination measuring instrument allows the efficient measuring of machine tool guideways and surfaces in the range of micrometers.

In our example, the inclination α is expressed as a height H in relation to base length R, which is represented by one meter. The corresponding trigonometric function between the height H and the base length R is tangent.

INCLINATION α defined as a height "H" related to base line "R", for instance in [mm/m] or [μm/m]



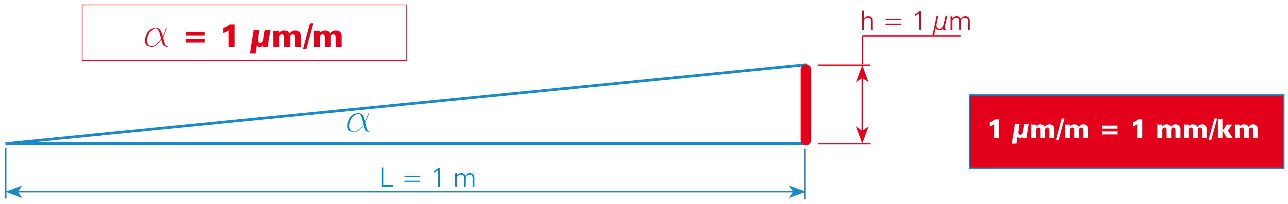
Trigonometric function:
*Height "H" = base line "R" * tan α*

Assumption: inclination α = 1 arcsec

Height "H" = Height "R" * tan α
Height "H" = Height of 1m * 0.000004848
Height "H" = 0.000004848 m = 4.848 μm

Accordingly, an inclination of 1 arcsec corresponds to an inclination of 4.848 μm/m

1.5 What is a µm/m?

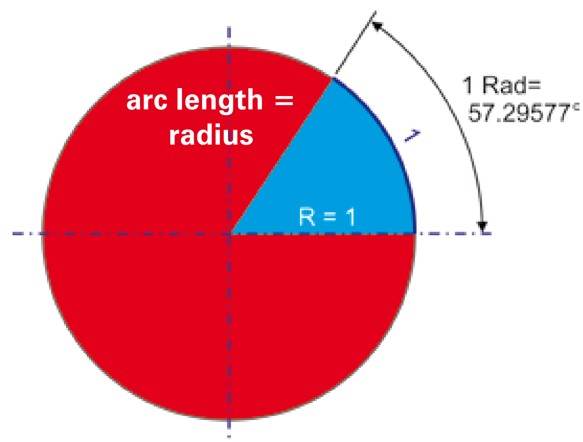


It is quite difficult to imagine an inclination of the size of 1 µm/m. Using a small mathematical relation it becomes more imaginable. By multiplying the baselength "L" and the height "h" by a factor of 1000, the relation remains the same, L=1km and h=1 mm (1 mm/km). This way, it is much easier to imagine an inclination of 1 µm/m. As an illustration, a human hair has a diameter of **50...70 µm**.

1.6 What is a Radian?

The radian is the standard unit of angular measure, used in many areas of mathematics. It describes the plane angle subtended by a circular arc as the length of the arc divided by the radius of the arc. The unit radian is considered an SI derived unit. One radian is the angle subtended at the center of a circle by an arc that is equal in length to the radius of the circle.

As stated, one radian is equal to 180°/π degrees, therefore:
1 Rad = 360° / 2π = 180° / π = **57.29577°**
1 mRad = 0.05729° = 3' 43,77"
1 µRad = 0.206" = ca. 1 µm/m



The unit radian (symbol: Rad) has the great advantage that this unit can be used from 0 to 360°. Also for the processing in the analysis software, this unit has great benefits. It is obvious that the processing of a single number is easier than processing units such as degrees / minutes / seconds. The conversion to other units is carried out via mathematical libraries that are part of the application software.

For the output of values at the instruments and interfaces like digital display, transceivers/converters and so on WYLER AG, always used radians [Rad]. The conversion in the desired unit is available in the display device or software.

Important: 1 µRad = 1 µm/m is only valid in the range of very small inclinations (angles)!

1.7 Correlation between the most common units (SI)

	µm/m	mm/m	arcsec	arcmin	degree	mRad	Rad
1 µm/m →	1	0.001	0.20627	0.00344	$5.730\ 10^{-5}$	0.001	$1\ 10^{-6}$
1 mm/m →	1,000	1	206.265	3.43775	0.0573	1	$9.99\ 10^{-4}$
1 arcsec →	4.848	0.00485	1	0.01667	$2.778\ 10^{-4}$	0.00485	$4.848\ 10^{-6}$
1 arcmin →	290.89	0.29089	60	1	0.01667	0.29089	$2.909\ 10^{-4}$
1 degree →	17,455.1	17.46	3,600	60	1	17.45	0.01745
1 mRad →	1,000	1	206.26	3.43775	0.0573	1	0.001
1 Rad →	$1.557\ 10^{6}$	1,557	206,264.8	3,437.75	57.3	1,000	1

Important: 1 µRad = 1 µm/m is only valid in the range of very small inclinations (angles)!

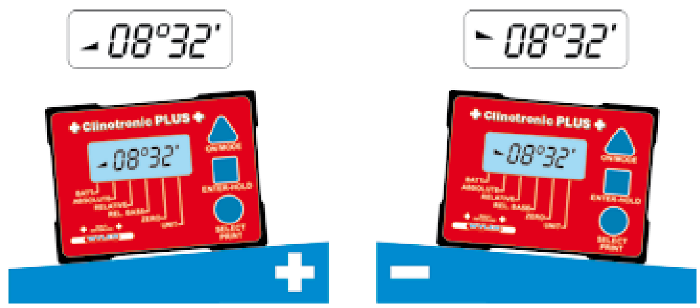
1.8 Correlation between the most common units in inclination measurement

1 Rad corresponds to 57.30°
1 mRad corresponds to 206.26 Arcsec
1 degree corresponds to approx. 17.45 mm/m or 17.45 mRad
1 Arcsec corresponds to approx. 4.85 μm/m

1.9 What are positive and negative inclinations?

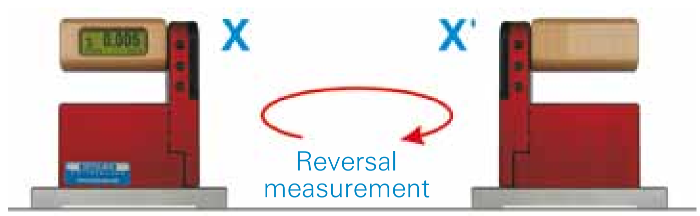
WYLER definition:

An inclination is positive when the instrument, on that side on which an electrical connector is installed, is lifted. When the instrument under the same precondition is declined, we define this as a negative inclination.



1.10 The absolute zero by means of a reversal measurement

Using the reversal measurement is a simple way to determine the exact ZERO-OFFSET of the instrument as well as the exact inclination of the surface the instrument is placed on.



The absolute zero represents a base for absolute inclination measurements (deviation from horizontal or vertical). In order to achieve best results, take care that the measuring instrument and measuring object are at identical temperatures and put the measuring instrument into operation a few minutes prior to zero setting. The absolute zero is automatically calculated and set from the two values entered while conducting a reversal measurement (reversal measurement = two measurements made on the same spot, but in exactly opposing directions). For this operation, place the measuring instrument upon a suitable surface, (rigid location; as flat as possible; as near to horizontal as possible). In order to allow positioning in exactly the same location after rotating the instrument through 180 degrees, mark out position and particularly the orientation of the measuring instrument.

The determination of the absolute zero of the instrument is essential when an absolute measurement is performed. Before the actual measurement with the measuring instruments, a reversal measurement has to be performed. The determined deviation of the zero point (ZERO-OFFSET) of the instrument is considered in the display readings. For measuring instruments of earlier generations, the ZERO-OFFSET has to be corrected manually. For spirit levels the zero-point deviation has to be adjusted by means of the vial. Normally, the reversal measurement is part of the application software used.

The results of a reversal measurement are:

- ZERO-POINT DEVIATION OF INSTRUMENT (ZERO - OFFSET) of the inclination measuring instrument
- the exact INCLINATION of the surface of the object on which the reversal measurement was carried out

ZERO-POINT DEVIATION
of the measuring instrument (ZERO-OFFSET)

$$= \frac{(X + X')}{2}$$

INCLINATION
of the surface of the object

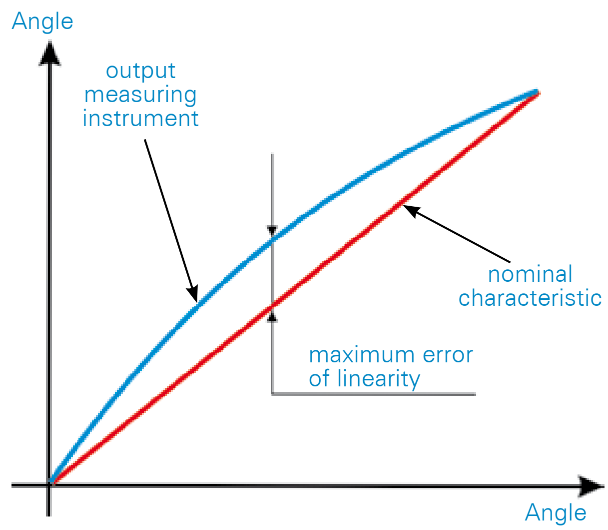
$$= \frac{(X - X')}{2}$$

1.11 Linearity

Definition:

The word “linear“ comes from the Latin word *linearis*, which means created by lines. Usually, the term is used to describe a linear character.

Often, the basis between a measured quantity and the measurement signal (e.g. the output of the measuring instrument or the voltage of a sensor) is a linear function. The aim for a measuring device is proportionality and a small error of linearity.



Linearity according to DIN 2276:

Measured value below half the measuring range:

Maximum error $f_{max} = 0{,}01 * |M_v|$, at least 0.05% (BlueLEVEL at least 1 digit ≙ 0.005% M_f) of the measuring range M_f

For measured values above half the measuring range:
Maximum error $f_{max} = 0.01\ (2 * |M_v| - 0{,}5 * M_f)$

M_v: Measured Value
M_f: Measuring Range

1.12 Effect of gravitational force and compensation with inclination measuring instruments

The inclination displayed by inclination measuring instruments and sensors is based on the gravitation. However, gravitational force is not consistent around the globe, varying with latitude and height above sea level. Furthermore, variations of the density in the lithosphere cause additional local deviations.

As an example, the gravity at sea level is

- 9.78033 m/s² at the equator
- 9.80620 m/s² at 45 degree of latitude
- 9.83219 m/s² at the poles

In the table below the values of gravity for some cities are listed.

Amsterdam	9.813	Istanbul	9.808	Paris	9.809
Athens	9.807	Havana	9.788	Rio de Janeiro	9.788
Auckland	9.799	Helsinki	9.819	Rome	9.803
Bangkok	9.783	Kuwait	9.793	San Francisco	9.800
Brussels	9.811	Lisbon	9.801	Singapore	9.781
Buenos Aires	9.797	London	9.812	Stockholm	9.818
Calcutta	9.788	Los Angeles	9.796	Sydney	9.797
Cape Town	9.796	Madrid	9.800	Taipei	9.790
Chicago	9.803	Manila	9.784	Tokyo	9.798
Copenhagen	9.815	Mexico City	9.779	Vancouver	9.809
Nicosia	9.797	New York	9.802	Washington	9.801
Jakarta	9.781	Oslo	9.819	Wellington	9.803
Frankfurt	9.810	Ottawa	9.806	Zurich	9.807

An inclination measuring instrument or sensor will be calibrated at the head office of WYLER AG in Winterthur. The inclinations displayed are exact only in this location. In different locations the displayed value must be corrected. If the correction of the local gravity is switched on, the inclination measured will be corrected accordingly before the value is displayed.

The correction is calculated according the following formula:

$$\alpha_{eff} = \arcsin\left(\frac{g_c}{g_m}\sin(\alpha_m)\right)$$

whereby

g_c gravity at the location of calibration
α_m displayed inclination at location of measurement
g_m gravity at the location of measurement
α_{eff} effective inclination

For further information about the effect of gravitational force and compensation with inclination measuring instruments, see appendix at the end of the compendium.

1.13 Measuring uncertainty

In order to perform a valid measurement, a number of conditions must be fulfilled.

A precision measurement is usually dependent on the influence of a number of different factors, such as:

- Temperature of the object and ambient temperature
- Temperature of the measuring instrument
- Linearity of the measuring instrument
- Vibrations
- Dirt, dust, and humidity

These influencing factors are generally termed **measuring uncertainty**.

What are the major causes of measuring uncertainty?

Measurements can never deliver an exact figure. In every measurement there is a large amount of insufficient and imperfect information included. Some of these imperfections have their cause in a random effect, such as a short-term change of temperature or other climate influence. Also errors on the part of the person taking a measurement can be the cause of insufficient data.

The source of other insufficiencies can also be a systematic error which can not be defined exactly. Such elements include: the zero point deviation of the instrument, the characteristic change of the date of a master between two calibrations (drift) or the uncertainty which is defined for a certain material in a certificate or a manual at the moment of use.

Measuring uncertainty is an important byproduct of every measurement. This value is particularly important when the measurement is close to the required data limit. The publication of a measured value including the measuring uncertainty is common practice in the field of calibration. However, a number of laboratories common practice in the field of calibration in the proper allocation of this information. It will certainly be common practice to include in every measured value of importance the respective value of measuring uncertainty.

1.14 Length of measuring bases

Inclinometers that are mainly used for adjustment and levelling jobs, but not for flatness or straightness measurements, should be equipped with a measuring base (or complementary base) that is as long as possible. The influence of local errors on the measured object (e.g. buckles) can be reduced when long measuring bases are used. (Naturally, light measuring instruments should be used for light construction work!)

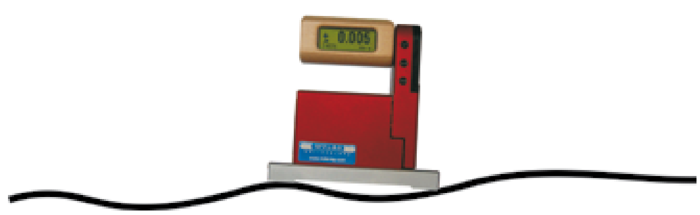
For straightness measurements of guideways and for flatness measurements of surfaces, the following criteria should be observed:

- Short measuring bases detect short waves (local error) and thus generate a dense information content
- Short measuring bases require more time during the measurement process and thus create higher costs
- Short measuring bases used on large work pieces end up in a large number of measurements increasing the total measuring error
- Long measuring bases detect only long-wave errors
- Long measuring bases reduce the measuring time required, thus saving costs
- Long measuring bases require a smaller number of measurements, thus reducing the possibilities for measuring errors. Therefore the measuring uncertainty in respect of the total dimension of a measured object is drastically reduced

Medium Information density

Short waves of 50 to 200 mm in length.

These can be the result of unsuitable machining methods in production, e.g. when too small lapping tools are used for the lapping of a surface plate. Local wear can also lead to errors of this type. This category of errors is interesting for the flatness measurement being discussed.

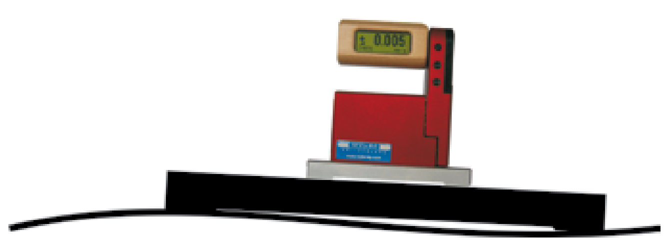


Low Information density

Long waves over the whole surface. The general shape of a surface.

Reasons for this category of errors are:

- Copied geometrical errors originating from the production machine
- Deformation due to clamping and support
- Distress of the material
- Thermal lamination within the workpiece



1.15 Absolute measurement - relative measurement - long-term monitoring

From an application perspective, there are three different options available.

A Relative measurement

When measuring the flatness of an object, such as a granite surface plate, it is important to set the plate horizontally. For the measurement of the surface it is only important, however, to look at the difference between the individual measurement steps. In other words, in this application the measured values are not taken using absolute measurement (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.

Especially well suited for such measurements are the instruments called BlueSYSTEM with or without wireless data trans-mission.

B Absolute measurement

Monitoring of buildings, bridges and dams requires the measurement of 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 necessary when, for example, a horizontal guideway must be compared with a vertical spindle. For measurements in the absolute mode, a number of different inclination instruments and sensors are available.

I. Handheld instruments from the BlueSYSTEM family with wireless data transmission as described under "Relative measurements" are exceptionally well-suited for the measurements of 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 measurement in the absolute mode are the completely digitalized inclination measuring sensors from the ZEROTRONIC product line. 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, they are also well suited for use in a greater temperature range. The design of the sensor is such that no permanent deformation or damage is done to the sensor cell even when heavy shock loads occur.

C Long-term monitoring of objects

For high precision, long-term monitoring of dams, bridges and buildings, the ZEROMATIC 2/1 and 2/2 family of two-dimensional inclination measuring sensors was developed. The sensors are based on an automatic reversal measurement for determining and eliminating a possible zero point deviation as described earlier. The point in time when such a reversal measurement should take place can be set by the user. The difference between the two instruments are as follows:

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

II. ZEROMATIC 2/2 is equipped with two inclination sensors. This allows users to receive values in the X and Y axes continuously. After a preset time an automatic reversal measurement is done in order to compensate for a possible zero point offset.

For more details, see chapter 6.3.2 "Measuring Software MACHINE TOOLS INSPECTION SOFTWARE MT-SOFT"

1.16 Quality Control and Calibration Lab SCS WYLER AG

For more than 75 years WYLER SWITZERLAND is specialized in the development, production and distribution of precision instruments to measure inclination. The wide range includes various lines from high precision spirit levels through hand held electronic inclinometers to high-tech sensors for measuring angles in a digital bus system.

The continuously increasing quality expectations as well as the demand for traceability of the measuring values and calibration data has lead at an early stage to the application for accreditation as a calibration laboratory. This accreditation has been granted by METAS / Metrology and accreditation Switzerland for the first time in 1993 under their **registration number SCS 044**.

The Swiss Accreditation Service confirms that a laboratory, which is accredited in accordance with standards ISO/IEC 17025, operates a quality system for its testing and calibration activities that also meets the relevant requirements of ISO 9001:2000 for the scope of accreditation Type C and ISO 9002:1994 for Type A and Type B. Further, standard ISO/IEC 17025 covers several technical competence requirements that are not covered by Standards ISO 9001:1994 and ISO 9002:1994.

THE CERTIFICATES

Within the framework of the certification possibilities, WYLER AG can issue 3 types of certificates:

Declaration of Conformity

All our products are delivered with a „Declaration of Conformity" stating that the product is in conformity with the applicable standards as well as with the technical specification published in our sales documentation.

The WYLER certificate

For products respectively measurements for which our laboratory is not accredited (e.g. straight and angular knife edges, special setting squares, etc.) we can issue a „WYLER certificate". The instruments or squares are inspected according to the relevant standards. The certificate issued consists of a confirmation that the measuring object is in accordance with the respective standard and of the measuring results recorded.

The SCS certificate

The measuring instruments respectively the surface plates or setting angles are inspected and certified according to the relevant standard. The certificate issued consists of a confirmation that the measuring object is in accordance with the respective standard, that it has been measured and certified according to the procedures prescribed by METAS / Metrology and accreditation Switzerland. All the respective traceable measuring results are part of the certificate.

S Schweizerischer Kalibrierdienst
C Service suisse d'etalonnage
S Servizio di taratura in Svizzera
S Swiss Calibration Service
SCS 044


Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Department of Economic Affairs EEA
Swiss Accreditation Service SAS

Based on the Accreditation and Designation Ordinance dated 17 June 1996 (as of 4 April 2006) and on the advice of the Federal Accreditation Commission, the Swiss Accreditation Service (SAS) grants to

WYLER AG
Inclination measuring systems
Im Hölderli 13
CH-8405 Winterthur

the accreditation as

Calibration laboratory for length (flatness) and angles

in accordance with the Standard ISO/IEC 17025. The ranges and measurement uncertainties are listed in the Official SCS-Directory of the Accredited Calibration Laboratories.

Accreditation mark and number: SCS 044
Date of accreditation: 28 April 1993
Date of the last renewal of accreditation: 12 May 2008
The accreditation is valid until: 11 May 2013

CH-3003 Berne-Wabern, 14 April 2008
Swiss Accreditation Service

The Head
Hanspeter Ischi

SAS is a signatory of the multilateral agreements of the European co-operation for Accreditation (EA) for calibration, testing, inspection and certification of products, personnel, quality and environmental management systems, of the International Accreditation Forum (IAF) for certification of products, quality and environmental management systems and of the International Laboratory Accreditation Cooperation (ILAC) for calibration and testing.

The calibration of high precision inclinometers requires high quality measuring equipment and environmental conditions.

Our air conditioned calibration lab is equipped with special measuring and calibration equipment certified by METAS / Metrology and accreditation Switzerland and covers thus a wide variety of requirements. The calibration range for instruments and sensors reaches from insignificant angles (0.2 Arcsec) to the full circle (360°). Our laboratory is also equipped for the calibration of NON-WYLER products.

Measuring possibilities of the SCS laboratory
Measuring uncertainty at a confidence level of minimum 95%

QUALITY CONTROL WYLER AG

SCS 044

Measuring categories Measuring object	Measuring range	Measuring conditions	Measuring uncertainty ±	Remarks
Flatness (Length) Surface plates	up to 12.5 m2		**(0.5 + 0.5 x L) µm** *L = length in [m]*	----
Angles / Inclination • Electronic inclinometers • Spirit levels with glass vial • Mechanical inclinometer	± 20 mm/m		**(1 + 0.002 x E) µm/m** *E = measured value in [µm/m]*	----
Angles / Inclination Inclinometers	**Full circle: 360°**	In intervals of 1/2°	**1.3 Arcsec**	----
	Segment of a circle: ± 60°		**1 Arcsec**	
Rectangularity of measuring bases	width: <150 mm length: <300 mm	Resolution: 1 µm/m 5 µm/m 10 µm/m	**5 µm/m** **7 µm/m** **8 µm/m**	Prismatic and flat measuring bases
Rectangularity of flatness like angular standards and machine geometry	50 mm<width<2500 mm 200 mm<length<2500 mm		**(1.7 + 0.5 x SL) µm** SL=length of the longer side in [m]	Particularly objects made of granite, ceramic or cast iron

2 Measurement systems and application software at a glance

Precision Spirit Levels

Besides the vial, the frame or body of a precision level is extremely important for a precision spirit level. The material, most often cast iron or special steel, must be as free from tension as possible (distortion). The treatment of the material before, during and after the machining and assembling is of greatest importance. Usually the bases of the levels for measuring surfaces have two contact faces. These allow the exact setting of the instrument. Prismatic bases with two contact faces are used for measuring round shafts and bars.

Standard vial

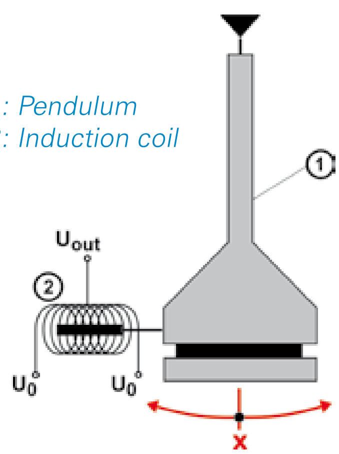

Magnetic spirit level


CLINOMETER
with vial for measurements ±180°

Electronic measuring instrument with inductive measuring system

Measuring principle:
Inductive probes function according to the principle shown in the diagram on the right. Differential coil systems are widely used. Depending on the inclination of the instrument, or more specifically the position of the ferrite core in relation to the inductive coil, the inductivity on one side of the coil increases whereas on the other side the inductivity decreases. The subsequent electronic treatment assures that the signal output U_{out} is exactly proportional to the inclination of the instrument.

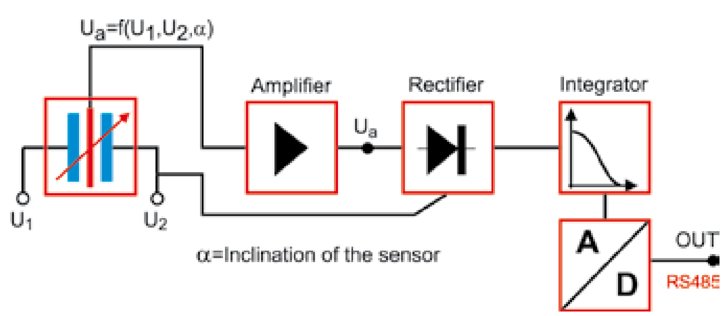
1: Pendulum
2: Induction coil




nivelSWISS

Electronic measuring instrument with capactive measuring system and analog signal output

Measuring principle:
The electronic levels are based on the pendulum properties of a friction free supported disc of mass weighing less than 1 gram. A two-phase frequency (4.8 kHz) is supplied to two electrodes, which together with the pendulum disc supported in the shielded and dustproof gap between them, build a differential capacitor. The inclination signal is created at the pendulum.




BlueLEVEL

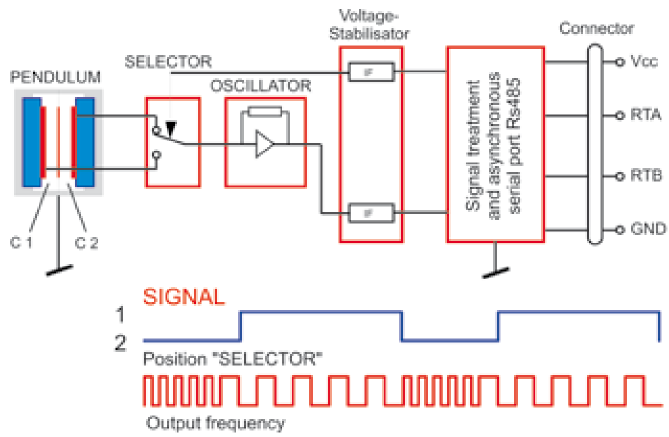

BlueLEVEL BASIC

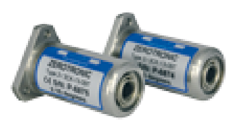
Electronic measuring instrument with capactive measuring system and digital signal output

Measuring principle:

The pendulum, suspended by three Archimedes helical springs, is mounted between two electrodes. Depending on the inclined position of the system, the pendulum will swing out of the zero position and in doing so change the capacity between the pendulum and the two electrodes.

These capacitances are transformed into different frequencies through the RC-oscillator. The ratio of the two frequencies returned is used as the primary signal for detecting the required angle.




ZEROTRONIC sensor

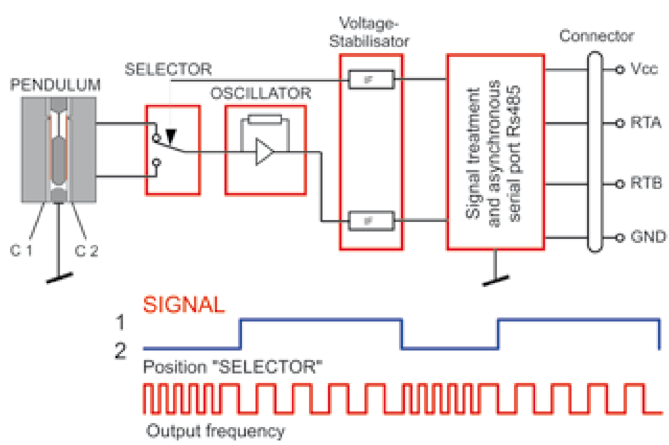

ZEROMATIC

Electronic measuring instrument with capactive measuring system, consisting of a digital signal output and a semiconductor sensor

Measuring principle:

Semiconductor sensor with a classic pendulum and capacitive measuring system. This technology is used in the WYLER instruments with a measuring range equal to or higher than ±10°.

The dimension of this sensor is about 1.1 x 1.2 mm.



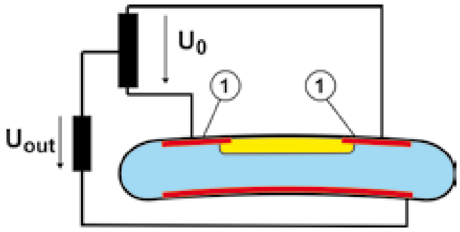
CLINOTRONIC PLUS

BlueCLINO

Other inclination measuring systems and alignment systems

Electrolyte vials

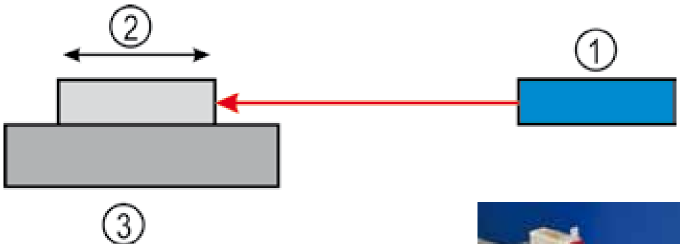
Electrolyte vials are made of glass, similar to precision vials, but filled with a liquid that is an electrical conductor. By inclining the vial, the outer portions of the vial (electrodes) will be more or less covered by the liquid. The electrolyte vial will supply a voltage proportional to the inclination.



1: Outer electrodes

Target laser

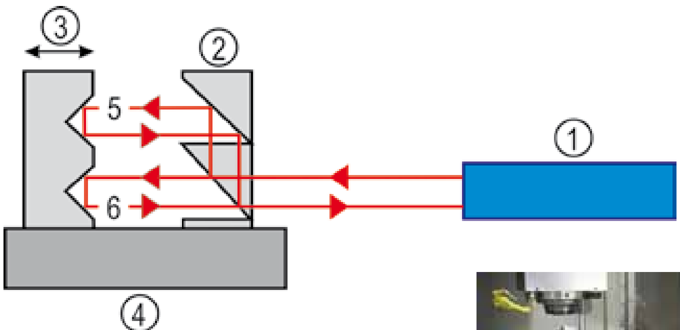
The system consists of a laser sender and a laser receiver unit. The sender unit is a high stabilility semi-conductor laser precisely adjustable with a mechanical device for targetting. The receiver unit is a 10x10 mm PSD (Position Sensing Detector), an opto-electronic device with a complete amplifying and computing electronic unit based on a DSP (Digital Signal Processor).



1: Laser transmitter
2: Laser receiver
3: Object to be measured

Laser Interferometer

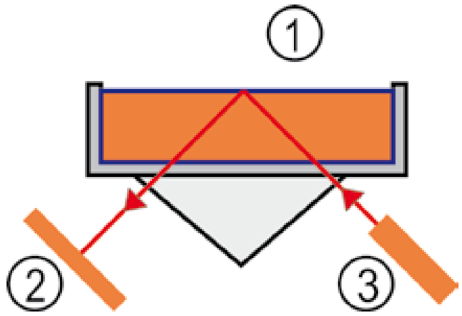
The measuring system consists of a laser with detector, an angular interferometer-reflector and a retroreflector.The laser beam is split in the interferometer and runs from there on in two different paths (measuring beam and reference beam). On the return path the two beams will be superimposed to form one beam again. The difference in path distance leads to a difference in return time and therefore a phase difference is the result. This phase difference results in an interference that can be measured.



1: Laser with detector
2: Angular reflector
3: Reflector
4: Object to be measured
5: Laser beam
6: Reference beam

Opto-electronic principle

A liquid horizontal surface is the basic reference. Changing the object's position automatically results in changing the reflection of the sensors optical beam on the liquid's (horizontal) surface. The reflection is detected by a photo detector in two axes (X and Y)



1: Liquid
2: Photodetector
3: Source of light

Sextant

A sextant is an instrument used to measure the angle between any two visible objects. Its primary use is to determine the angle between a celestial object and the horizon which is known as the altitude. Making this measurement is known as sighting the object, shooting the object, or taking a sight, and it is an essential part of celestial navigation. The angle, and the time when it was measured, can be used to calculate a position line on a nautical or aeronautical chart.

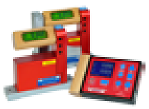
Autocollimator

An autocollimator is an optical instrument for non-contact measurement of angles. They are typically used to align components and measure deflections in optical or mechanical systems. An autocollimator works by projecting an image onto a target mirror, and measuring the deflection of the returned image against a scale, either visually or by means of an electronic detector. A visual autocollimator can measure angles as small as 0.5 arcseconds, while an electronic autocollimator can be up to 100 times more accurate.

Theodolite

A theodolite is a precision instrument for measuring angles in the horizontal and vertical planes. Theodolites are mainly used for surveying applications, and have been adapted for specialized purposes in fields like metrology and rocket launch technology. A modern theodolite consists of a movable telescope mounted within two perpendicular axes — the horizontal or trunnion axis, and the vertical axis. When the telescope is pointed at a target object, the angle of each of these axes can be measured with great precision, typically to seconds of arc.

Measuring systems and application software



Standard software packages, which are used with WYLER Engineer-sets:

LEVELSOFT PRO

The software LEVELSOFT PRO is our standard software for measuring lines, flatness of surfaces and geometry measurements, and is based on ISO 1101.

➡ Details can be found on the following pages: 47

MT-SOFT

MT-SOFT is the expanded version of LEVELSOFT: MT-SOFT is an ideal tool for measuring and for quality inspection on machine tools and their components

➡ Details can be found on the following pages: 67

Software packages that can be used together with inclination measuring sensors:

LabEXCEL

The software LabEXCEL is an easy-to-use software package for displaying the measuring values of WYLER inclination measuring instruments and sensors. The measurement results are automatically transferred into a csv file and can then be further processed with EXCEL, for example.

➡ Details can be found on the following pages: 100

DYNAM

With the software DYNAM, all the sensors and instruments of the ZEROTRONIC family can be operated. With the DYNAM software the data of the connected sensors can be sampled, computed and displayed in various forms or it can be transmitted.

➡ Details can be found on the following pages: 99

WyBus Development kit

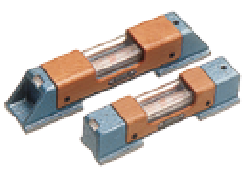
For customers intending to develop their own analyzing software for WYLER instruments, WYLER AG provides several software examples, which explain how to interact with WYLER instruments or sensors either directly or via a software interface developed by WYLER.

➡ Details can be found on the following pages: 101

3 Product groups in the area of inclination measuring instruments

At WYLER AG the instruments and sensors are distinguished in the following product groups:

3.1 Precision spirit levels and clinometers

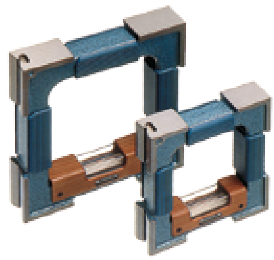


Horizontal spirit levels for small inclinations

HORIZONTAL SPIRIT LEVEL 55 SPIRIT

Angular spirit levels for small inclinations

MAGNETIC SPIRIT LEVEL 48 SPIRIT



Frame spirit levels for small angles

FRAME SPIRIT LEVEL 58 SPIRIT

Inclination spirit level for inclinations from 0 up to 90°

INCLINATION SPIRIT LEVEL 57

Clinometers for large inclinations up to 360°

CLINOMETER 80

3.2 Electronic measuring instruments

Electronic measuring instrument with inductive measuring system

nivelSWISS / nivelSWISS-D

Electronic measuring instrument with capacitive measuring system

CLINOTRONIC PLUS

Electronic measuring instrument with capacitive measuring system

CLINO 2000

Electronic measuring instrument with capacitive measuring system

BlueCLINO / BlueCLINO HP

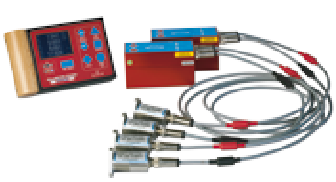
Electronic 2D-measuring instrument with capacitive measuring system

BlueLEVEL-2D

Electronic measuring instrument with capacitive measuring system, an external readout system and wireless data transfer

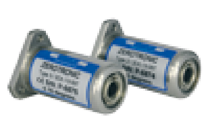
BlueSYSTEM / BlueSYSTEM BASIC

3.3 Inclination measuring sensors with a digital measuring system



Inclination measuring sensors with a capactive measuring system and an external read out system

ZEROTRONIC sensor



Inclination measuring sensors with a capactive measuring system

ZEROTRONIC sensors

Customized solution with ZEROTRONIC sensors in specially designed adapters using BlueTCs for wireless data transmission (Bluetooth technology)

Example: Measuring set for high-speed printing machines

2-dimensional inclination measurement sensors ZEROMATIC with integrated reversal measurement device

ZEROMATIC

4 Applications with WYLER inclination measuring instruments and systems

There is a very wide range of applications for spirit levels, as well as inclination measuring instruments and -systems

- **Measurement**
- **Adjustment**
- **Monitoring**

4.1 Applications with inclination measuring instruments

Civil engineering / Bridge monitoring

Subject:
The deformation in the body of a highway bridge must be continuously determined over a longer period. The data collection and supervision is to be performed during the construction work as well as later on when the bridge is put into service.

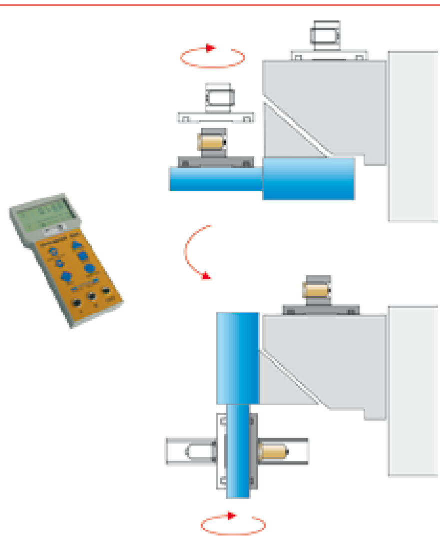
Measuring task:
Inclinometers are used for long-term monitoring, the measuring results of which must be collected, recorded and analyzed with corresponding software. The analysis of the angular results is specially interpreted with separate software by converting the angles to length dimensions.

Printing industry / Adjustment of stands and printing cylinders

Subject:
A modern multi-color printing system consists of several separate units, one unit per primary color. To achieve high-quality print products, these units must be precisely aligned and adjusted when assembled.

Measuring task:
Each single-color unit provides horizontal and/or vertical reference faces which must be used during the manufacturing process in the production plant as well as for the adjustment of the printing line. The positions of the reference faces must be adjusted in accordance to each other, measured, and a record must be printed. The positions of the printing cylinders must be precisely aligned to each other (horizontally).

Machine tools / Spindle Alignment



Subject:
The main spindle of a milling machine can be set by CNC commands for vertical as well as for horizontal milling. To change between the two settings, the milling head rotates on a bearing set at 45°, the median angle between the two positions.

Measuring task:
The deviation from the right angle between the two working positions “horizontal” and “vertical” must be determined.

This determination is made during assembly, when error correction is done using a scraper if the unit is mounted on a temporary frame with doubtful stiffness as well as during the final inspection of the ready-mounted machine tool.

The measuring uncertainty must not exceed two seconds of arc. Calculations involved must be possible without the aid of a computer.

Flatness measurement on a circular support of a turntable

Subject:
The software LEVELSOFT PRO allows users to determine the flatness of a rectangular surface very easily. The measurement of the flatness of a circular support though, as it is used for large machine tools, is much more complex. However, with the software MT-SOFT and electronic inclination measuring instruments, appropriate means are available.

Measuring task:
The flatness of a circular support with a diameter of 2.3 m has to be measured.

Measuring calibration / flatness-measurement / angles

Subject:
In the production of granite tools, e.g. granite master squares, more and more customers ask for certificates proving the quality in respect of flatness and rectangularity where applicable. This requirement is important when selling new tools as well as in the course of repair or periodic calibration.

Measuring task:
The calibration of granite master squares should be performed as easily and efficiently as possible. The equipment used should offer a good cost-benefit relationship and requirements regarding the qualification of staff should be as moderate as possible, enabling workshop staff to easily make use of the system.

Continuous monitoring of an object that is exposed to significant temperature changes

Subject:
On a radar installation that is exposed to significant temperature changes as well as to direct sunlight, precise, reliable and continuous inclination measurements should be carried out. All high-precision instruments are sensitive to temperature changes. Significant temperature changes inhibit precision measurements and can even prevent them.

Measuring task:
Precise and continuous monitoring of the inclination of the base of the radar station.

Precise and continuous monitoring of the inclination of reference casing of the incremental protractors of the radar.

Monitoring of a water intake tower at a dam

Subject:
The stability of a water intake tower is critical to the safety of a dam. The operator of the dam therefore requests continuous monitoring of the tower's inclination.

Measuring task / Goal:
The inclination of the water intake tower, that is its change in attitude, is to be monitored and registered continuously. The inclination sensor is to be mounted permanently, and must have excellent zero-point stability. The measuring values are to be registered and evaluated in the central station of the dam at a distance of about 500 m.

Heeling measurement on cargo ships

Subject:
Part of the homologation and certification of a ship is the measuring of the heeling: The buoyancy is measured as a function of the load and specifically of the maximal load. By pumping water into the ballast tanks, or by loading containers, the heeling of the ship is changed. Thereby certain limits of heeling may not be exceeded.

Measuring task / Goal:
On a ship that is at anchor in a harbor and tightened to the mole, the inclination, or heeling, should be measured during a loading test.

Large grinding machine with flat guideways

A manufacturer of large ground stock has several large surface grinding machines in his workshop. The geometry of these machines has to be checked periodically, the results documented, and where required, to be corrected. To solve this task professionally, the maintenance department responsible has decided to acquire a WYLER measuring system.

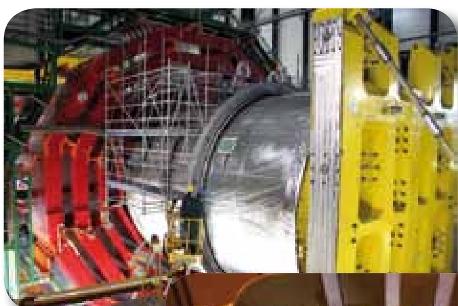
Measuring task / Goal:
On a surface grinding machine with 18-meter-long guideways set 1.3m apart, the co-parallelism of the two guideways has to be checked periodically. The guideways have to be within a plane with a maximum tolerance (error) of less than 0.1 mm. The complete machine and its guideways can be adjusted by means of supporting screws placed at 750 mm intervals.

Monitoring of six towers at a double sluice

Subject:
The sluice is almost 100 years old and consists of two parallel sluices. The vertical gates put a heavy strain on the six towers, which is the reason why continuous monitoring is required.

Measuring task / Goal:
Each of the six towers should be permanently monitored with suitable inclination sensors along the X- and Y- planes. The measuring values should be transmitted online to the local water authority, thus facilitating the ability to sound alarms in timely fashion.

ZEROTRONIC sensors in strong magnetic fields



Subject:
A customer would like to measure his machine in spite of the presence of a strong magnetic field.

Measuring task / Goal:
The user of a particle accelerator would like to accurately measure and adjust the parts of his accelerator. The strong magnetic fields allow only the use of non-magnetic material. Only instruments that are not sensitive to heavy magnetic fields can be used.

Alignment of the holes of flanges

Subject:
Between two vertical flanges with holes, pipes between 2 m and 10 m long with a diameter between 400 mm and 1,000 mm are welded in. The material of the flanges and the tubes is either aluminium or stainless steel.

Measuring task / Goal:
Before the welding process, the holes of the flanges have to be aligned (twisted) in such a way that the holes have less than ±15 Arcsec deviation from each other after the welding process.

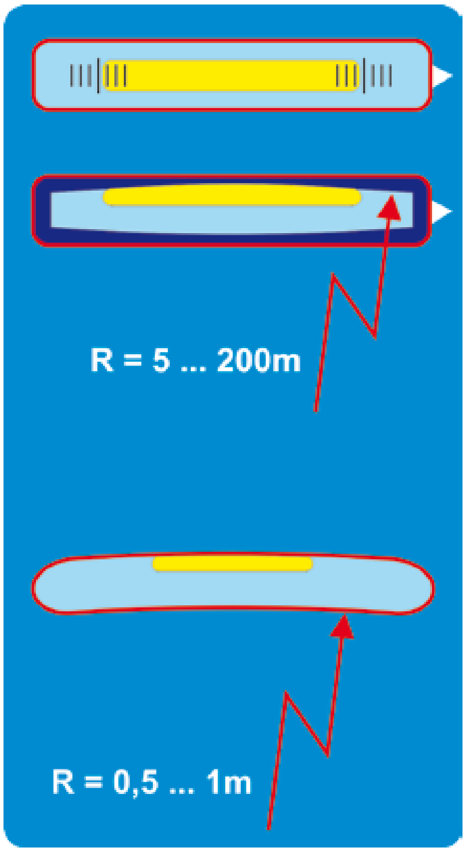
5 Precision spirit levels

With the advent of the electronic age, the classic spirit level was expected to be outdated. Despite this, the spirit level is still widely used and prized as a precision measuring instrument. Specialists in the measuring field expect a measuring instrument to be easily understandable, simple to use and reliable. All these expectations as well as excellent cost effectiveness are fulfilled by the spirit level. The heart of the spirit level is the vial.

The precision of the spirit level is heavily influenced by the quality and the sensitivity of the vial. If a spirit level with a sensitivity of 0.020 mm/m is inclined in such a manner that the bubble of the vial travels from one line to the next (the standard distance from one line to the next line is 2 mm), then the spirit level was inclined by 20 μm in relation to 1000 mm.

The vials of medium and high sensitivity are ground on the inside like a barrel. The radius of this barrel side conforms to the desired sensitivity and comes to about 200 m when the vial has a sensitivity of 0.020 mm/m. The radius is about 5 m when the sensitivity is 0.500 mm/m.

The vials of WYLER precision levels are additionally mounted in a steel tube. These tubes can be adjusted in the body of the spirit level by fine thread setting screws. This patented system allows exact assembly and makes it possible for the necessary adjustments to be effected.



Ground vial for precision spirit levels, radius = 5 ... 200 Meter Hight arc based on 80 mm = 160 ... 4 μm

Bent vial (low cost version), radius = 0.5 ... 1 Meter

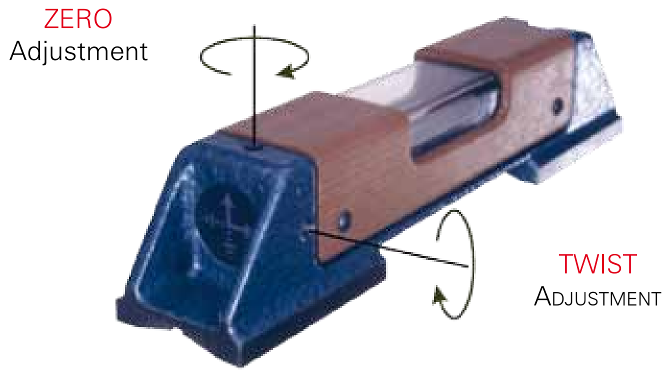
Besides the precision of a vial, it is quite clear that the body of the spirit level has a great influence on the performance. The material, mostly cast iron or special steel must be free of tension. The treatment of the material before and during the manufacturing process is of utmost importance. The bases of a spirit level usually have two surfaces for secure positioning on a measuring object. Prismatic bases are used for measurements on shafts and spindles. In addition, the bases can be equipped with magnetic inserts.

Of greatest importance is the fact that the axis of the vial must be adjusted parallel to the base's contact surfaces. This is be done by grinding and/ or manual scraping. Only by this process can it be guaranteed that the instruments measure correctly even when the level is slightly placed offset on a surface (no twist error).

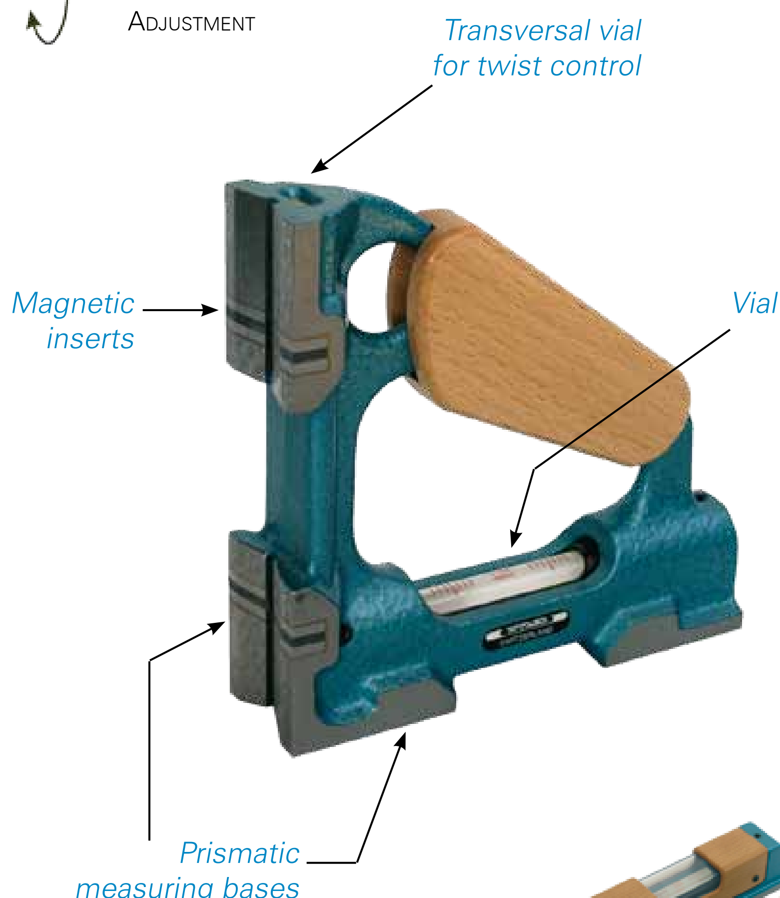
Here a WYLER AG specialist scrapes the base of a spirit level

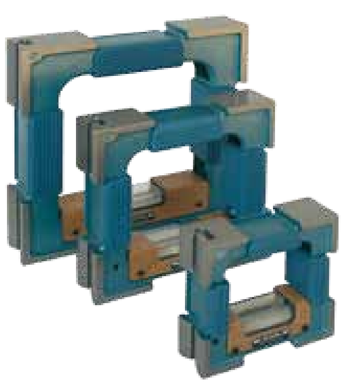
5.1 ZERO ADJUSTMENT (TWIST)

Only by precision work it is assured that, even when the level is slightly tilted, no measuring error occurs (twist stability).

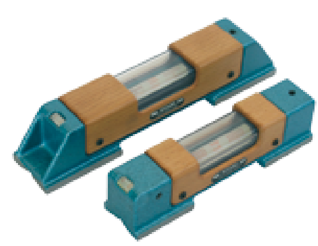


The user is able to adjust the ZERO as well as the TWIST thanks to a simple adjustment system.





Frame spirit levels for small inclinations



Horizontal spirit levels for small inclinations

Clinometers for large angles up to ±180° inclinations

Circular spirit levels in various sizes

5.2 Precision spirit levels and Circular spirit levels

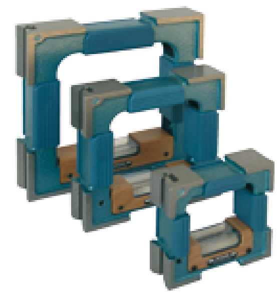
Magnetic Spirit Level No. 48 SPIRIT

For horizontal and vertical measurements with strong magnetic adhesion, for surfaces, whether plane or cylindrical, with insulating handle.

Sensitivities:
0.02 mm/m, 0.04 mm/m, 0.05 mm/m, 0.10 mm/m, 0.30 mm/m

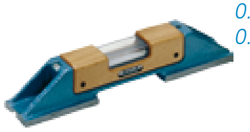
Precision Frame Spirit Level No. 58 SPIRIT

With two flat bases (upper and right hand) and two prismatic bases (bottom and left hand) for checking on horizontal and vertical surfaces, plane or cylindrical, with insulating handles and vial protection,



Sensitivities:
0.02 mm/m, 0.04 mm/m, 0.05 mm/m, 0.10 mm/m, 0.30 mm/m

Horizontal Spirit Level No. 55 SPIRIT



For measurements on horizontal surfaces and cylinders, with insulating handle and vial protection.

Sensitivities:
0.02 mm/m, 0.04 mm/m, 0.05 mm/m, 0.10 mm/m, 0.30 mm/m

Inspection Spirit Level No. 61

With prismatic base for measurements on flat faces or cylinders, with insulating handle and vial protection.

Sensitivities:
0.02 mm/m, 0.04 mm/m, 0.05 mm/m, 0.10 mm/m

Crankpin Spirit Level No. 56

With two prismatic groves in cross-wise directions, sensitivity of transversal vial 1 mm/m.

Sensitivities:
0.05 mm/m, 0.10 mm/m, 0.30 mm/m

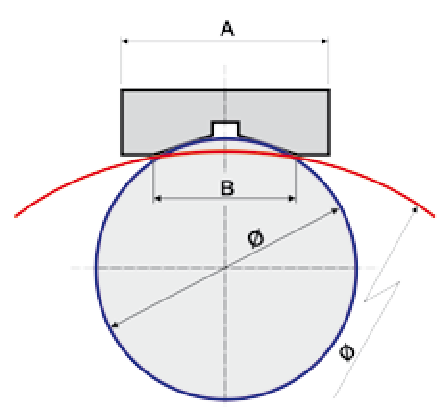
Adjustable Micrometer Spirit Level No. 68

Used for measuring the flatness of surfaces, inclinations, taper or conicity, with prismatic measuring base of steel, hardened and ground, vial sensitivity 0,02 mm/m, with insulating handles.

Sensitivitiy:
0.02 mm/m

Standard dimensions of prismatic bases for shafts measurement

Length of base L	A	B	Measurable shaft diameter Ø
100 mm	30 mm	21 mm	Ø 17 ... 80 mm
100 mm	32 mm	22 mm	Ø 17 ... 84 mm
150 mm	35 mm	24.5 mm	Ø 17 ... 94 mm
200 mm	40 mm	28 mm	Ø 19 ... 108 mm
250 mm	45 mm	31.5 mm	Ø 19 ... 120 mm
300 mm	50 mm	35 mm	Ø 22 ... 135 mm
500 mm	60 mm	42 mm	Ø 22 ... 160 mm



Micrometric Spirit Level No. 53

For measuring irregularities of plane surfaces, measuring range ±5 mm,

Sensitivities:
0.02 mm/m, 0.05 mm/m, 0.10 mm/m, 4 Arcsec, 10 Arcsec, 20 Arcsec

Adjustable Spirit Level No. 52

For checking plane and cylindrical surfaces being not absolutely horizontal, with adjusting system.

Sensitivities:
0.02 mm/m, 0.05 mm/m, 0.10 mm/m

Magnetic Angle Spirit Level No. 47

For vertical measurements, with strong magnetic adhesion to plane and cylindrical surfaces, with plastic vial protection, vial sensitivity 0.3 mm/m.

Sensitivity: 0.3 mm/m

Universal Angle Spirit Level No. 64

With removable tubular level, prismatic measuring base 150 x 40 mm for vertical measurements, flat face of the tubular level 150 x 10 mm for horizontal measurements, vial sensitivity 0.5 mm/m.

Sensitivity: 0.5 mm/m

Horizontal Spirit Level No. 69

Available with flat or prismatic base.

Sensitivities:
0.30 mm/m, 1.0 mm/m

Tabular Spirit Level No. 59

With flat measuring base
Option No. 59 A:
length 80 and 150 mm are also available with 2 holes to screw on.

Sensitivities:
0.05 mm/m, 0.10 mm/m, 0.30 mm/m, 1.0 mm/m

Screw-on Spirit Level No. 66

For machines, apparatus and other technical applications.

Sensitivities:
0.10 mm/m, 0.30 mm/m,1.0 mm/m, 2.0 mm/m, 2-5 mm/m

Cross Spirit Level No. 78

To screw on, for machines, apparatus, etc.

Sensitivities:
0.02 mm/m, 0.04 mm/m, 0.05 mm/m, 0.10 mm/m, 0.30 mm/m

Cross Spirit Level No. 76

With two perpendicular vials, to screw on, for machines, apparatus, etc.

Sensitivities:
0.30 mm/m, 1.0 mm/m, 2-5 mm/m

Circular Spirit Level Nos. 72 / 73 / 74

For fitting on to machines, apparatus, etc.

Sensitivities: various

5.3 Clinometer

Clinometer
Nr. 80

Instrument for measuring angular deviation accurately, with circular scale 2 x 180 deg., with finely ground prismatic base of hardened steel for measuring on shafts and flat surfaces, with micrometer graduated 1 Div. = 1 Arcmin,

Vial sensitivity:
0.3 mm/m (1 Arcmin)

Frame Angle Spirit Level
No. 79

With fine setting device, two flat bases and two prismatic bases, with circular scale, division of 2 x 180 deg., vernier for reading at 3 Arcmin.

Vial sensitivity: 0.3 mm/m

CLINORAPID
Nr. 45

As soon as the pendulum disc supported by ball bearings and equipped with magnetic damping is released, it aligns to the gravity. The inclination can be read on the large circular scale (±180 deg.) against a 10 min. vernier. The reading is retained until next release. Measuring base with V-section made of hardened steel, precisely ground.

Protractor spirit level
No. 62

For checking any inclination, division of 2 x 180 deg. without vernier, prismatic cast iron base.

Vial sensitivity: 2 mm/m

5.4 Communicating Water Level

Communicating Water Level
No. 77

Based on the law of communicating vessels, for measuring two or more distant points not being in direct interconnection to each other, with wooden box. Depth micrometer feeler with needle available as accessory.

Dimensions:
H (total) = 250 mm
Ø of base = 100 mm

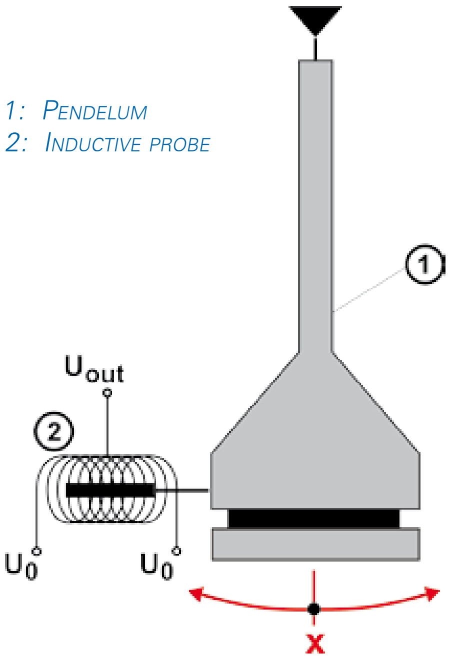
6 Electronic handheld inclination measuring instruments

We distinguish between the following measuring systems:

- **Inductive measuring systems**
  (e.g. for the measuring instrument nivelSWISS)
- **Capactive measuring systems**
  (e.g. for the measuring systems BlueSYSTEM familiy and for ZEROTRONIC sensors

6.1. Inductive measuring systems / nivelSWISS and nivelSWISS-D

1: Pendelum
2: Inductive probe



Measuring principle:

Inductive probes generally work according to the principle shown in the diagram on the left. Different coil systems are widely used. Depending on the inclination of the instrument, or more specifically the position of the ferrite core in relation to the induction coil the inductance on one side of the coil, increases whereas on the other side the inductance decreases. The subsequent electronic treatment assures that the signal output U_{out} is exactly proportional to the inclination of the instrument.

Positive:	Excellent zero point stability
Negative:	Impact sensitivity

6.1.1 nivelSWISS classic

The first electronic handheld inclination measuring instrument, which came to market in 1970, was the nivelSWISS (formerly Niveltronic) with built-in analog display. The instrument is still very popular among users and has been constantly improved and adapted to the latest technologies.

The instrument consists of three main elements, namely the high-sensitivity precision mechanical pendulum, the analog processing electronics and the robust cast iron housing. The measured value is generated inductively by a pendulum. The device is not suitable for use in close proximity to electromagnetic fields and is very sensitive to impact due to its construction.

The device is very popular for the alignment of large machine beds as well as machine components. The display means of a galvanometer is particularly suitable for this application because the detection of trends is in the foreground. The excellent stability of the zero point is very much appreciated.

Battery powered electronic inclinometer with analog display on a built-in galvanometer. The remarkable stability of the zero-point makes this instrument particularly suitable for long-term measuring tasks and for adjustment or alignment works on large guideways.

The nivelSWISS is mounted in a rugged body of carefully treated cast iron.

It is available in two versions:

nivelSWISS 50-H HORIZONTAL VERSION

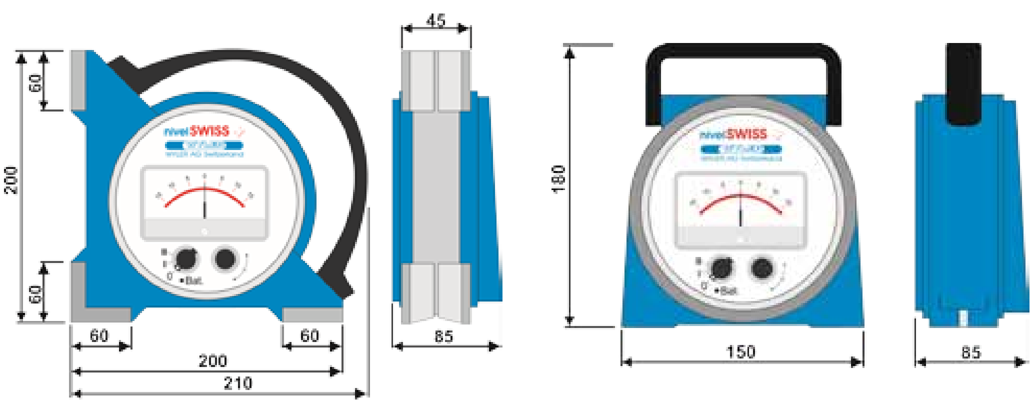
with a horizontal flat measuring base, equipped with slots for screwing onto special measuring bases (i.e. granite measuring bases) or on customer's own special measuring equipment. Mainly used for the adjustment or alignment of horizontal machines and for checking the flatness of machine tables and guideways.

nivelSWISS 50-W ANGULAR VERSION

equipped with two prismatic measuring bases in rectangular position to each other for measuring flat surfaces and shafts (diameters Ø 20 ... 120 mm) horizontally or vertically.

The measuring faces are carefully hand scraped to obtain an extraordinary precision. This makes the instrument extremely suitable for adjustments or checks on rectangular geometrical components of machine tools and structures.

A software program well-proven in practical use is the WYLER LEVELSOFT PRO FOR GEOMETRICAL MEASUREMENTS, based on ISO 1101, serving for measurements of lines and surfaces and being continuously enhanced according to the requirements of the users.



Dimensions nivelSWISS with horizontal and angular base

nivelSWISS TECHNICAL SPECIFICATIONS			
		Range I	Range II
Measuring range		±0.750 mm/m ±150 Arcsec	±0.150 mm/m ±30 Arcsec
Sensitivity		0.050 mm/m 10 Arcsec	0.010 mm/m 2 Arcsec
Settling time, reading available after		<3 seconds	
Repeatability		1 µm/m	
up to ½ F.S. (DIN 2276) from ½ F.S. to F.S. (DIN 2276)		max. 1% of M.V. / min. 0.001 mm/m max. 1% of (2* M.V. - 0.5*F.S.)	
Data output analog		ca. ±0.27V / resistance (Rout) 5 kOhm	
Power supply with battery		4 x size AAA 1.5V (LR03;MICRO;UM4)	
Measuring faces	Horizontal type	1 flat face, 150 x 45 mm	
Measuring faces	Angular type	STANDARD: Two prismatic measuring bases horizontal and vertical, for diameters from Ø 20 up to Ø 120 mm	
Weight net (w/o case)	Horizontal version Angular version	3.700 kg 4.350 kg	

6.1.2 nivelSWISS-D (DIGITAL SYSTEM)

nivelSWISS is well known and well established in the machine tool industry. nivelSWISS-D is the consequent further development of the classic nivelSWISS:

- Stable cast iron body
- Ergonomic handle supporting accurate measurement even on vertical surfaces
- Well-proven measuring system
- Digital display allowing the full utilization of the accuracy of the measuring system. Furthermore, the digital and back-lid display allows excellent readability even under difficult light conditions
- The display can be inclined to allow optimal readability from above
- Simple integration into WYLER measuring systems: nivelSWISS-D can be connected to a PC/laptop with a USB cable. The instrument is powered from the USB port. The digital measuring data transmission allow evalution with LEVELSOFT PRO or MT-SOFT

- An infrared zapper facilitates the transfer of the measurement data to the Software

The nivelSWISS-D is the ideal symbiosis of the well-proven measuring system of the nivelSWISS and the simple handling of digital WYLER measuring systems.

The nivelSWISS is mounted in a rugged body of carefully treated cast iron.

It is available in two versions:

nivelSWISS 50-DH HORIZONTAL VERSION

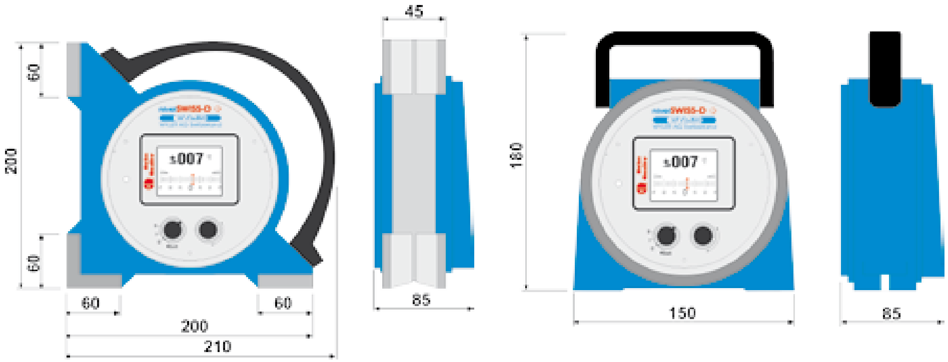
with a horizontal flat measuring base, equipped with slots for screwing onto special measuring bases (i.e. granite measuring bases) or on customer's own special measuring equipment. Mainly used for the adjustment or alignment of horizontal machines and for checking the flatness of machine tables and guideways.

nivelSWISS 50-DW ANGULAR VERSION

equipped with two prismatic measuring bases in rectangular position to each other for measuring flat surfaces and shafts (diameters Ø 20 ... 120 mm) horizontally or vertically.

The measuring faces are carefully hand scraped to obtain an extraordinary precision. This makes the instrument extremely suitable for adjustments or checks on rectangular geometrical components of machine tools and structures.

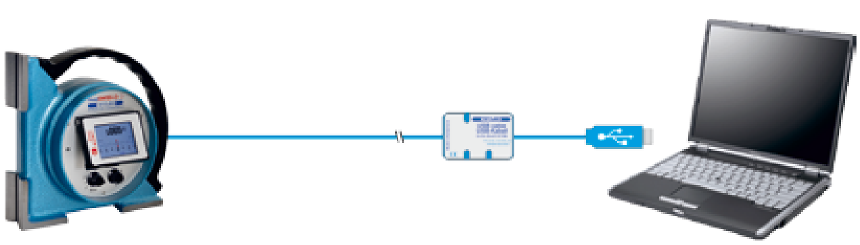
A software program well-proven in practical use is the WYLER LEVELSOFT PRO FOR GEOMETRICAL MEASUREMENTS, based on ISO 1101, serving for measurements of lines and surfaces and being continuously enhanced according to the requirements of the users.



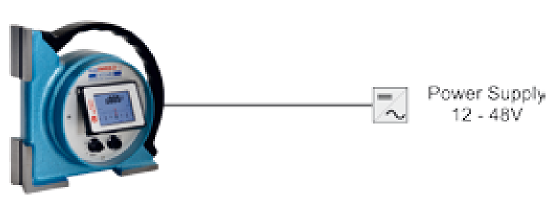
Dimensions nivelSWISS-D with horizontal and angular base

nivelSWISS-D TECHNICAL SPECIFICATIONS			
		Range I	Range II
Measuring range		± 0.750 mm/m ca. ± 150 Arcsec	± 0.150 mm/m ca. ± 30 Arcsec
Sensitivity		0.005 mm/m 1 Arcsec	0.001 mm/m 0.2 Arcsec
Settling Time, reading available after		<5 seconds (DIN 2256)	
Repeatability		5 µm/m	1 µm/m
up to ½ F.S. from ½ F.S. to F.S.		max. 1% of M.V. / min. 0.001 mm/m max. 1% of (2* M.V. - 0.5*F.S.)	
Data connection		RS232 / RS485, asynchr., 7 DataBits, 2 StopBits, no parity, 9600 bps	
Power supply with battery		1 x size C, total voltage 1.5V maximum Primary types: NiMH, NiCd, NiZn (ca. 16 hrs)	
External power supply		+5V (USB port) +24V DC (external power supply)	
Measuring faces	Horizontal type	1 flat face, 150 x 45 mm	
Measuring faces	Angular type	STANDARD: Two prismatic measuring bases horizontal and vertical, for diameters from Ø 20 up to Ø 120 mm	
Net weight (without case)	Horizontal type Angular type	3.700 kg 4.350 kg	

Possible configurations with nivelSWISS-D (Examples)



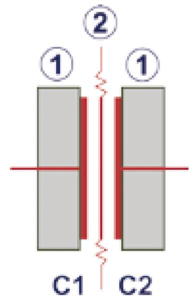
nivelSWISS connected to a laptop with the USB cable. The instrument is powered from the USB port



nivelSWISS with external 24V power supply

6.2 Capacitive measuring system

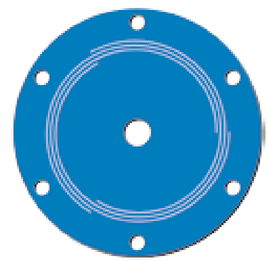
Measuring principle:



1: Ceramic electrodes

2: Pendulum

The rotationally symmetrical disk, the actual pendulum



The electronic levels with a capacitive measuring system are based on the measuring values on the pendulum properties of a friction-free supported disc weighing less than 1 gram. A two-phase frequency (4.8 kHz) is supplied to two electrodes which, together with the pendulum disc supported in the shielded and dustproof 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, and even overhead measurements are possible. The shielded sensor and the capacitive measuring principle make the system impervious to magnetic and electric fields.

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

Advantages of capacitive measuring systems:

- Shield against magnetic and electrical influences
- Very resistant to heavy acceleration and shock since the deflection of the pendulum is limited to a maximum of 0.3 mm
- Excellent rotational symmetry, due to the shape of the membrane

The concept of the measuring cell is used for handheld instruments as well as for the inclination measuring sensors. The different measurement systems differ only in the interpretation of the measured signals. We distinguish between analog and digital interpretation.

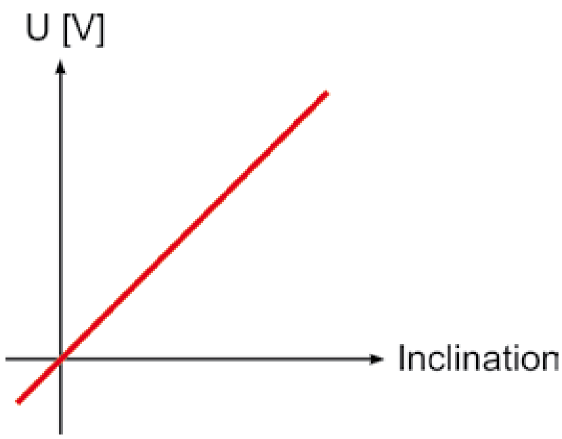
The analog measuring principle

The measuring principle is used in handheld instruments such as the BlueLEVEL.

Advantages of the **analog measuring principle**:

- The analog measuring principle is optimized for the measurement of straightness, flatness, etc. with handheld instruments because this measurement principle provides a stable value very quickly, which is very important for precise measurements and an efficient measurement process.
- Very insensitive to low-frequency interference, as can sometimes occur in machine tools.

Analog measuring principle



Measuring value of the system:
DC voltage

Output of the instrument:
DC voltage mV/unit
and/or
digital after A/D conversion

Unit: Radian [Rad]

The digital measuring principle

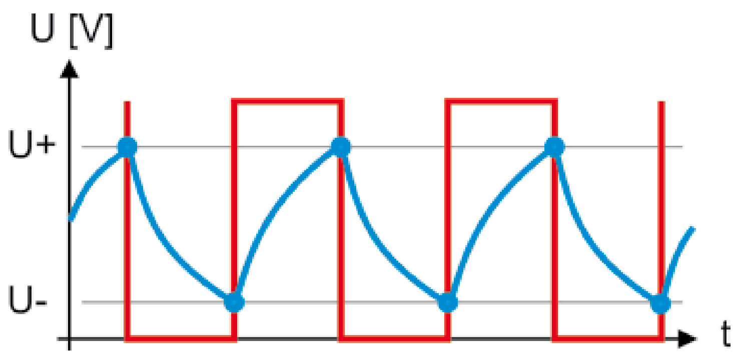
The digital measuring principle is used in all inclination measuring sensors, as well as in handheld instruments with greater measuring range, such as the CLINOTRONIC PLUS, the CLINO 2000 or the BlueCLINO.

Advantages of the **digital measuring principle**:

- Thanks to the measuring frequency of up to 20 measurements per second (ZEROTRONIC sensor) dynamic movements can be measured very precisely.*)
- Measuring frequency and data integration can be specified in a wide range and can be adjusted very flexibly to the measuring task
- Multiple sensors can be synchronized so that the filtering of external interference is possible

*) The dynamics are limited by the requirement of accuracy: rapid inclination changes can influence the measurement accuracy since external acceleration can be interpreted as a variation of the inclination. It is very important to analyze the measuring task accurately and adjust the measurement parameters for the sensor to the measurement conditions (see Chapter 7.2 : ZEROTRONIC sensors).

Digital measuring principle



Measuring value of the system:
Quotient of frequencies f_1 and f_2

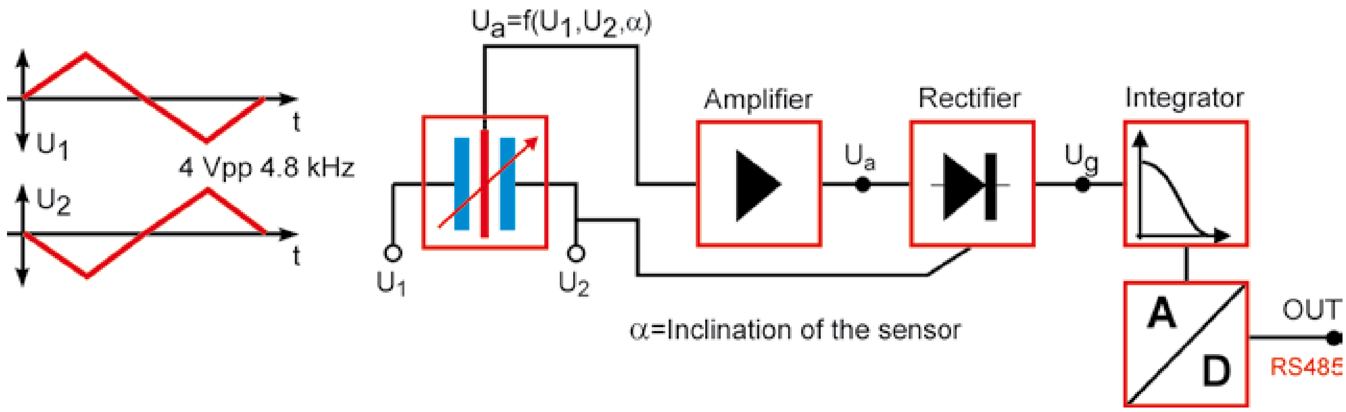
Output of the instrument:
digital

Unit: Radian [Rad]

HANDHELD MEASURING INSTRUMENTS WITH ANALOG SIGNAL PROCESSING

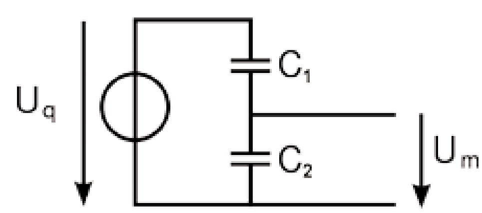
The following diagram shows the input voltage U_1, and U_2, with a frequency of 4.8 kHz and an amplitude of 4 Vpp (pp: peak to peak). The output signal is amplified (Amplifier) and then rectified (Rectifier). Then, the signal is "smoothed" (Integrator) and is available as a DC voltage ±2000 mV (1 mV / unit) at the output.

Simultaneously or alternatively, the analog signal is fed to an A / D converter and is available as a digital value in the WyBUS format at the RS 485-, or RS 232 output. The unit is Radian.



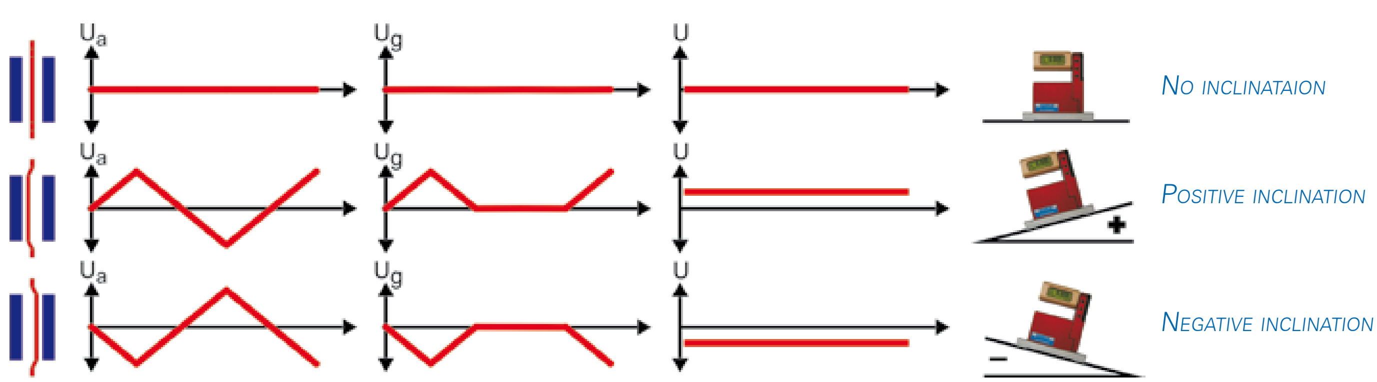
Schematic of an inclination measuring instrument with capacitive measuring system (BlueLEVEL + BlueLEVEL BASIC)

The two capacitors C_1 and C_2, formed by the two electrodes and the ground plate form a capacitive voltage divider. The voltage U_m depends on the position of the pendulum.



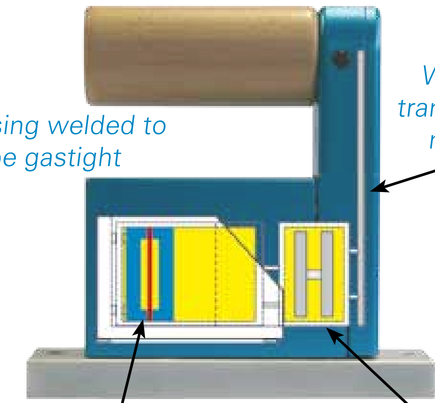
The corresponding formula is: $U_m = U_q \left(\frac{C_1}{C_1 + C_2} \right)$

The figure below shows the function of the analog measuring system and the relationship between the deflection of the pendulum (mass disc) and the analog output signal.



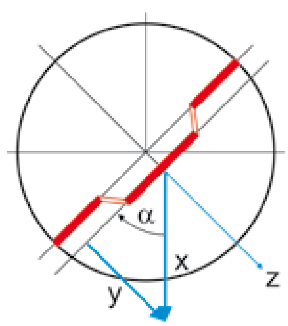
Our **SEALTEC technology** was developed in response to demand for instruments that perform under extreme environmental conditions such as high humidity and large temperature ranges. The sensor cells of the instruments are filled with nitrogen, and laser welded to be gastight.

Thanks to this engineering advancement, the BlueLEVEL and BlueLEVEL BASIC can be used in very difficult climatic conditions.

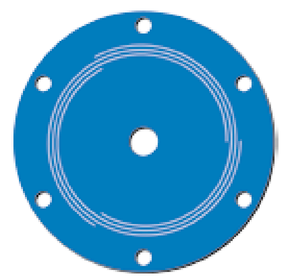


The picture shows a blue level with view of the sensor and the prints with wireless module

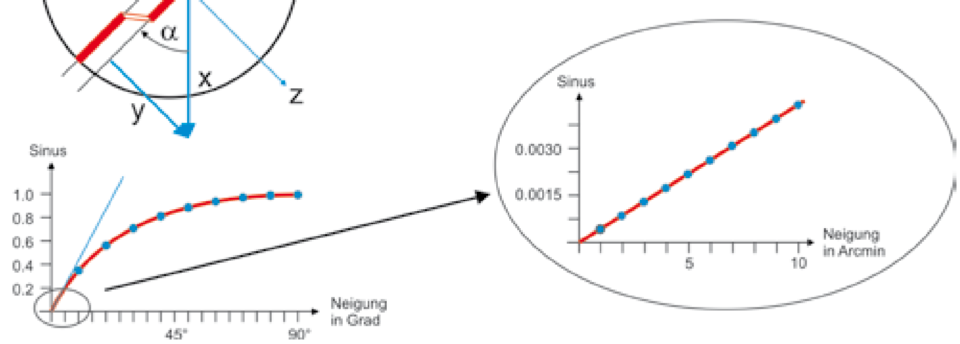
The deflection of the pendulum follows a sine function. For small inclinations up to about ±1 degree we are in the linear range of the sine curve (see right). The magnitude of the deflection depends of course on the material (module of elasticity), the thickness of the pendulum, the length and the air gap of the spiral.



X = Gravitation of pendelum
Y = f (sin α, X)
Z = Deflection of pendulum



For larger inclinations the curve corresponds to the sine function and is no longer linear. Accordingly, devices with greater measuring range have to be calibrated with so-called calibration points.



Sine of angle in a range up to 90 degrees

Sine of angle in a range from 0...10 Arcmin

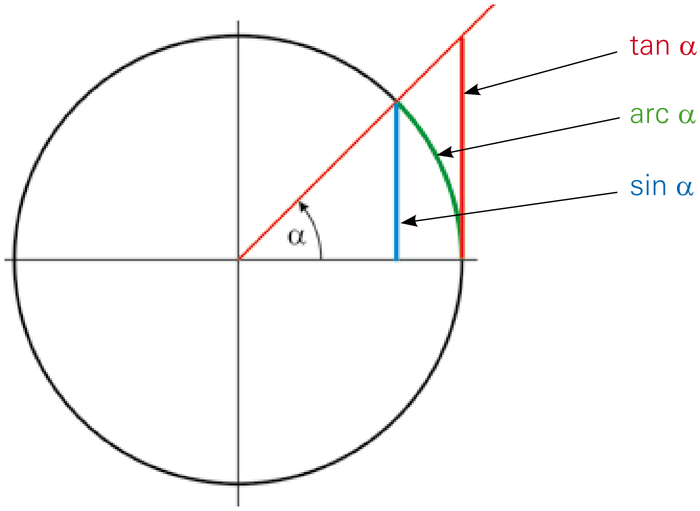
In measuring instruments with a smaller range, for example ±1 degree, the pendulum has to be more sensitive to the slightest inclination in order to achieve optimal resolution. This sensitivity is achieved in this case by a thin membrane with a long spiral spring. For larger ranges, a thicker pendulum with a shorter spiral length is selected.

Variable as a function of the measuring range:

- Thickness of the pendulum from 50 up to 100 μm
- Length of the spiral from 300° up to 630°

Deflection of the pendulum with a measuring range of ±10 degrees:

Deflection at an inclination of 1 μm/m: approx. **10 nm**

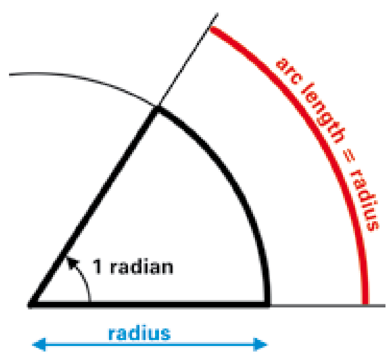


	sin α	tan α	arc α
α = 0.5°	0.0087266	0.0087269	0.0087266
α = 45°	0.70711	1	0.78540

As can be seen from the above list, the values for sin α, tan α and arc α up to an angle of 0.5° are identical to six decimal places. When the angle (inclination) increases, the values diverge continuously.

$$1 \text{ Rad} = \frac{360°}{2 \times \pi} = 57.30 \text{ degrees}$$

Important:
1 μRad = 1 μm/m
is only valid in the range of very small inclinations (angles)



The International system of units, abbreviated SI (International System of Units)

Number	Potency	Unit	SI prefix
0,000 000 000 000 000 001	10^{-18}	Trillionth	Atto
0,000 000 000 000 001	10^{-15}	Quadrillionth	Femto
0,000 000 000 001	10^{-12}	Trillionth	Piko
0,000 000 001	10^{-9}	Billionth	Nano
0,000 001	10^{-6}	Millionth	Micro
0,001	10^{-3}	Thousandth	Milli
0,01	10^{-2}	Hundredth	Zenti
0,1	10^{-1}	Tenth	Dezi
1	10^{-0}	One	
10	10^{1}	Ten	Deka
100	10^{2}	Hundred	Hekto
1 000	10^{3}	Thousand	Kilo
1 000 000	10^{6}	Million	Mega
1 000 000 000	10^{9}	Billion	Giga
1 000 000 000 000	10^{12}	Trillion	Tera
1 000 000 000 000 000	10^{15}	Quadrillion	Peta
1 000 000 000 000 000 000	10^{18}	Quintillion	Exa

6.2.1 The BlueSYSTEM / BlueLEVEL with BlueMETER

The BlueLEVEL in combination with BlueMETER is extremely suitable for precision measurements of small angles. This includes flatness measurements on surface plates in particular, and the measuring of geometrical features on machines of all kinds. The new sensor cell made of ceramic materials and equipped with high-tech electronics allows perfect applications even under extremely difficult environmental conditions with high humidity or in the rough environment of a workshop. The BlueLEVEL and the BlueLEVEL BASIC series can be equipped with wireless transmission to the BlueMETER, or BlueMETER BASIC equipped with a "Radio Module".

BlueLEVEL with angular base

The BlueSYSTEM is a systematic further enhancement of the well known and well established measuring instruments MINILEVEL NT and LEVELTRONIC NT. A BlueSYSTEM normally consists of one or two BlueLEVEL measuring instruments and a BlueMETER display unit. Depending on the application, the BlueMETER can also be connected to a PC with evaluation software allowing the on-line evaluation and presentation of the measured values.

The key features of this new series of instruments are:

- Compact and appealing design which is functionally optimized for precision measurement
- Wireless data transmission based on the internationally approved Bluetooth™ standard (option)
- Large and easily readable LCD display which can be read from both sides since the handle can be rotated
- There are 3 sensitivities available:
  - BlueLEVEL 1 µm/m: Range ±20 mm/m
  - BlueLEVEL 5 µm/m: Range ±100 mm/m
  - BlueLEVEL 10 µm/m: Range ±200 mm/m

The BlueLEVEL can be used as a standalone instrument, e.g. to adjust objects as well as for measuring of straightness of guideways. It can also be used as part of an engineering set.

A set of instruments, also called ENGINEER SET BlueSYSTEM, normally consists of one or two BlueLEVEL devices and one BlueMETER, forming the ideal tool for measuring flatness and machines under workshop conditions. Furthermore, the ENGINEER SET can be used for any levelling task or analysis of rotations.

The ENGINEER SET is specifically adapted to the needs of the metrology specialist taking care of machine tool components. There is a broad range of applications due to the ability to use differential measurements.

Thanks to its outstanding features and to the special carrying case the ENGINEER SET can be used in-house or taken along to customers.

BlueSYSTEM ENGINEERS SET in combination with a Laptop and MT-SOFT-software

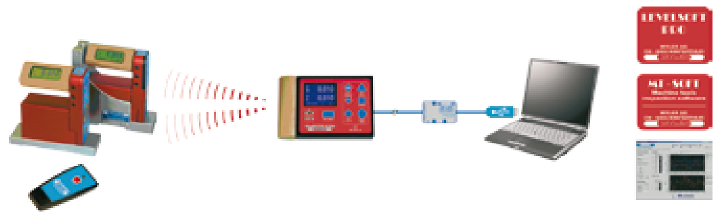
The image at the top right shows an engineer set with wireless data transmission from the measuring instruments to BlueMETER. The BlueMETER is also an interface between the measuring instruments and the PC/laptop.

The lower picture shows an engineer set connected by cables to the PC/laptop.

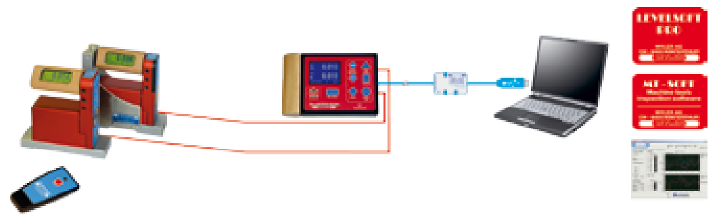
In each set, which is equipped with radio, the measurement data can be transmitted via the supplied cables. This can be advantageous if the user is in an environment where the use of wireless systems is impossible or prohibited.

Notes on measuring with wireless data transmission:

Why is a BlueMETER as an interface to PC/laptop needed, although Bluetooth is available on any PC or laptop?



Set with BlueLEVEL and BlueMETER SIGMA with wireless data transmission



Set with BlueLEVEL and BlueMETER SIGMA connected by cables

Justification for the use of an interface:

- There are different classes of Bluetooth systems, which directly affect the transmission distance. The Bluetooth components used in WYLER instruments guarantee a transfer of up to 100 meters
- With Bluetooth modules from a PC/laptop, only one device can be controlled. We need a module with multi-point capabilities
- Setting up the Bluetooth software on a PC/laptop is very complex
- The BlueMETER can be used as a pure display unit without the use of a measuring software. That is of great advantage if the measurement site is not properly accessible

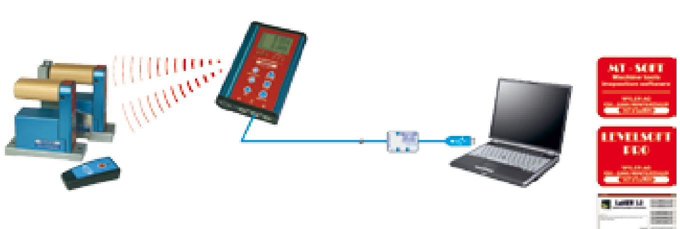
6.2.2 The BlueSYSTEM BASIC / BlueLEVEL BASIC with BlueMETER BASIC

The BlueSYSTEM BASIC forms part of the BlueSYSTEM family, the latest generation of electronic inclination measuring instruments and systems. The main difference between the BlueLEVEL BASIC and the BlueLEVEL are as follows:

Whereas the BlueLEVEL has an individual display in each of the instruments and can therefore be used as a standalone instrument, the BlueLEVEL BASIC requires a BlueMETER BASIC to display the measuring values. Furthermore, the measuring range of a BlueLEVEL is double the range of a BlueLEVEL BASIC.

The instruments of the BlueSYSTEM BASIC family can be equipped with wireless data transmission as well.

BlueSYSTEM BASIC ENGINEERS SET in combination with a Laptop and MT-SOFT-software



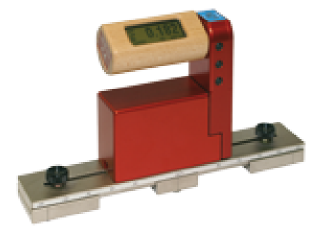
Set with BlueLEVEL BASIC and BlueMETER BASIC with wireless data transmission

The BlueSYSTEM measuring instruments are available in various configurations. The following images show a small variety of possible versions.

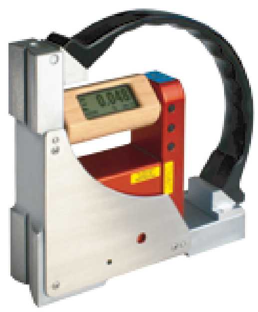

BlueLEVEL with horizontal base


BlueLEVEL with flat and prismatic angular base

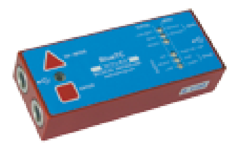

BlueLEVEL with horizontal base with a handle made of aluminium for clean rooms


BlueLEVEL with a flexbase for steplength from 90 up to 240 mm


BlueLEVEL mounted on a prismatic measuring base for large shafts up to a diameter of 600 mm

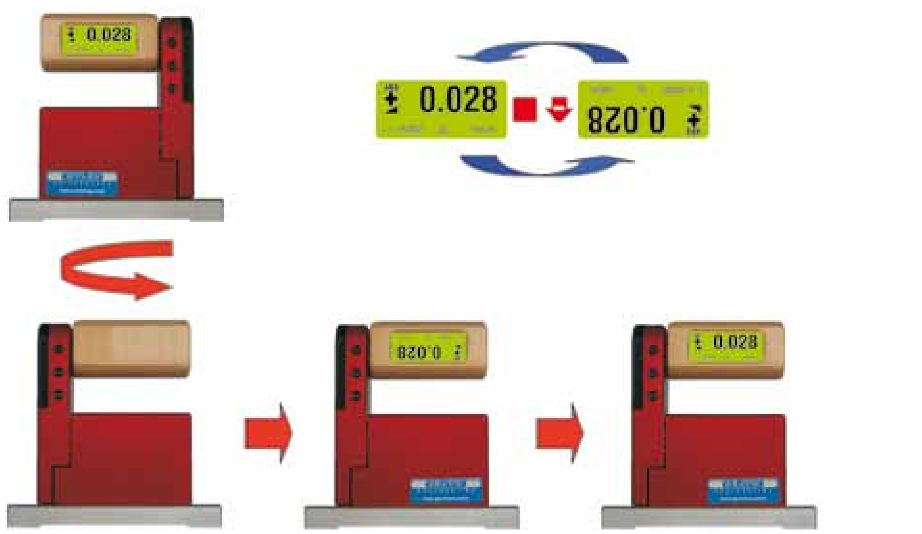

BlueLEVEL with flat and prismatic angular base and a nivelSWISS handle


BlueMETER


BlueTC (Transceiver/Converter)

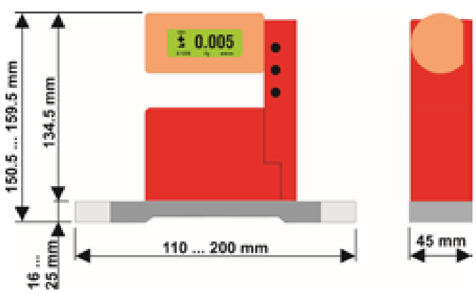

BlueMETER SIGMA

A special feature of the BlueLEVEL is mirroring the display. With this function in combination with the rotary handle bar, the values displayed can be perfectly seen from all possible angles. This function can be executed at all times, even when the instrument is remotely controlled by a BlueMETER.

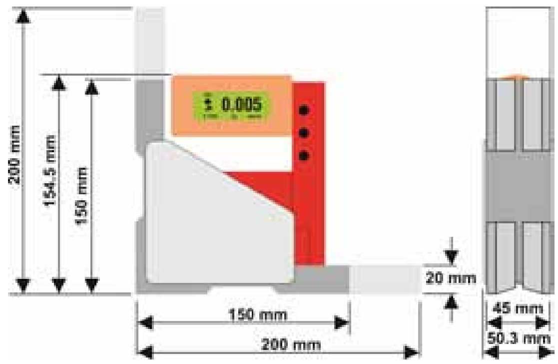


The measurement can be triggered by an infrared remote. The same applies in the case of the BlueSYSTEM BASIC.

For the BlueLEVEL and BlueLEVEL BASIC measuring instruments, various horizontal and angular measuring bases in different materials (cast iron, chrome-plated surfaces, hardened steel, chromium-plated surfaces, and aluminium hard-anodised with PTFE) as well as various dimensions (height and length) are available.

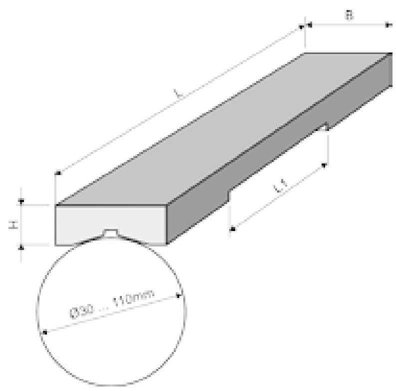


BlueLEVEL with horizontal base



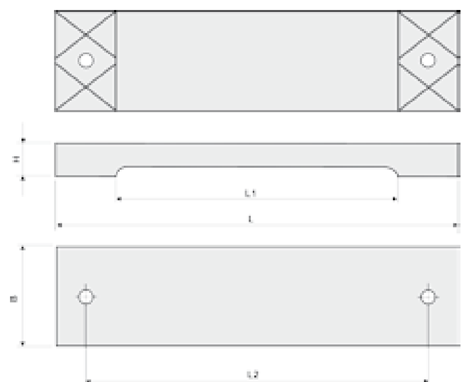
BlueLEVEL with angular base (cast iron only)

Dimensional drawings of the different versions of bases for BlueLEVEL and BlueLEVEL BASIC



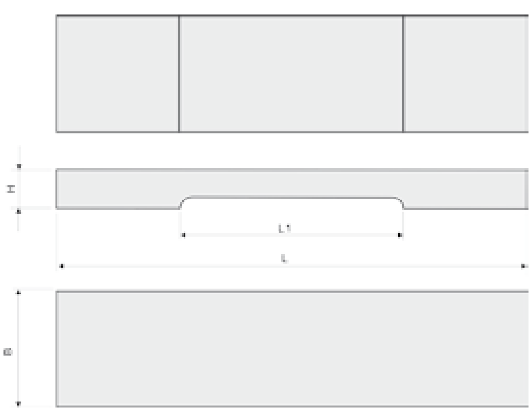
in [mm]

L	B	L1	H	Weight	
				Cast iron	*Aluminum*
110	45	40	15	0.436 kg	0.150 kg
150	45	50	19	0.790 kg	0.260 kg
200	45	80	24	1.300 kg	0.430 kg



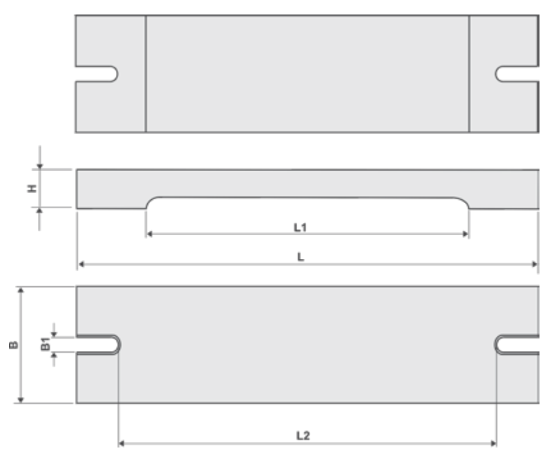
in [mm]

L	L1	L2	B	H	Weight	
					Hardened steel	*Aluminum*
110	68	-----	45	16	0.575 kg	0.192 kg
150	100	130	45	16	0.776 kg	0.258 kg
200	140	170	45	20	1.350 kg	0.450 kg



in [mm]

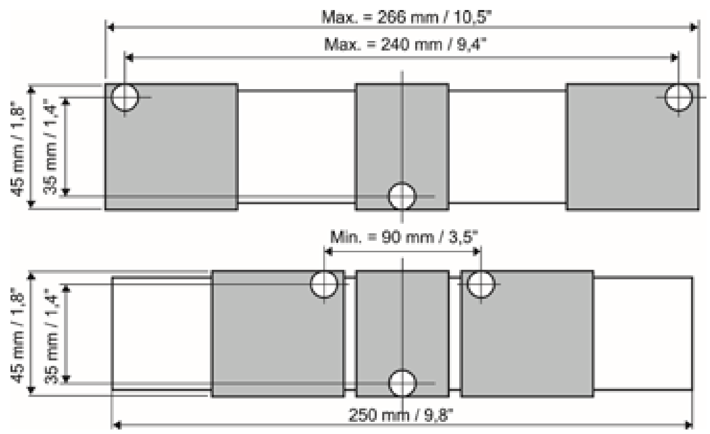
L	L1	B	H	Weight	
				Cast iron	*Aluminum*
110	40	45	16	0.600 kg	0.200 kg
150	50	45	20	0.760 kg	0.251 kg
200	80	45	24	1.250 kg	0.413 kg



in [mm]

L	L1	L2	B	B1	H	Weight	
						Cast iron	*Aluminum*
150	100	113	45	7	16	0.760 kg	0.253 kg
200	140	162	45	7	20	1.250 kg	0.417 kg

Inch - scale



mm - scale

FLEXBASE TECHNICAL SPECIFICATIONS	Dimensions	
Base length / base width	9.8" x 1.8"	250 mm x 45 mm
Adjustable step length / standard	3.5" ... 9.4"	90 mm ... 240 mm
Extended range (adjustable step length)	2.75" ... 10.6"	70 mm ... 270 mm
Dimensions of three-point Tungsten carbide bases	Diameter = ~ 3/8 inch Distance width = 1.4 inch	Diameter = 10 mm Distance width = 35 mm

TECHNICAL DATA FOR THE RADIO TRANSMISSION BLUESYSTEM (IF AVAILABLE)		
SENDER / RECEIVER BlueSYSTEM with Bluetooth™ wireless technology	Frequency:	ISM-Band / 2,4000 - 2,4835 GHz
	Modulation:	FHSS (Frequency Hopping Spread Spectrum)
	Net structure used	Point to point / Point to multi-point
	RF output power	max. +17 dBm / Class 1
	Sensitive level receiver	-80 dBm

BLUELEVEL TECHNICAL SPECIFICATIONS			
Sensitivity	1 µm/m 0.2 Arcsec	5 µm/m 1 Arcsec	10 µm/m 2 Arcsec
Display range	±20 mm/m	±100 mm/m	±200 mm/m
Limits of error <0.5 full-scale (DIN 2276)	max. 1% of measured value + min. 1 digit		
Limits of error >0.5 full-scale (DIN 2276)	max. 1% of (2 x measured value - 0.5 x full-scale)		
Temperature error / °C (Ø10 °C) / DIN 2276	up to 2000 µm/m: max. 2 µm/m up to 20000 µm/m: max. 20 µm/m	up to 10000 µm/m: max. 10 µm/m up to 100000 µm/m: max. 100 µm/m	up to 20000 µm/m: max. 20 µm/m up to 200000 µm/m: max. 200 µm/m
Settling time, value available	within 3 seconds		
Digital output	RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps		

BLUESYSTEM BASIC TECHNICAL SPECIFICATIONS			
Sensitivity	1 µm/m 0.2 Arcsec	5 µm/m 1 Arcsec	10 µm/m 2 Arcsec
Display range	±10 mm/m	±50 mm/m	±100 mm/m
Limits of error <0.5 full-scale (DIN 2276)	max. 1% of measured value + min. 1 digit		
Limits of error >0.5 full-scale (DIN 2276)	max. 1% of (2 x measured value - 0.5 x Full-scale)		
Temperature error / °C (Ø10 °C) / DIN 2276	up to 2000 µm/m: max. 2 µm/m up to 10000 µm/m: max. 15 µm/m	up to 10000 µm/m: max. 10 µm/m up to 50000 µm/m: max. 75 µm/m	up to 20000 µm/m: max. 20 µm/m up to 100000 µm/m: max. 150 µm/m
All other specifications are the same as for BlueSYSTEM			

The key features of these new series of instruments are:

- Compact and pleasant design which is functionally optimized for precision measurement
- Wireless data transmission based on the internationally approved Bluetooth™ standard (Option)
- Large and easy-to-read LCD display which can be read from both sides since the handle can be rotated
- Each instrument has its own specific address allowing the use of several independent systems in the same room without interfering with each other
- Since each instrument has a built in infrared-receiver, the measurement can be initiated at any instrument
- There are three sensitivities available:
  - BlueLEVEL 1 µm/m: Range ±20 mm/m
  - BlueLEVEL 5 µm/m: Range ±100 mm/m
  - BlueLEVEL 10 µm/m: Range ±200 mm/m
- Linearity according to DIN 2276
- All instruments are equipped with RS 232 / RS 485 interfaces
- Powered by standard 1.5V batteries type "C"
- In compliance with CE regulations and all applicable EMC regulations

BlueSYSTEM, consisting of BlueLEVEL, BlueMETER SIGMA and IR-Zapper

The main features of the BlueSYSTEM BASIC instrument are the same as for BlueSYSTEM, but with the following differences:

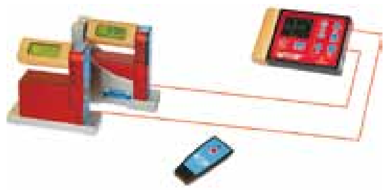
- No individual LCD display
- There are three sensitivities available:
  - BlueLEVEL 1 µm/m: range ±10 mm/m
  - BlueLEVEL 5 µm/m: range ±50 mm/m
  - BlueLEVEL 10 µm/m: range ±100 mm/m

BlueSYSTEM BASIC, consisting of BlueLEVEL BASIC, BlueMETER BASIC and IR remote

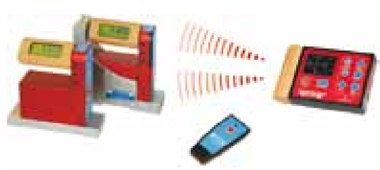
Typical configuration of an engineer set for BlueSYSTEM or BlueSYSTEM BASIC:

- 1 BlueLEVEL or BlueSYSTEM BASIC, horizontal version
  BlueLEVEL or BlueSYSTEM BASIC with horizontal base, flat contact surfaces of hardened steel, precision lapped, with dust grooves, base length 150 mm, sensitivity 1 µm/m
- 1 BlueLEVEL or BlueSYSTEM BASIC, angular version
  BlueLEVEL or BlueSYSTEM BASIC with angular base, made of cast iron, contact surfaces hand scraped, horizontal and vertical bases prismatic, base length 150 mm, sensitivity 1 µm/m (can be used to measure vertical and horizontal planes and shafts)
- 1 BlueMETER/BlueMETER SIGMA or BlueMETER BASIC
- 2 cables, length 2.5 m each

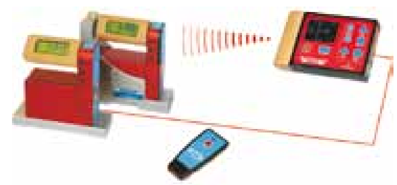
Overview of possible configurations with BlueSYSTEM (BlueMETER SIGMA ans BlueTC)



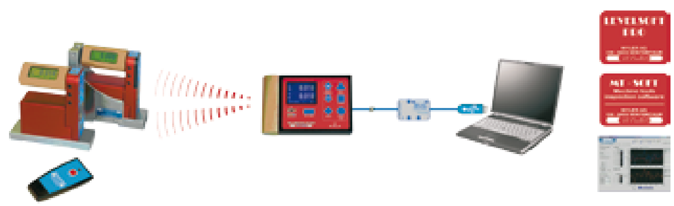
Set with BlueLEVEL and BlueMETER SIGMA connected by cables



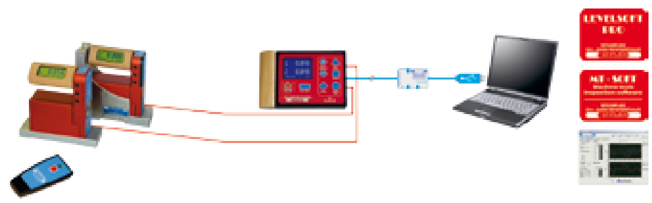
Set with BlueLEVEL and BlueMETER SIGMA with wireless data transmission



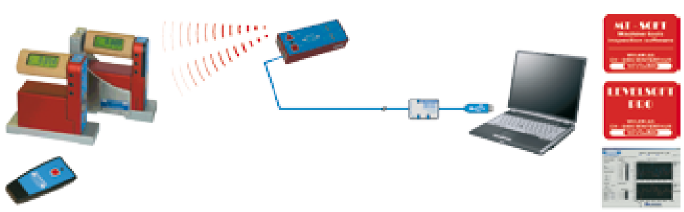
Set with BlueLEVEL and BlueMETER SIGMA with wireless data transmission and connected by cables, mixed version.



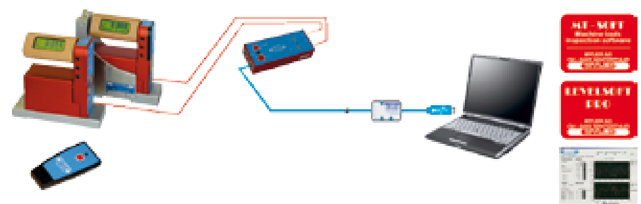
Set with BlueLEVEL and BlueMETER SIGMA with wireless data transmission



Set with BlueLEVEL and BlueMETER SIGMA connected by cables



Set with BlueLEVEL and BlueTC with wireless data transmission



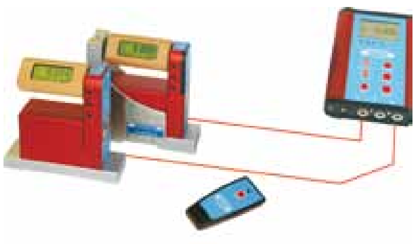
Set with BlueLEVEL and BlueTC connected by cables

BlueMETER SIGMA TECHNICAL SPECIFICATIONS	
Digital output	RS232, asynchronousous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Resolution	depends on the measuring instruments / sensors connected
Power supply with batteries	2 x Size “C”, max. 3 volt (for ca. 20 hrs)
External power supply	+24V DC
Resolution	depends on the measuring instruments / sensors connected
Operating temperature range Storage temperature range	0 ... + 40 °C - 20 ... + 70 °C

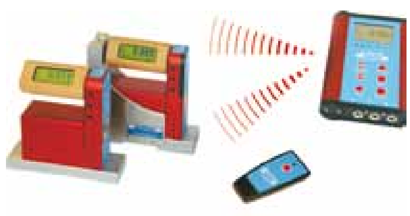
BlueTC TECHNICAL SPECIFICATIONS	
Format of transmission	RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
External power supply	+5V DC, max. 450 mW (PIN 3) or 8…28 V DC (PIN 1)
Operating temperature range	0 ... +40 °C

Overview of possible configurations with BlueSYSTEM

BlueSYSTEM

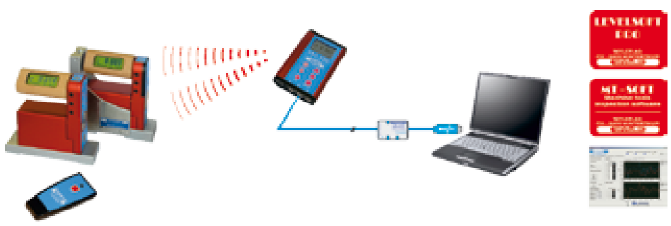


Set with BlueLEVEL and BlueMETER connected by cables

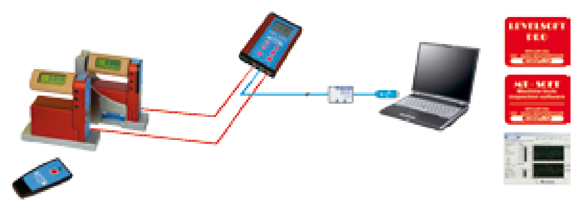


Set with BlueLEVEL and BlueMETER with wireless data transmission

Set with BlueLEVEL and BlueMETER with wireless data transmission and connected by cables, mixed version.

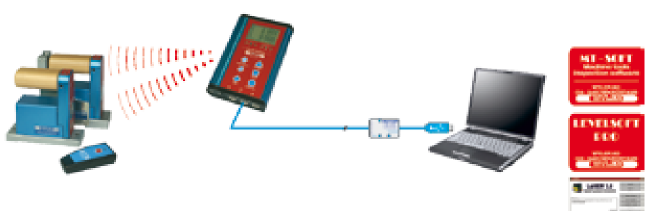


Set with BlueLEVEL and BlueMETER with wireless data transmission

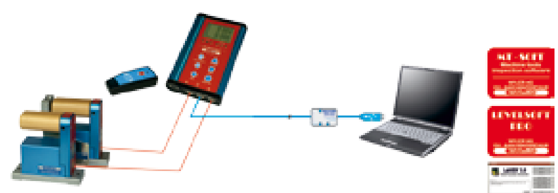


Set with BlueLEVEL and BlueMETER connected by cables

BlueSYSTEM BASIC



Set with BlueLEVEL BASIC and BlueMETER BASIC with wireless data transmission



Set with BlueLEVEL BASIC and BlueMETER BASIC connected by cables

BlueMETER + BlueMETER BASIC TECHNICAL SPECIFICATIONS	
Display available	within 3 seconds
Digital output	RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity,9600 bps
External power supply	8…28 V DC
Operating temperature range	0 ... +40 °C

BlueMETER BASIC

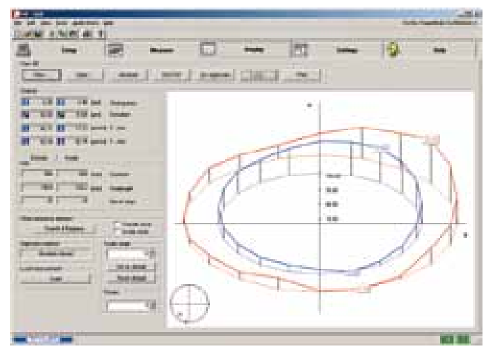
BlueMETER

6.3 Application Software

There are three software products available for measuring objects:

- **LEVELSOFT PRO**
  This software is a basic solution for measuring
  - Lines (straightness)
  - Lines with twist (torsion)
  - Parallelism
  - Squareness
  - Measuring the flatness of surfaces
  - Measuring of geometrical components on machines

- **MT-SOFT** (Machine Tools Inspection Software)
  MT-SOFT is a sophisticated software for the measurement of machine parts on machine tools such as:
  - All types of horizontal and vertical guideways
  - Rotating axis, e.g. rectangularity between the horizontal surface of a working table and a vertical spindle
  - Rotation of machine tool components: PITCH and ROLL
  - Circles: flatness and angular deviations of circular horizontal paths
  - Partial surfaces: flatness and relative position of several independent surfaces (co-planarity)
  - LEVELSOFT PRO, the well known software LEVELSOFT PRO to measure flatness as well as straightness is also available as an optional module within MT Soft



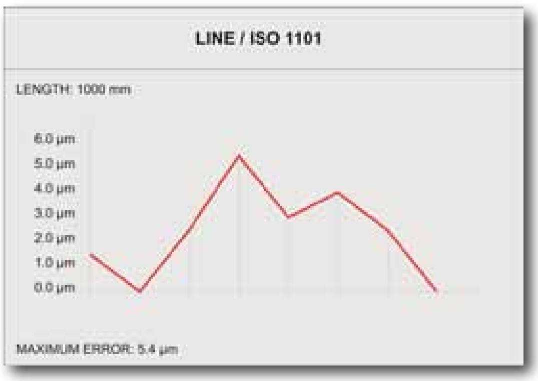
- **LabEXCEL** (LabView® Application)
  The software LabEXCEL is an easy-to-operate software for displaying the measuring values of WYLER hand held measuring instruments. The software is based on the programming environment of LabVIEW™ by National Instruments. The core is the WYLER WyBus module. This module ensures the communication between the inclination measuring instruments and the user interface of LabVIEW™.

6.3.1 Analyzing in combination with WYLER LEVELSOFT PRO software

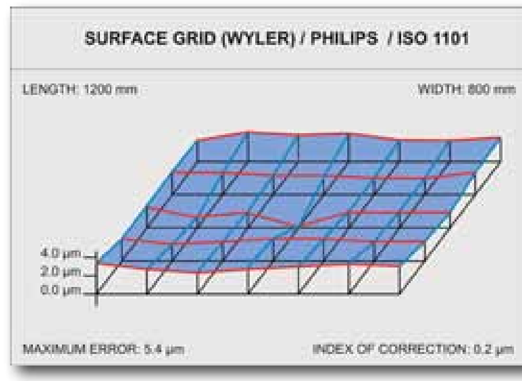
The WYLER LEVELSOFT PRO software for flatness and geometry measurements is a software application well-proven in practical use, and based on ISO 1101 for measuring lines and surfaces. It is continuously being enhanced according to the requirements of users.

The following measurements can be performed with WYLER software for flatness and geometry measurements using LEVELSOFT PRO in combination with suitable measuring instruments:

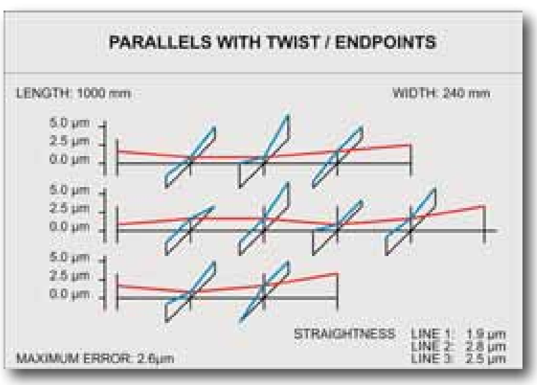
- Lines (straightness)
- Lines with twist (torsion)
- Parallelism
- Squareness
- Measuring the flatness of surfaces
- Measuring of geometrical components on machines



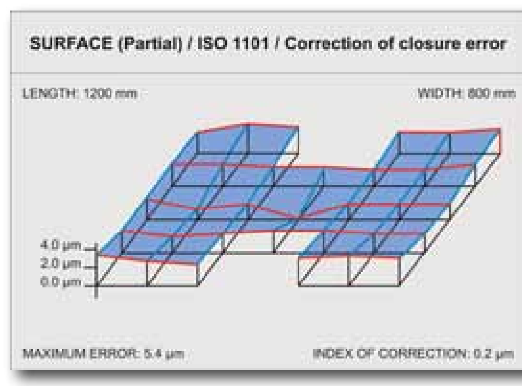
Straightness of lines with or without twist, in accordance with ISO1101



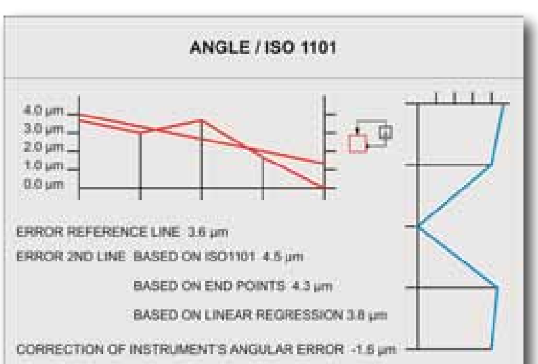
Flatness in accordance with DIN876 / ISO1101



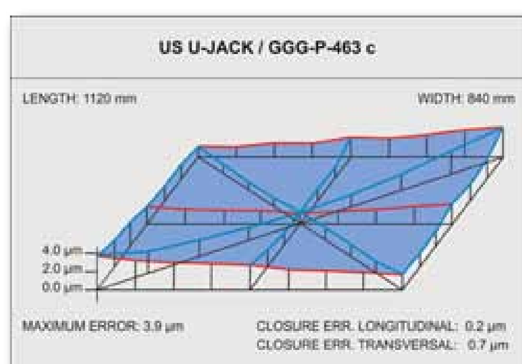
Parallels in accordance with endpoints with or without twist



Flatness of partial surfaces in accordance with DIN876 / ISO1101



Squareness in accordance with ISO1101



Flatness in accordance with US GGG-P-463c standard

What needs special attention when measuring?

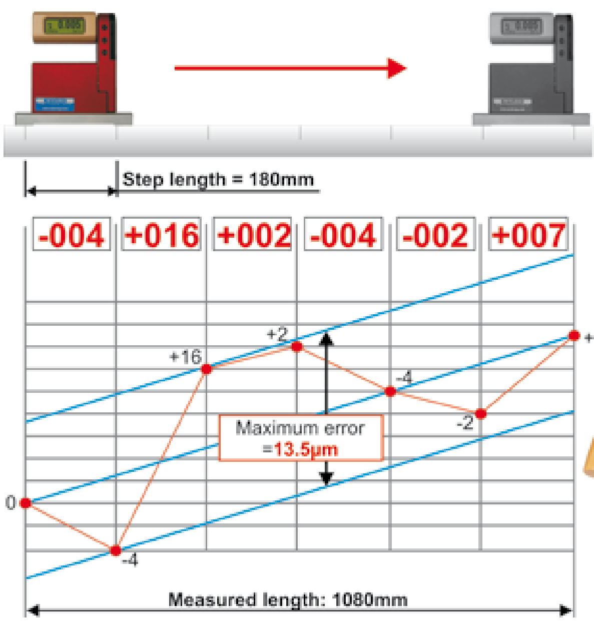
- Influence of temperature:
  A temperature difference of 1 degree Celsius between the upper and the lower side of a plate of 1m length already results in a deformation of the plate of 6 to 7 μm.

- Choice of measuring base:
  For the measurement of a surface:
  Ideal measuring base: Flat steel base with dust grooves

- Measuring step length:

Length of the base	Optimal step length	Recommended step length
110 mm	90 mm	85 ... 105 mm
150 mm	126 mm	120 ... 145 mm
200 mm	170 mm	160 ... 190 mm
SPECIAL BASE (Flexbase)		

The terms are explained in more detail with the aid of a line measurement by hand



Maximum error (straightness) =

$$\frac{15.5\,\mu m \times 180\text{ mm}}{1000\text{ mm}} = 2.79\,\mu m$$

A measuring bar 1080 mm in length is to be measured for straightness. The BlueLEVEL has a base length of 200 mm. According to the above list, a step length of 180 mm has been chosen. The chosen step length will be marked on the measuring bar with a fine line.

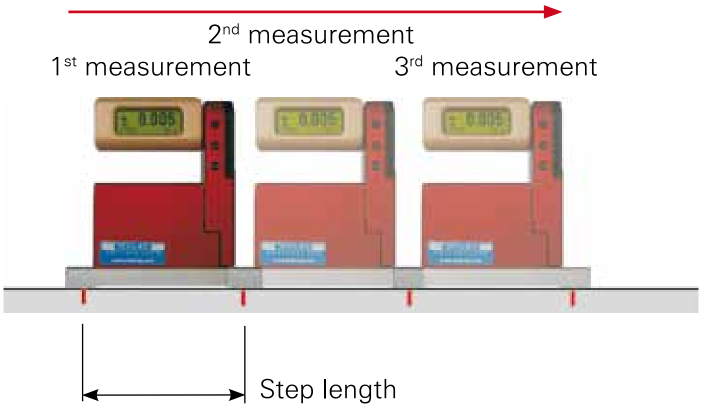
For the measurement it is now important that

- the temperature of the object and the instrument are identical
- the individual measurements are **overlapping**, which means that the beginning of a measurement is always the same as the end point of the previous measurement
- the measuring instrument has to be moved in the direction of the cable connector
- you wait for about 5 to 8 seconds after moving the instrument to stabilize the sensor of the instrument

The thus measured values are marked in a corresponding graph and the individual measuring points have to be connected to each other. We then connect the two end points (in our example starting point (0) and last measuring point (+7)) with a straight line. Parallel to this line, we draw an additional line on each side through the most distant points. The vertical distance between these parallels corresponds with the straightness of the measured line, resp. of the measured setting straight edge. In our example, these are supposedly 15.5 μm. Why supposedly?

For simplicity, we have taken over the readings of the display from the BlueLEVEL into the graph. The unit of the value displayed on the instrument is x μm/m. In fact, we would have to reduce each measured point to the step length of 180 mm. We now obtain this, by converting the intermediate result of 15.5 μm to 180 mm and thus obtain an effective straightness of 2.79 μm. When measuring the straightness with the software, this is not an issue since the measured values are directly converted to the step length.

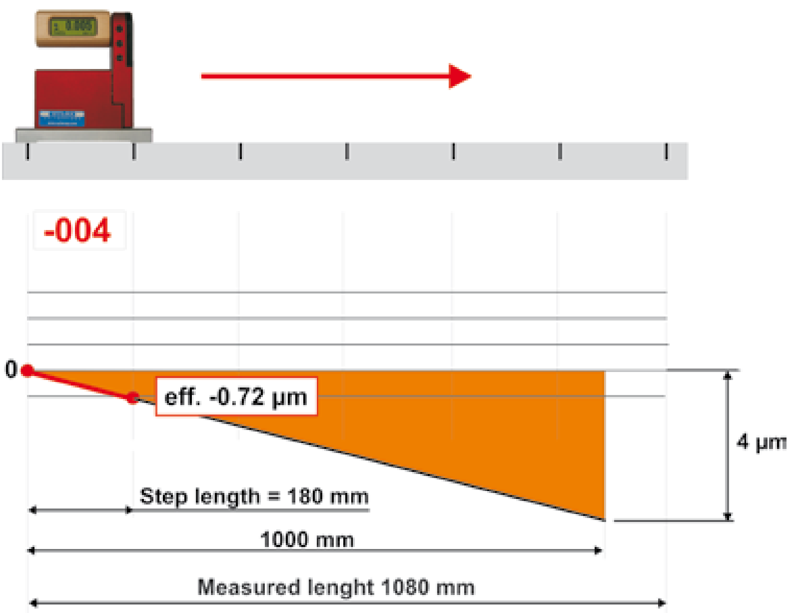
Comments on step length and overlap of measurements



The individual measurements must always be **overlapping**, i.e. the starting point of the new measurement corresponds exactly to the endpoint of the previous measurement (see picture left).

The measurement is always in the direction of the connector on the instrument.

Comments regarding display on measuring instrument and the effective measurement reading



Following the first measurement, the display on the instrument shows -4 μm/m. This corresponds to a height difference of -4 μm relative to a base length of 1000 mm.

Relative to a base length of 180 mm, the height difference corresponds to -0.72 μm only.

When measuring with a software, the value displayed is directly converted to the step length and displayed.

Possible causes of measurement errors are:

- Temperature difference between the measuring base and the object to be measured
- Change in position of the object during the measurement, and/or vibrations
- Careless measurement
- Dirty surface of the object to be measured
- The display on the instrument is not stabilized before pressing the remote release
- No resp. insufficient overlap in measurement
- Warped or worn measuring base
- “Short wave“ hump-like surface defects, which can not properly be captured by the measuring base provide no clear support (unstable measuring base means poor repetition)

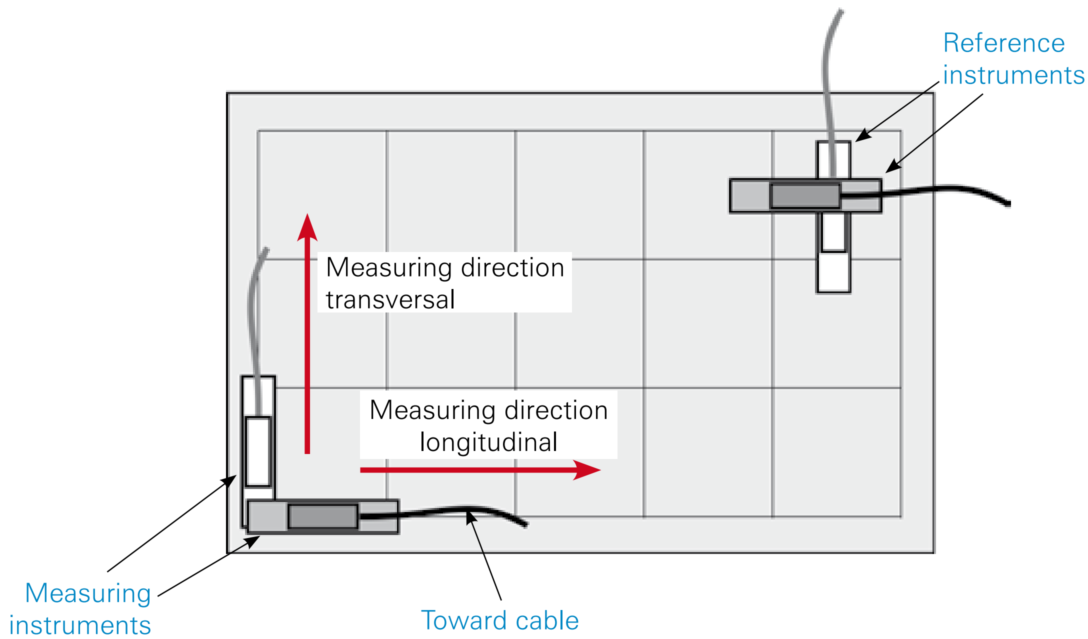
If these criteria, or conditions are not met, this affects the measurement uncertainty. The more accurate the measurement should be, the more time must be given to preparation and measurement.

Further principles for measuring inclinations

Measuring direction

To ensure accurate measurements, it is important to:

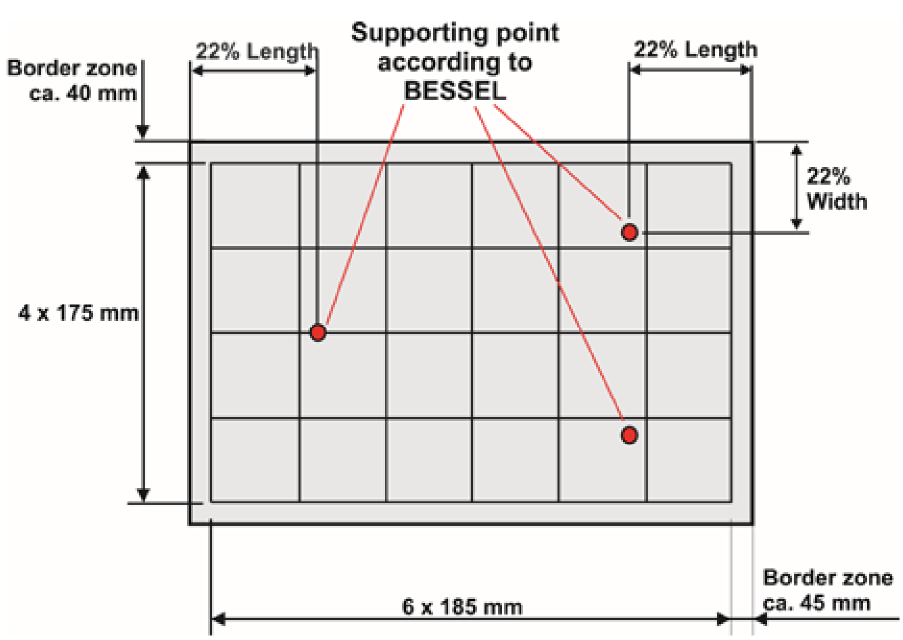
- Always move the instrument toward the cable from left to right or from front to back
- Touch the instruments only by using the handle (temperature)



The supporting points of a surface plate according to Bessel (Bessel Points)

Friedrich Wilhelm Bessel (1784 – 1846) was a German mathematician, astronomer, and systematizer of the Bessel functions (which were discovered by Daniel Bernoulli). He was a contemporary of Carl Gauss, also a mathematician and astronomer.

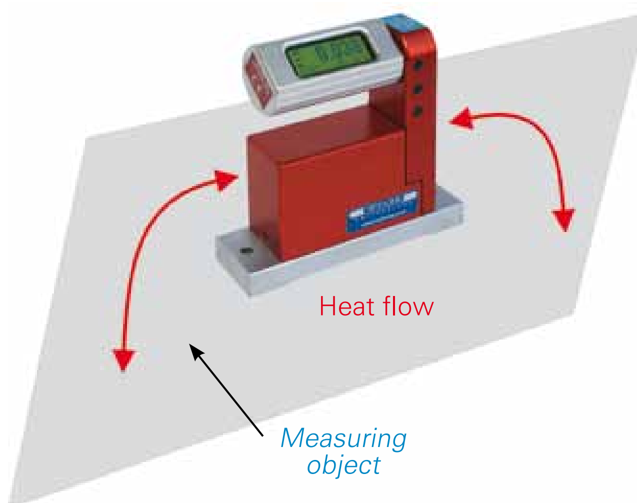
In simplified terms, it can be said that a measuring and control plate that is placed on three supports bends the least when the supports are placed at 22% of the length or width.



Influence due to the temperature differences between the instrument and the object to be measured:

Temperature differences within the workpiece or between the workpiece and the measuring base have a great influence on the accuracy of the measuring results. The following chapter deals with some of these related problems.

A temperature difference between the measuring base and the object to be measured causes a heat flow. The amount of such a heat flow depends on the area of contact, the difference in temperature, the materials of base and object as well as on the base length and the cross-section of the measuring base.



In the base a temperature lamination occurs, which bends and warps the base because of material expansion. This results in constantly changing the area of contact, which in turn changes the flow of heat. Consequently, the measuring base is constantly in motion until temperature equivalence is achieved. These partially brisk motions can be observed by the continuously changing of the instrument's display value.

The temperature dependant volume changes of the base itself are also visible in the instrument's display value.

Important:

- Before conducting of a precision measurement, the temperature of the instrument and the object must be checked.
- The time for temperature acclimatization of the instrument's base depends on the temperature difference and the material used and will take between 30 minutes and 2 hours.

Influence of temperature differences within the measuring object

The influence of the temperature difference within a measuring object can be demonstrated with the formula applied for calculating the deviation from flatness of a Diabas granite surface plate. The formula is valid for stable conditions only and deals with the difference of temperature between the bottom of the plate and the top of the plate.

Deviation from straightness (X)

$$\boxed{X = \frac{D_T * a * L^2}{8 * B} \quad \text{in [m]}}$$

D_T: Temperature difference between top and bottom of the plate in deg. Kelvin
a: Coefficient of expansion of granite in (m) per deg Kelvin ($5.6 * 10^{-6}$ [m/°K])
L: Length of the plate (m)
B: Thickness of the plate (m)

About the LEVELSOFT PRO software

The handling of the LEVELSOFT PRO software is intuitive and very clearly laid out. To use the software a license is required.

The software has the following characteristics:

- Different languages can be selected. It is possible to measure in one language (e.g. German) and to print the report in a other language (e.g. English)
- It is possible to create templates for repetitive measurement tasks
- Customized measuring protocols including the client's logo can be printed
- The closure error caused by the measurement can be inferred visually. The corresponding correction index appears
- Depending on the measurement, different alignment methods such as adjustment according to the end-point method, ISO 1101 and linear regression are possible
- The values of individual data points can be displayed on the screen and the report can be printed with or without these values
- The measured values can be entered manually if necessary
- The limit of variation can be selected. In heavy vibration caused by the environment, the scattering threshold can be increased. Thus also "less accurate" values are read, which increases uncertainty

Closure error correction according to Philips and alignment method according to ISO 1101

Introduction to the closure error correction according to "PHILIPS"

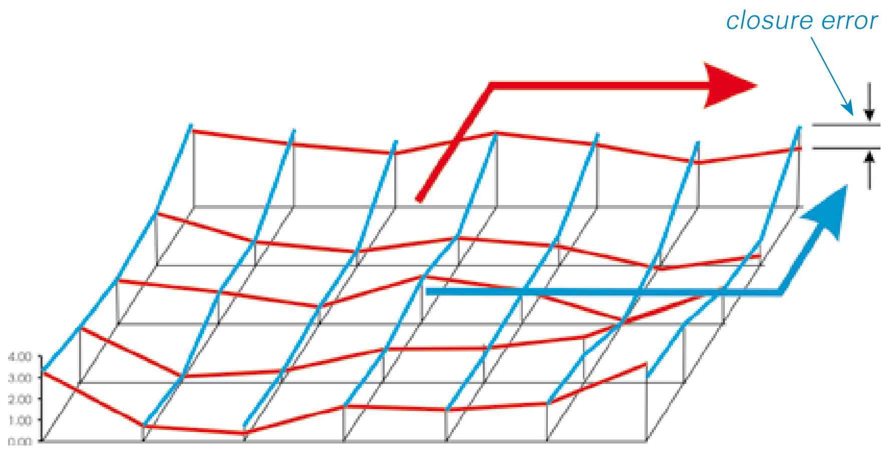
The closure error correction according to PHILIPS is used in the WYLER grid flatness measuring method. At the end of a measurement, the result (flatness of a surface) can be displayed in two versions:

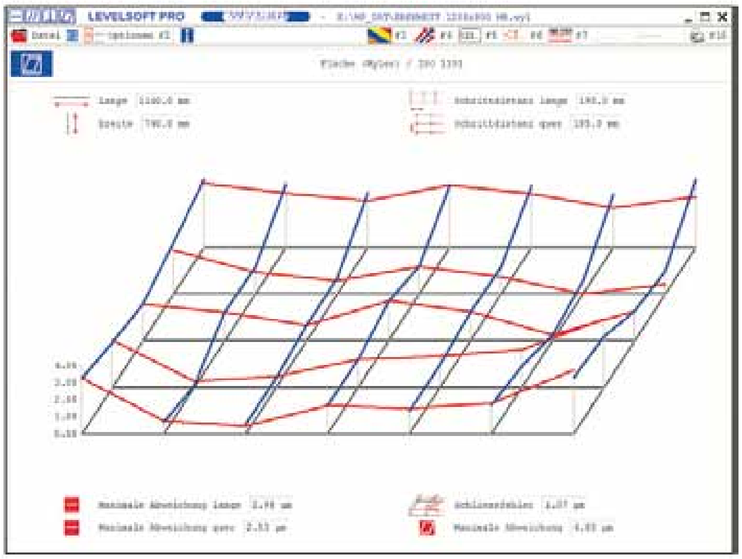
- without correction of the closure error
- with correction of the closure error

When the version without the correction of the closure error is used, all these errors will be seen in numerical and graphical form. The so-called closure error is an indication of the quality of the measurement.

Definition of the
"CLOSURE ERROR"

The CLOSURE ERROR is the LARGEST DEVIATION of a measuring point in an over-determined grid when the calculation of the height at this measuring point is done by using different paths (see illustration at the right).



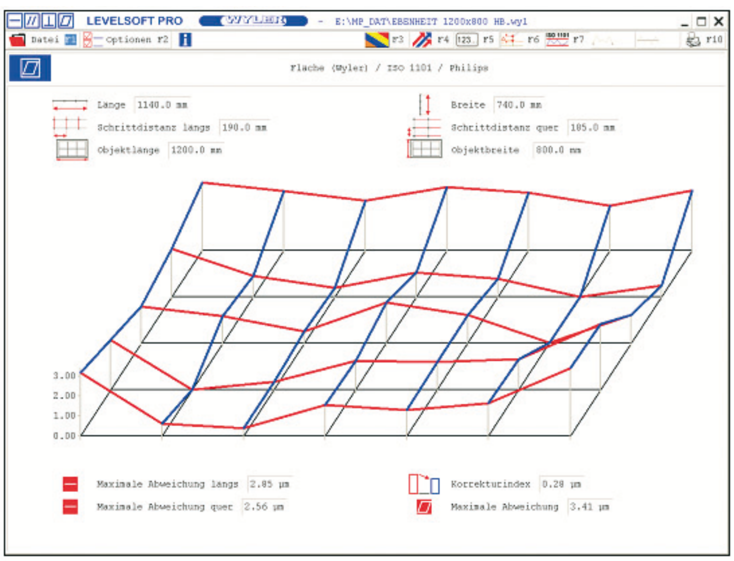


Display of a flatness measurement without correction of the closure error according to PHILIPS

The correction of the closure error according to PHILIPS is a mathematical process by which a closure error of linearly spreading characteristic can be successfully corrected and eliminated.

After the closure error correction a so called "Index of correction" is an indication of the "success" of the mathematical treatment. (the "Index of correction" is the result of the standard deviations of all the closure error corrections)

THE LARGER THE INDEX OF CORRECTION, THE LARGER THE MEASURING UNCERTAINTY



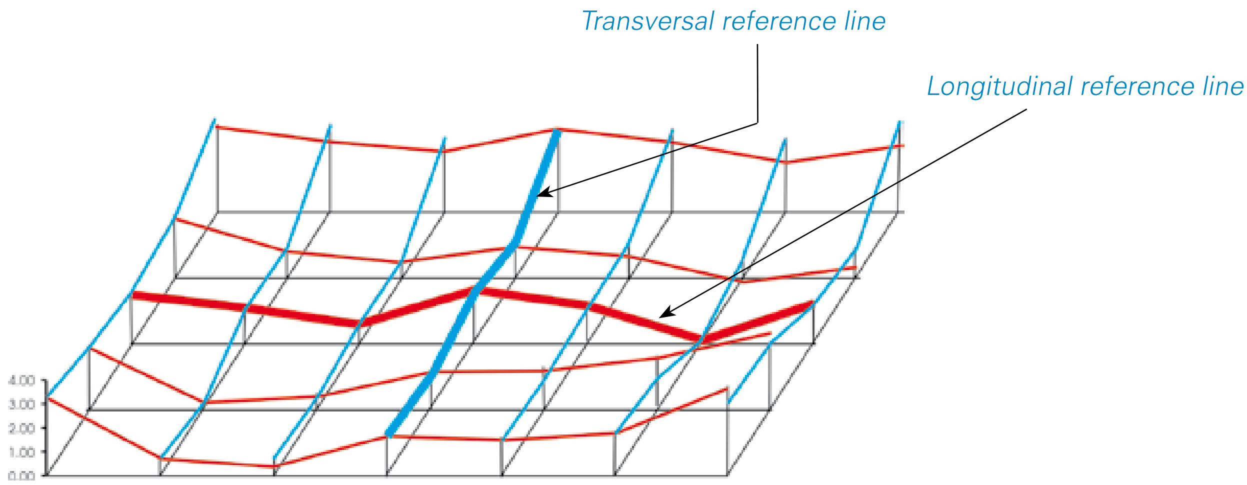
Display of a flatness measurement with correction of the closure error according to PHILIPS

Remarks regarding closure error correction:

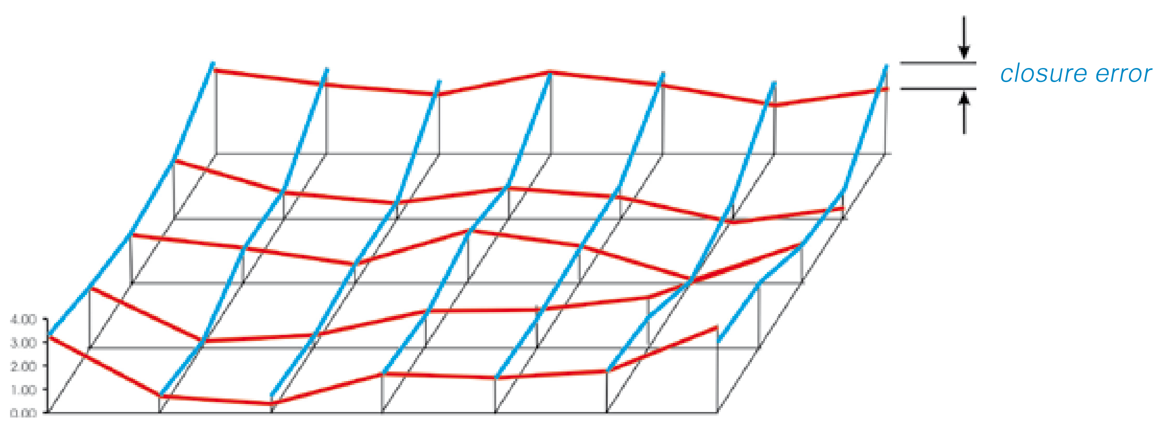
- After finishing a measurement, the display of the grid without correction of the closure error must be consulted. The closure error is an important indicator of the quality of the measurement and the measuring uncertainty.
- Normally the closure error should not exceed 20% to 25% of the maximum error.
- Exception: When the maximum error is <4 μm, the percentage of the closure error may be larger.
- In the previously shown example the closure error of 26% (1.07 μm related to 4.03 μm) is still acceptable because the maximum error is quite small 4.03 μm.

Closure error / alignment method according to ISO1101

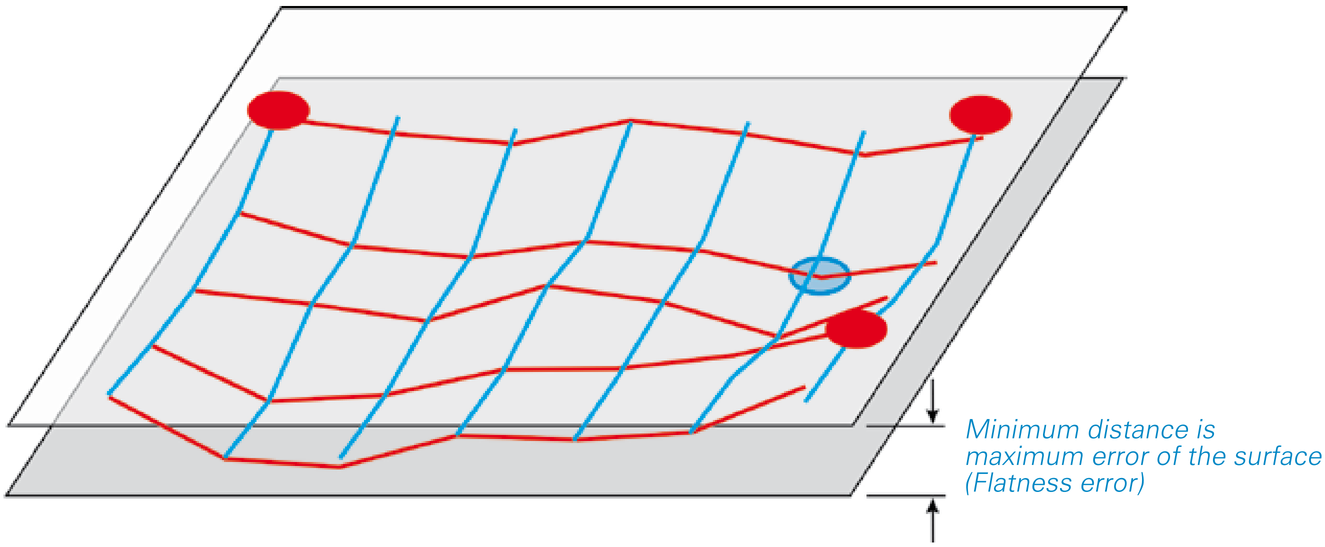
- The angular relationship of all measurements taken in the longitudinal and the transversal direction must remain unchanged.
- The lines in the centre of the longitudinal and the transversal directions are used as reference line. Should the number of lines in a direction be even, the line closer to the first longitudinal or transversal line is used as reference line.



- Both reference lines are adjusted to connect at an even elevation at their intersection (same height).
- All other longitudinal and transversal lines are moved up or down until they cross the reference line at the even elevation.
- The largest deviation in height of two lines crossing is the closure error of the measurement.



- Two virtual flat parallel surfaces making contact with the measured grid surface at the highest and the lowest points are turned freely in space until the distance between the two virtual surfaces is the minimum. This distance is the FLATNESS ERROR ACCORDING TO ISO 1101



Remarks:

Both parallel virtual surfaces make contact with the measured grid on four points. Three options are possible:

- Option 1:
  Three contact points on top and one on the bottom (The one single point must lay within the triangular area created by the three other points)
- Option 2:
  Three contact points on the bottom and one on top (The one single point must lay within the triangular area created by the three other points)
- Option 3:
  Two contact points on top and two contact points on the bottom (Connecting line between the two top contact points and connecting line between the two bottom contact points must virtually cross each other)

Only when one of these three requirements is fulfilled has the alignment been correctly performed according to ISO 1101.

Correction of closure error according to PHILIPS

The goal of the correction of the closure error according to PHILIPS is the determination and the correction of the deviation in height at all the intersections of all the lines other than the reference lines.

Procedure:

The starting point for the corrective actions is the intersection, of the two reference lines and working its way out to the borders. At every intersection the height difference between the longitudinal and the transversal line is eliminated by lowering the upper line and lifting the lower line by the same value. The outbound portion of the same lines will be subject to the same change in elevation at each cross section. In this way the relation at the outbound cross sections will remain unchanged.

Order of treatment of the various rectangles starting at A … D (from inside to outside)

D	C	B	B	C	D
C	B	A	A	B	C
C	B	A	A	B	C
D	C	B	B	C	D

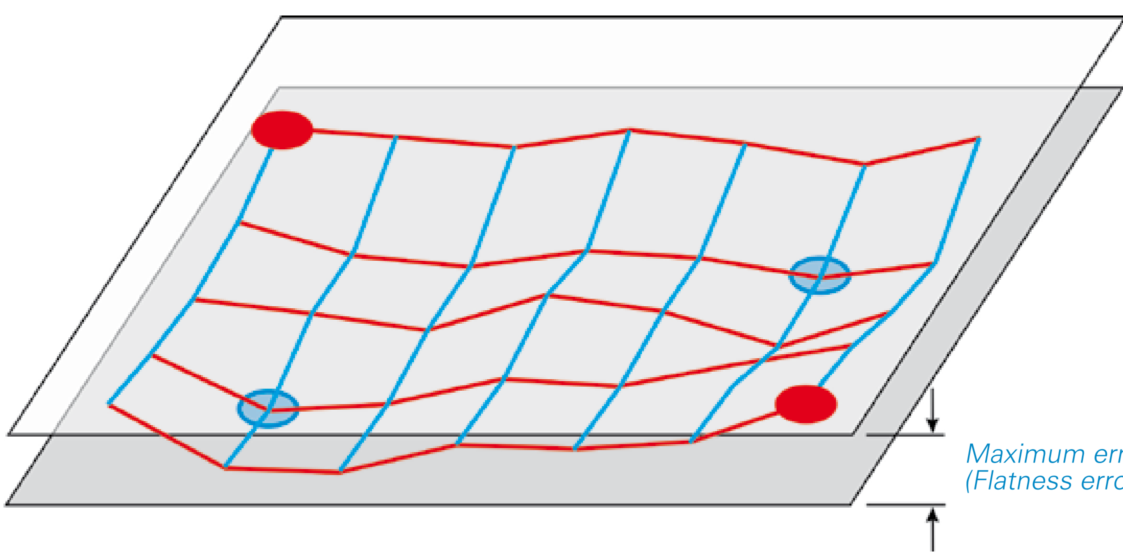
For all corrected values, the standard deviation is calculated and displayed as the index of correction.

Remarks:

- Measurements not done with the required care will lead to excessive corrections, and the index of correction will be high
- Carefully taken measurements will lead to uniform and minimal corrections and the index of correction will be quite low

If the measurement has undergone a correction according to PHILIPS, this can be seen when the "Index of correction" is displayed in the graph.

The definition of the flatness error is calculated in the same manner as described previously. Two virtual flat parallel surfaces making contact with the measured grid surface at the highest and the lowest points are turned freely in space until the distance between the two virtual surfaces is the minimum. This distance is the FLATNESS ERROR ACCORDING TO ISO 1101.



Maximum error of the surface (Flatness error)

Remarks:

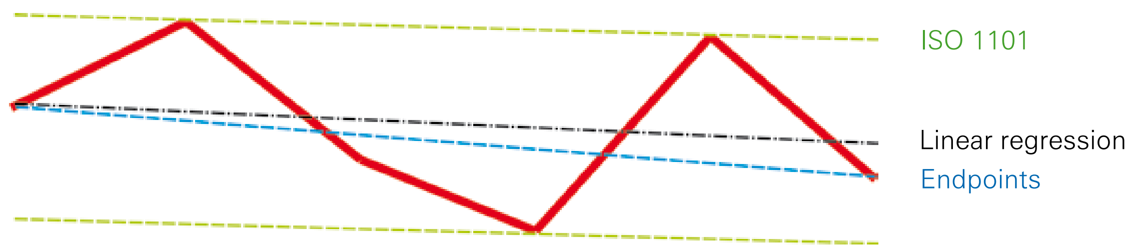
The maximum deviation from a completely flat surface (flatness error) is smaller now. It is also quite possible that due to the correction of the closure error a new distribution of the contact points with the virtual surfaces has taken place. In the example above there are now two points on top and two points on the bottom.

METHODS OF ALIGNMENT

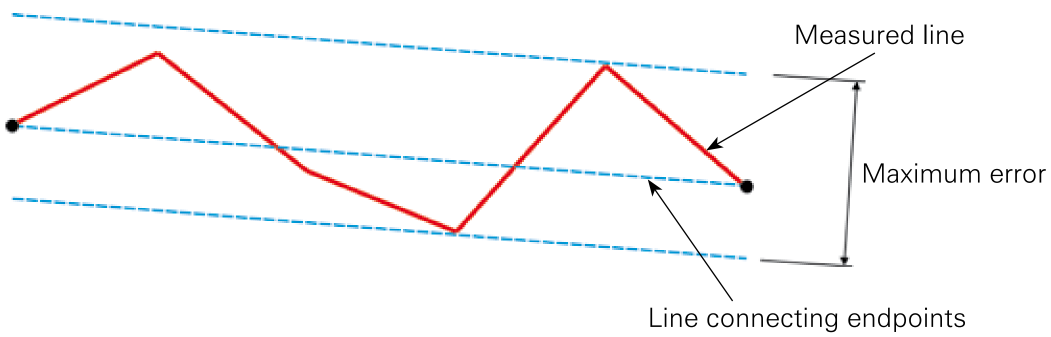
With WYLER LEVELSOFT PRO the following methods of aligning the measuring objects are possible:

- Alignment according to the endpoints method
- Alignment according to the ISO 1101 method
- Alignment according to the linear regression method

The different methods are described below, and a number of graphs are used for better understanding.

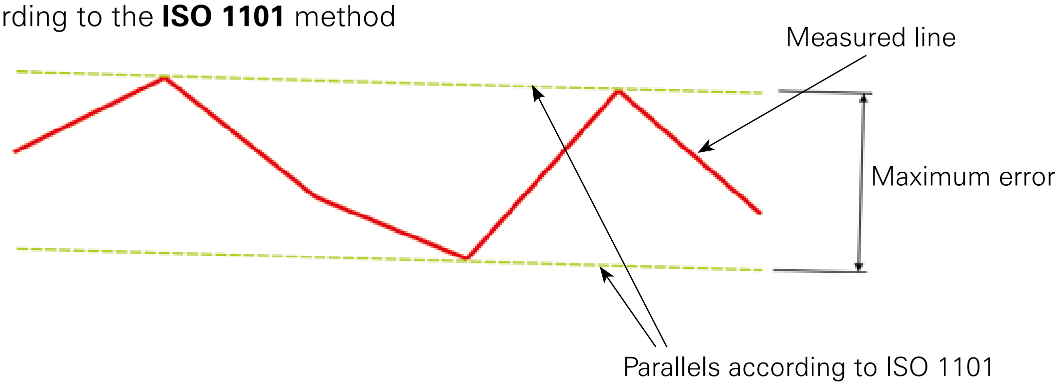


Alignment according to the **endpoints** method



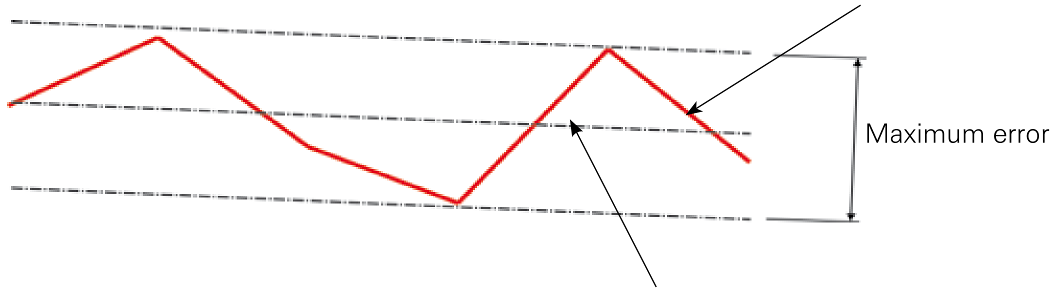
In this method the first and the last measured point are connected by a straight line. The connecting line is moved parallel to the highest and the lowest point of the object. The distance between the two lines is the maximum error calculated according the endpoints method.

Alignment according to the **ISO 1101** method



In the ISO 1101 method, two parallel lines are aligned in such away that the distance between them is the least possible.The distance between the two lines is the smallest possible error according the ISO 1101 method.

Alignment according to the **linear Regression** method



Using the linear regression method, a straight line is calculated out of a number of measuring points according to the smallest square method. The so calculated line is moved parallel to the highest and the lowest point of the object. The vertical distance between the two lines is the maximum error calculated according the linear regression method.

Measuring direction and single or reference measurement

Measurements conducted with the differential method allow the compensation of slight changes of an object orientation during the measurement and the compensation of low frequency vibrations.

These compensations are only satisfactory if the measuring object is of rigid design and the supports are of the three-point type. Also the surface on which the reference instrument is placed must be a solid part of the object to be measured and of good flatness so that the reference instrument is not wobbling. If these conditions are not fulfilled the planned compensation cannot be achieved.

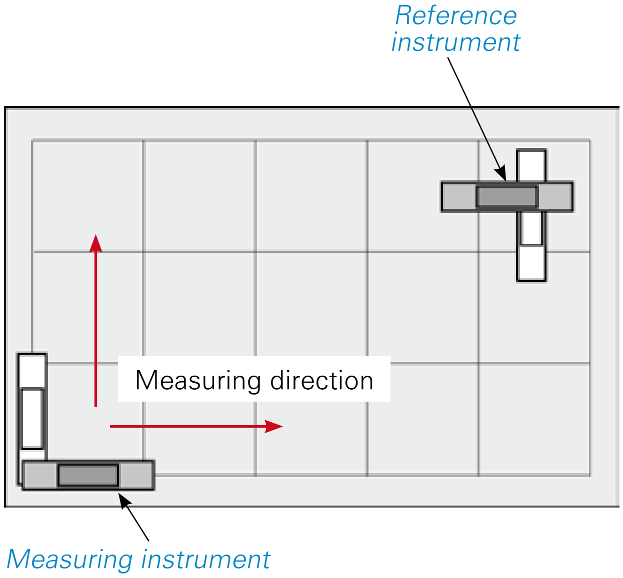
Flatness measurement with a measuring and reference instrument

Note:

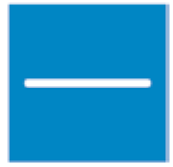
Long machine beds with several bearing points have a tendency to follow the shape of the foundation. This will also give false compensation readings. Because of this, the reference instrument placed on the machine bed will supply incorrect values. In these cases, applying the differential measuring method is not recommended.

For a reference or difference measurement, make sure that both devices are always oriented in the same direction.

The measurement is always in the direction of the cable connection. If this rule is not met, the result may be mirror inverted. The whole measurement is wrong and could lead to erroneous conclusions and decisions.



Measurement of straightness (Lines) - LEVELSOFT PRO SOFTWARE

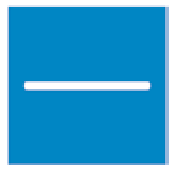


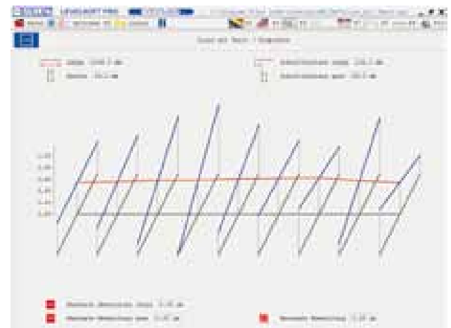
To measure the straightness of a line, e.g. a simple guideway, only a few inputs are necessary:

- Step length (coordinated with the base length of the instrument)
- Number of measurements (coordinated with the size of the object to be measured)

Alignment according to endpoints, to ISO 1101 or linear regression is possible.

Measurement of straightness with twist (Lines with twist) - LEVELSOFT PRO SOFTWARE



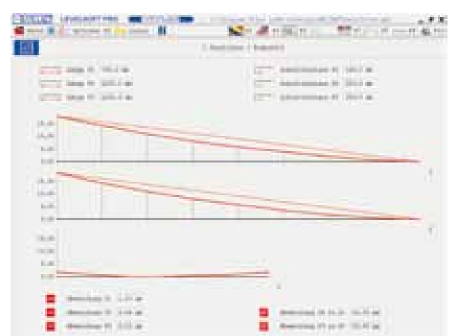


For the measurement of straightness of a line with twist, e.g. a simple guideway, only a few inputs are necessary:

- Step length longitudinal (coordinated with the base length of the instrument)
- Step length transversal (coordinated with the base length of the instrument)
- Number of measurements longitudinal (coordinated with the size of the object to be measured)
- Number of measurements transversal (coordinated with the size of the object to be measured)

Alignment according to endpoints, to ISO 1101 or linear regression are possible.

Parallels with two or three parallels - LEVELSOFT PRO SOFTWARE



To measure the straightness and the position of two or three parallels, e.g. guideways, only a few inputs are necessary:

- Number of parallels
- Step length and number of measurements for all parallels

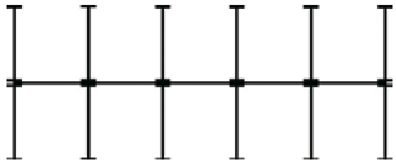
Alignment according to endpoints only.

Parallels with two or three parallels and twist - LEVELSOFT PRO SOFTWARE

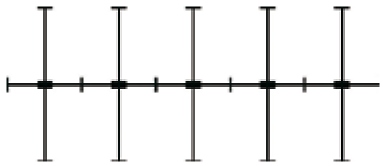
To measure the straightness and the position of two or three parallels, e.g. guideways, only a few inputs are necessary:

- Number of parallels
- Step length and number of measurements along all parallels
- Step length and number of measurements across all parallels

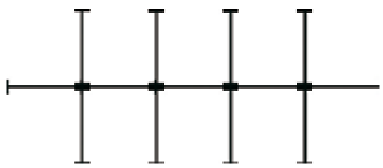
Alignment according to endpoints only.



TWIST LEFT OF STEP

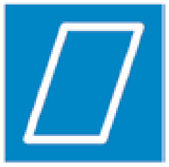


TWIST CENTRE OF STEP



TWIST RIGHT OF STEP

FOR THE MEASUREMENT OF FLATNESS, THE FOLLOWING OPTIONS ARE AVAILABLE:

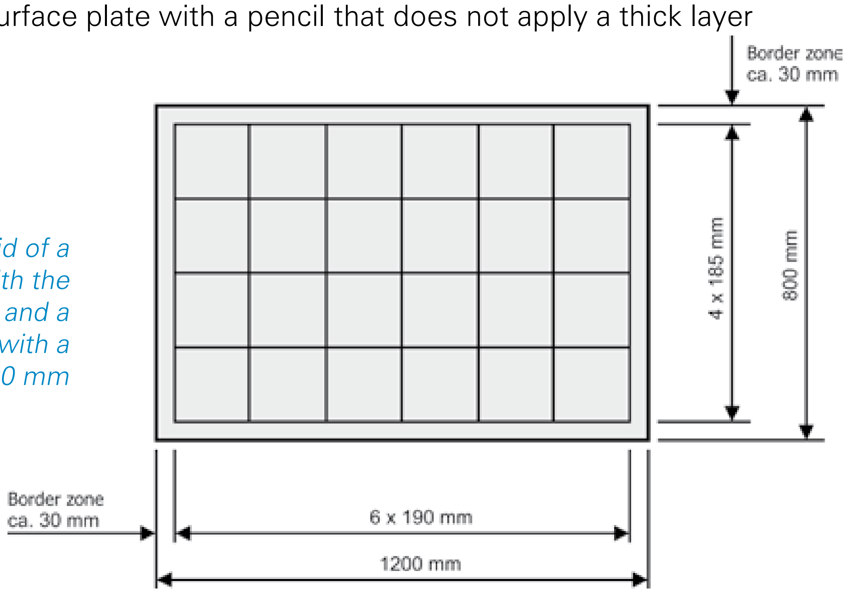


- Surface WYLER (GRID), standard flatness measuring method using a grid
- Rectangle
- Partial surface based on the measuring object Surface WYLER
- U jack / GGG – P – 463 c
- U jack / GGG – P – 463 c with layout proposal

For a precise measurement, the following preparatory work has to be done:

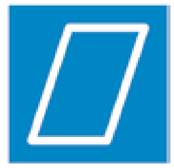
- The object to be measured must be adjusted horizontally in both directions (longitudinal and transversal) as well as possible (within approx. 50 μm/m). If not done, measuring errors may occur if the measuring instrument is not placed exactly in line with the measuring direction
- The object must now be divided in the measuring step length. The step length has to be such that an equal dimension of overlapping of the base length with each step is possible
- The best possible step length when using a 150 mm base is 126 mm. As a guideline it should be noted that if the surface is of bad quality (rough, buckling) then the step length should be as close as possible to the optimal length. (in this case 126 mm)
- In addition, it is important to make sure that the base as a whole comes to lay on the surface when placed in the measuring position
- The grid is to be marked on the surface plate with a pencil that does not apply a thick layer

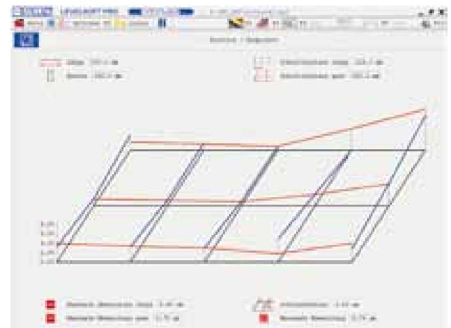
The figure on the right shows the grid of a measuring and setting plate with the dimensions 800 x 1200 mm and a measuring device with a base length of 200 mm

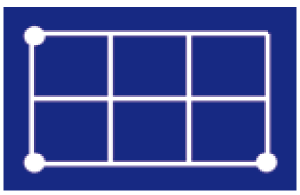


Surface flatness rectangle - LEVELSOFT PRO SOFTWARE

For the measurement of the two guideways or on a working table it is possible to select the rectangle measurement figure. The measured object is aligned in a way that the two endpoints of the first longitudinal line and the two endpoints of the first transversal line are on the same level.







Alignment according to endpoints only.

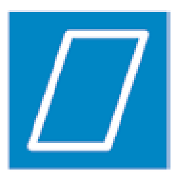
Required inputs:

- Step length longitudinal and transversal
- Number of longitudinal and transversal lines
- Measuring densitiy longitudinal and transversal

Important:
After the last measurement of longitudinal lines of a granite master plate, it is possible to exchange measuring instruments for all measurements of flatness.

Surface flatness according to the principle WYLER - LEVELSOFT PRO SOFTWARE

For measuring flatness of surfaces, e.g. measuring and setting plates, machine tables, etc., the flatness measurement according to WYLER is ideal. Various preparations are necessary:



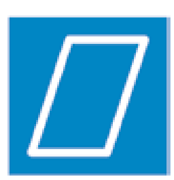
Required inputs:

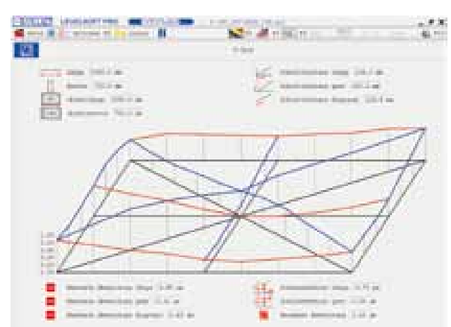
- Step length longitudinal and transversal
- Number of longitudinal and transversal lines
- Measuring densitiy longitudinal and transversal
- The grid can also be determined by means of a grid proposal

Alignment according to ISO 1101 only.

Surface flatness according to the U-Jack principle - LEVELSOFT PRO SOFTWARE

For measuring flatness of surfaces, e.g. measuring and setting plates, machine tables, etc., the U jack method can also be applied. Various preparations are necessary:





Required inputs:

- Step length longitudinal, transversal and diagonal
- Number of measurements longitudinal, transversal and diagonal
- It is advisable to have the grid displayed by means of the grid proposal

Alignment according to GGG-P-463c only.

THE FLEXIBLE MEASURING BASE FROM WYLER / WYLER FLEXBASE

For the flatness measurement according to the U jack method, there is a measuring device with a flexible measuring base available. Thanks to this instrument, it is possible to adjust the calculated step length exactly.

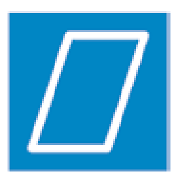
Characteristics of the WYLER flexbase:

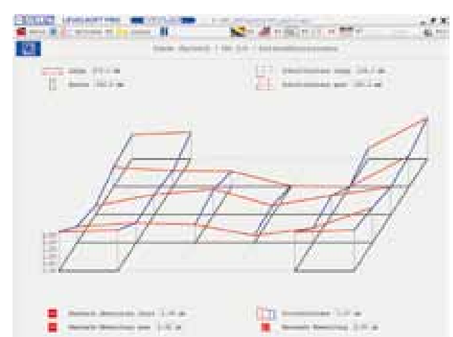
- The base features a scale, allowing an easy adjustment of the step length
- Easily visible marks allow a precise positioning of the base during the measuring procedure
- Experienced users can easily displace and re-adjust the support plates for enlarging the range of possible step lengths considerably

Technical data of the WYLER flexbase:

- Base length and width: 250 x 45 mm
- Adjustable step length standard 90 (100) mm to 240 mm
- Extended step length 70 mm to 270 mm
- Dimensions of three-point tungsten carbide base: Diam. = 3/8", Distance width = 1.4"

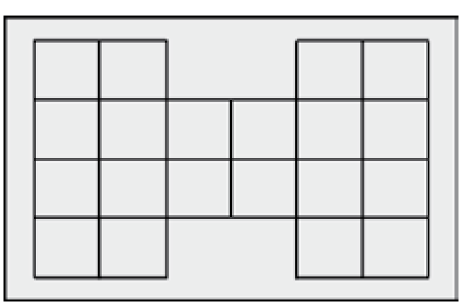
FLATNESS MEASUREMENT OF PARTIAL AREAS - LEVELSOFT PRO SOFTWARE





In practice it may happen that the measurement areas cannot be fully measured. Either there is a measuring device mounted on the plate, or the plate has cutouts.

The „partial surface" measuring task is available for such applications. The grid can be entered as in the normal measurement task "flatness WYLER". Then, the lines that should not be measured, can be clicked away with the mouse on the screen.

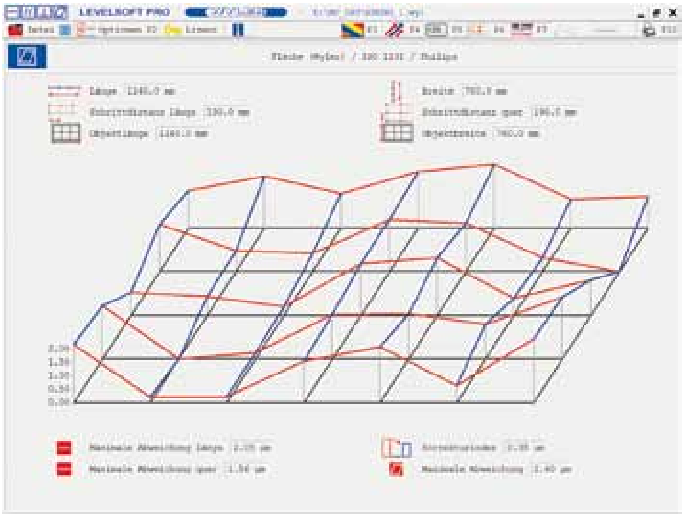


Required inputs:

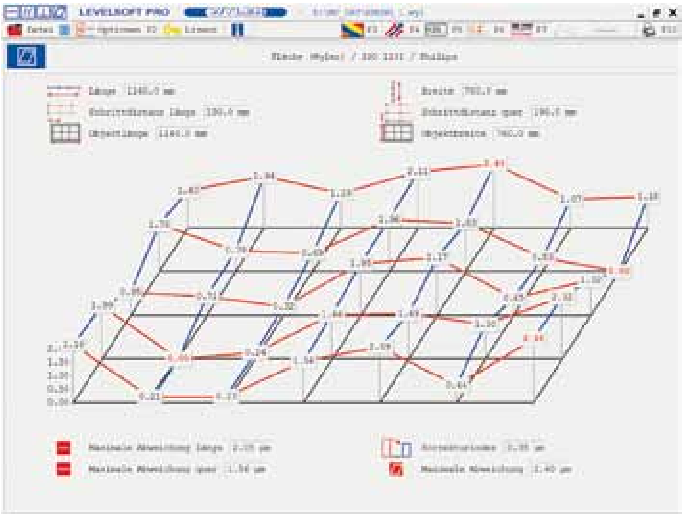
- Step length longitudinal and transversal
- Number of longitudinal and transversal lines
- Remove the redundant measurement lines

Alignment according to ISO 1101 only.

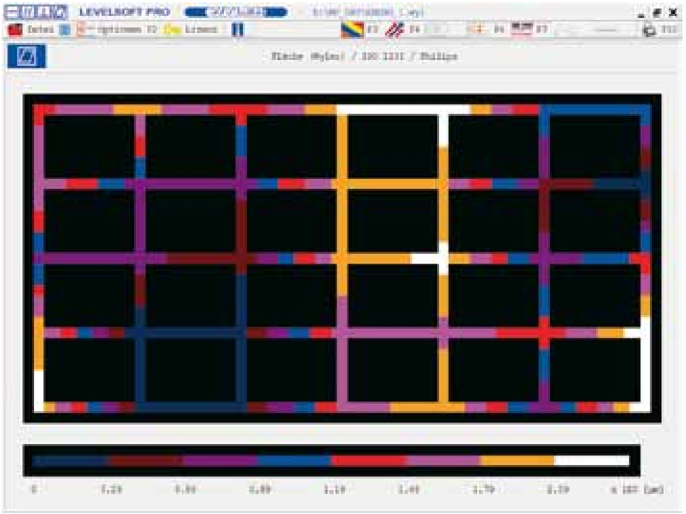
The result of the measurement can be represented in different ways. Various reports in different languages with a customer logo can be printed.



Classic printout, indicating the closure error, the maximum deviation (flatness error) and the maximum straightness of the longitudinal and transversal lines



Classic printout, indicating the closure error, the maximum deviation (flatness error), the maximum straightness of the longitudinal and transversal lines and the measured values of the individual measuring points.



The view of the measuring results can be shown in colored form. The brighter the color, the higher the measuring point.

"STANDARDS" FOR THE FLATNESS OF SURFACE PLATES

QUALITY OF THE MEASURED OBJECT:

Formulas for the different standards are as follows:

- **DIN 876:**
  - Grade 00   <2 x (1 + L/1000) µm   (L: Longer edge of plate in mm)
  - Grade 0   <4 x (1 + L/1000) µm   (L: Longer edge of plate in mm)
  - Grade 1   <10 x (1 + L/1000) µm   (L: Longer edge of plate in mm)
  - Grade 2   <20 x (1 + L/1000) µm   (L: Longer edge of plate in mm)

- **JIS**
  - Grade 00   <L x 0.0015 + 1.25 µm   (L: Diagonal of the plate in mm)
  - Grade 0   <L x 0.003 + 2.50 µm   (L: Diagonal of the plate in mm)
  - Grade 1   <L x 0.006 + 5 µm   (L: Diagonal of the plate in mm)
  - Grade 2   <L x 0.012 + 10 µm   (L: Diagonal of the plate in mm)

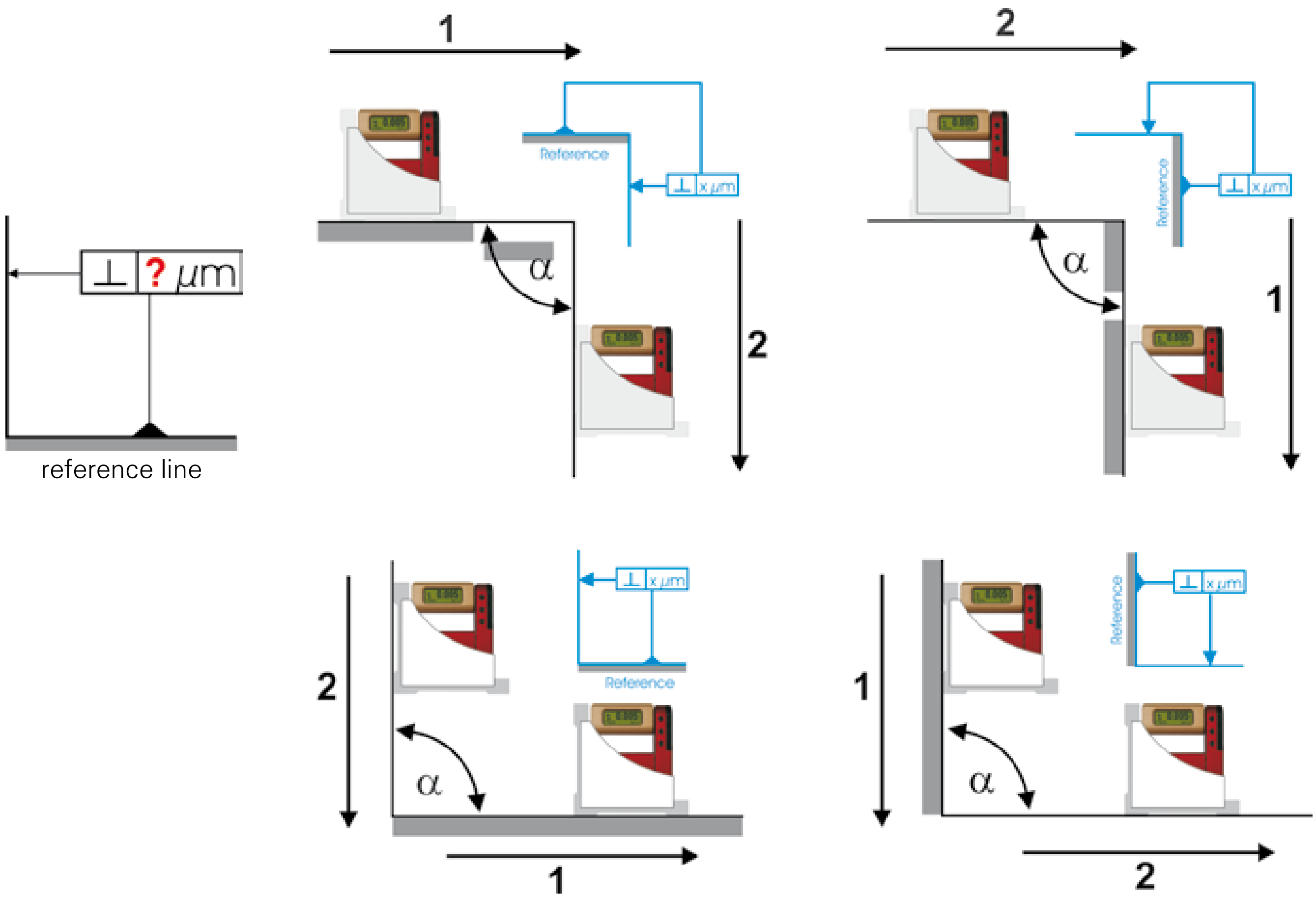
- **GGG-P-463c**
  - Grade AA   <40 + (D2/25)   D: Diagonal in inches
Result in x.xxx inches
  - Grade A   <[40 + (D2/25)] x 2   D: Diagonal in inches
Result in x.xxx inches
  - Grade B   <[40 + (D2/25)] x 4   D: Diagonal in inches
Result in x.xxx inches

- **BS 817**

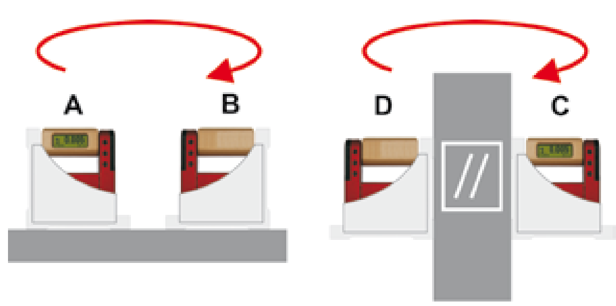
Length of plate in [mm]	Grade 0 in [µm]	Grade 1 in [µm]	Grade 2 in [µm]	Grade 3 in [µm]
180	3.0	Grade "0" x 2	Grade "0" x 4	Grade "0" x 8
250	3.5	ditto	ditto	ditto
400	4.0	ditto	ditto	ditto
630	4.5	ditto	ditto	ditto
1000	5.5	ditto	ditto	ditto
1600	7.5	ditto	ditto	ditto
2000	8.5	ditto	ditto	ditto
2500	10.0	ditto	ditto	ditto

Measurement of rectangular objects

The following options are possible. Please be sure to note which of the lines is the reference-line (shaded gray):



The first step is the determination of the instrument's error, which is done by two reversal measurements (horizontal and vertical) according to the sketch below.



$$\text{Index of correction} = \frac{C + D}{2} - \frac{A + B}{2}$$

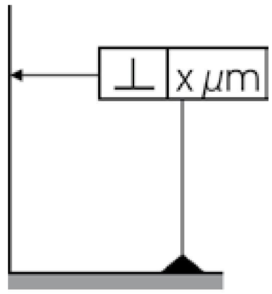
Procedure for the determination of the angular error of the measuring instrument:

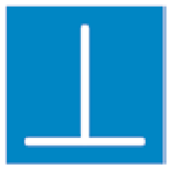
1. Reversal measurement on a horizontally aligned surface plate
2. Reversal measurement on a master, a cube of granite with two parallel surfaces in the quality 000

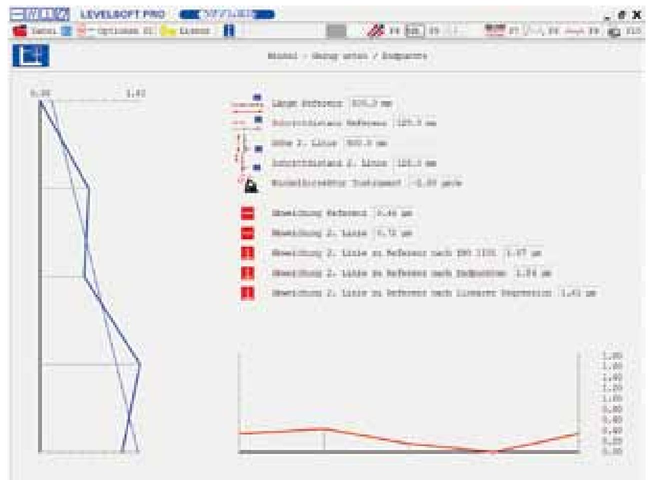
Remark:
For a detailed instruction, please visit our www.wylerag.com. Under Products>Software>MT-SOFT there is a video for the procedure.

If the possibility of a reversal measurement on a so-called master is not available, there are the following alternatives for the input of the angular error:

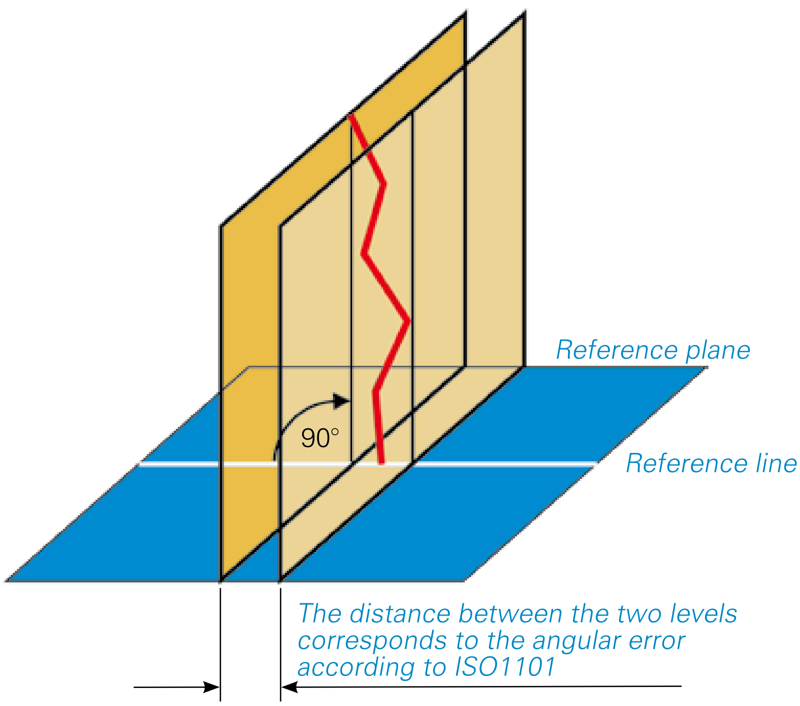
- If a calibration certificate exists, the value can be transfered from there
- You trust the measuring base and you type in a correction value of "0"







How is a right angle measured and interpreted?



The reference line (horizontal) and the measuring line (vertical) are measured with an instrument with an angular base. The lines are aligned with one of the alignment methods (in our example on the left according to ISO 1101).

The distance between the two vertical planes that are perpendicular to the reference line corresponds to the angular error of the measured object. Depending on the alignment method, the angular errors have different sizes.

All lines, i.e. measuring line and reference line, may be aligned according to all alignment methods such as

- Endpoints method
- ISO 1101 method
- Linear regression method

For each alignment method of the reference line, the deviations of the measured line are provided again in all three alignment methods.

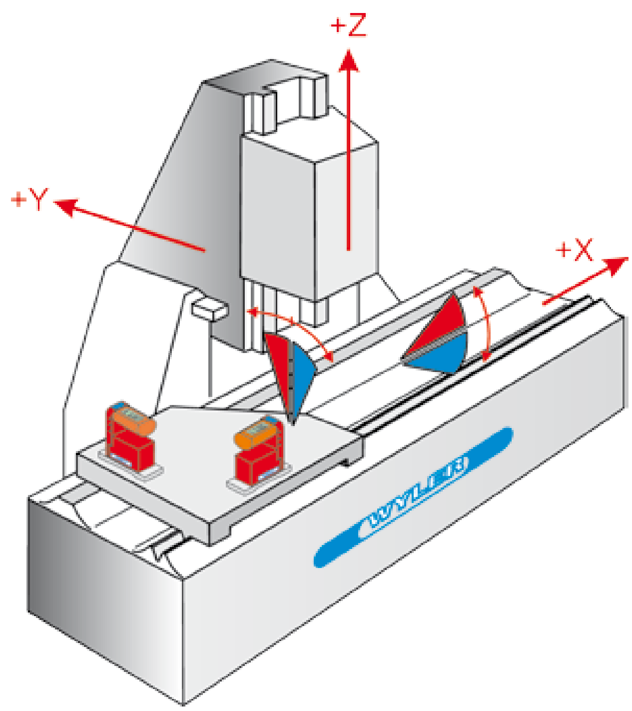
6.3.2 Measuring Software MACHINE TOOLS INSPECTION SOFTWARE MT-SOFT
Overview - Software for measuring machine geometries

Already more than 20 years ago WYLER AG wrote the first software to facilitate the measurement and evaluation of flatness and straightness. Through continuous enhancements this development led to the actual version of the well-known and well-established LEVELSOFT.

The new MT-SOFT (Machine Tool Inspection Software) allows users to now go beyond these limitations. For a highly skilled, specialized mechanic with extensive 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 becoming 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 tool as a fundamental pre-condition for a high-quality production brings the test personnel 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 determine the source of the possible errors in order to make the necessary corrections.

The major goal for developing MT-SOFT was to fill exactly this gap and to 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 as well as in the maintenance and repair phase.



The newly developed MT-SOFT software allows users to independently measure various geometrical components of a machine with standard inclination measuring instruments. The individual measuring results can be saved and consolidated three-dimensionally allowing the determination of the total error of the machine. A simple example of the great variety of the possibilities of the software is the measurement of the vertical spindle in relation to a horizontal guideway of a machine tool. The logical layout and the clear structure of the software allows easy measurement of even complex machines.

Who are the users of MT-SOFT SOFTWARE?

- Manufacturers of complex and precision machine tools
- Technicians who assemble and adjust such machines on site
- Owners and users who need to reevaluate and correct the accuracy of such machines regularly

What is the benefit of investing in MT Soft?

Cost effectiveness

- Reduced time per measuring task compared to other conventional methods
- Only the component that was re-worked or re-adjusted has to be measured again
- Due to its three-dimensional analysis, pinpointing the source for the overall error is substantially facilitated, allowing an efficient adjustment of the components and therewith of the total machine
- Once established and stored, complex measuring tasks can be carried out by less trained staff
- Software and measuring instruments out of one hand. WYLER AG has proven its competence with LEVELSOFT PRO and demonstrated its customer-oriented approach by providing regular and free software updates

Increased quality

- Eliminating geometrical errors during manufacturing reduces the risk of surprises during the acceptance test procedure
- Rotational errors of components can be excluded prior to assembly
- Sustainable quality assurance due to the fact that the measurements are always carried out the same way

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 components
- Corporate identity: Users' or owners' company logos can easily be added to the reports
- Each measurement is documented and each document is clearly assigned to one specific geometrical component of the machine
- If required, only a short report can be printed
- Operator guidance and printouts in several languages are possible

What can be measured with MT-SOFT?

- All types of horizontal and vertical guideways
- Rotating axis, e.g. rectangularity between
  the horizontal surface of a working table and a vertical spindle
- Rotation of machine tool components: PITCH and ROLL
- Circles: flatness and angular deviations of circular horizontal paths
- Surfaces: Measurement of surfaces

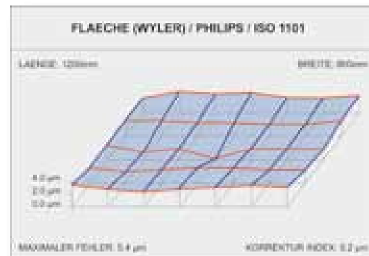
The well known LEVELSOFT PRO SOFTWARE to measure flatness as well as straightness can easily be integrated into MT-SOFT as a complementary module.

Relative and absolute measurements / Long-term monitoring

Before we go further into the Software MT-SOFT, we must look at the concepts of relative and absolute measurements in more detail.

From the viewpoint of applications, we must distinguish three basic areas:

- **Relative measurements**
  Relative measurements are then used when the horizontal position of the measured object is not relevant. When measuring the flatness of a measuring and setting plate made of granite, it is not the position of the plate that is decisive, but the form and structure of the surface. The decisive factor is the difference in the inclination from one measurement to the next.



- **Absolute measurement**
  Absolute measurements are used when the horizontal position of the measured object is relevant. For example, for the installation and commissioning of a machine tool, it can be very important that this is entirely horizontal. The decisive factor is the location of the object, or measurement points, in space.

- **Long-term monitoring**
  For long-term monitoring, an absolute measurement is a MUST. When monitoring a building, we want to know the absolute position, i.e. the deviation from the absolute zero.

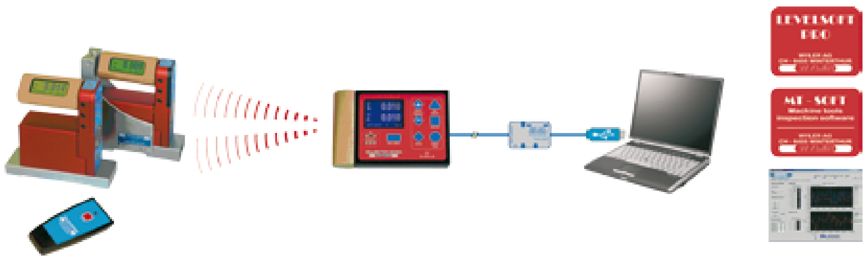
Relatve measurement

When measuring the flatness of an object, e.g. a measuring and setting plate, it must be horizontally aligned in both axes to measure. The decisive factor is the difference in the inclination from one measurement to the next. In other words, in this application, the object is not measured absolutely. The measurements can be performed with the LEVELSOFT PRO software and then analyzed according to the different alignment methods such as

I. Endpoints
II. ISO 1101
III. Linear regression

The handheld BlueSYSTEM units are particularly well-suited to this kind of application. The data transmission is wireless. The BlueMETER can be connected to a PC or laptop.

Below is a schematic illustration of a typical measurement configuration with two BlueLEVELS and a BlueMETER with connection to a PC or laptop. The LEVELSOFT PRO software is well suited for the evaluation of the results.

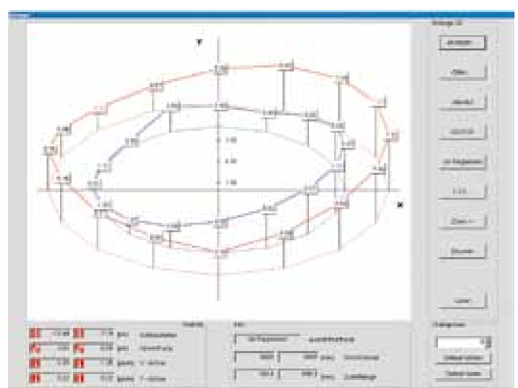


The readings are transmitted wirelessly from the measuring instruments to the BlueMETER. As a radio system for wireless transmission of measurement data, the Bluetooth®wireless technology is used.

Absolute measurement

For monitoring of buildings and dams, it is necessary to measure the absolute values. When measuring machine geometries with the MT-SOFT software, where different measuring tasks and machine components have to be compared, an absolute measurement is necessary. Only then can e.g. modules like a horizontal working table with a vertical spindle of the same machine be compared and analyzed.

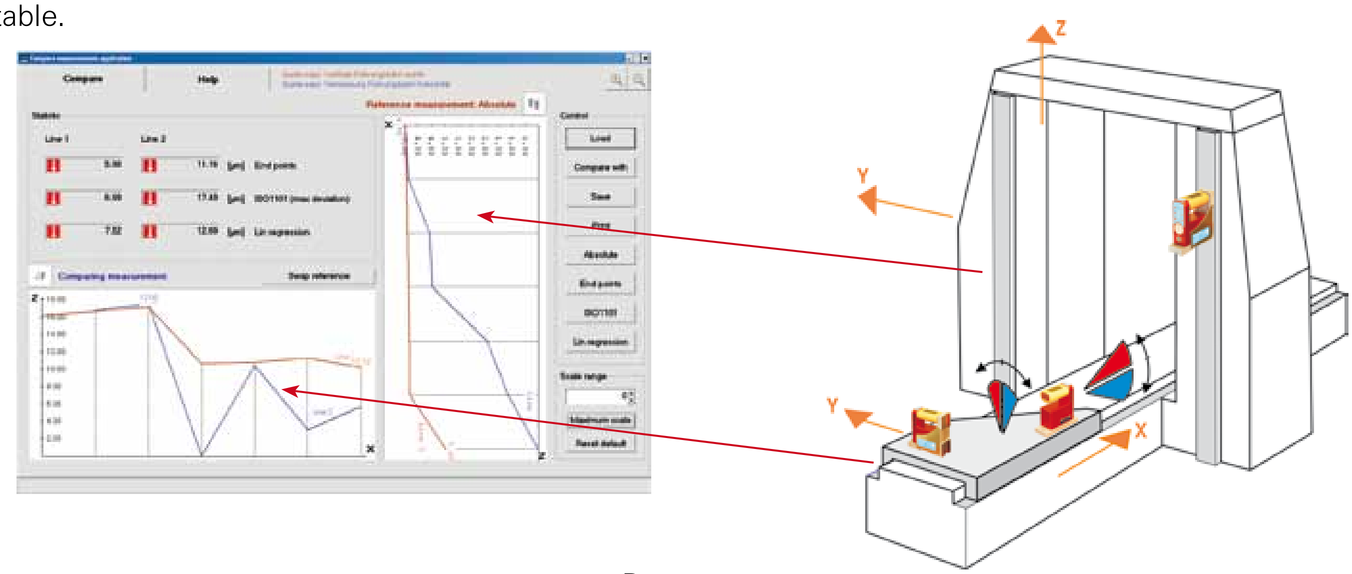
Flatness and angular deviations of circular horizontal paths (circles)



For absolute measurements, different inclinometers and inclination sensors can be used.

I. The handheld BlueSYSTEM instruments are perfectly suitable for measuring machine geometries. Thanks to the so-called reversal measurement, an integral component LEVEL SOFT PRO and MT-SOFT, the zero point deviation of the devices are established in advance and eliminated.

II. ZEROTRONIC inclination sensors with digital technology are particularly well-suited for absolute measurements. These sensors are characterized by excellent linearity and long-term stability. Thanks to the calibration over large temperature ranges (up to 5 calibration curves), the sensors are also very temperature stable.



The "chamber for the pendulum" is limited, so for larger deflections, caused by excessive vibration and shock, a permanent deformation of the sensor can be avoided. The ZEROTRONIC sensors can be connected via a network to a PC or laptop to record the readings.

Long-term measurements / monitoring

The long-term stability of sensors in general and inclination sensors in particular are dependent on factors such as:

- Temperature and humidity
- Vibration and shock
- Mechanical drift due to tension in the materials and electronic components
- Handling by the user

The long-term stability is also known as long-term drift. For long-term monitoring of machines, buildings, bridges, etc., it is essential to use tilt sensors with low zero drift.

The ZEROTRONIC sensor is treated in detail in the chapter "Digital Inclination Measuring Sensors"

Various measures are now known to improve long-term stability, and to reduce long-term drift of sensors.

1. Aging of the individual components
   All built-in electronic and mechanical components are subjected in the various stages of production to an aging process. The thermal and mechanical cycling can reduce the natural aging.

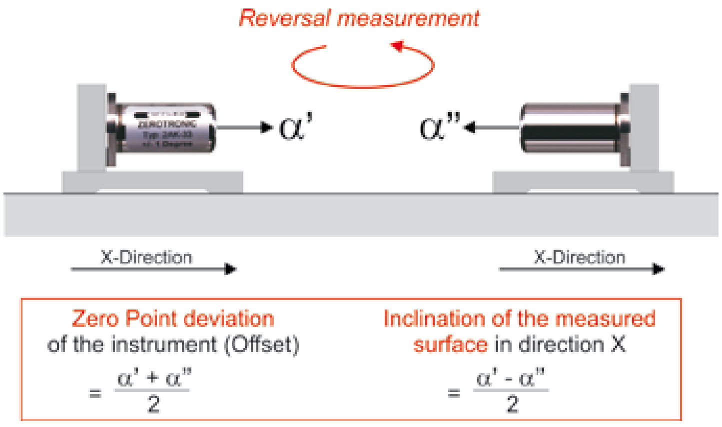
2. Materials with similar temperature, and expansion coefficients
   To avoid mechanical stress, which can occur especially as a result of temperature fluctuations, materials with similar temperature, and expansion coefficients are used. If this is not possible, the construction can be designed such that any mechanical stresses have no influence on measurement accuracy.

3. Temperature compensation
   Most of the inclination sensors are temperature compensated in different ways. Inclination sensors are calibrated at different temperatures, e.g. at -40 °C, 0 °C, 20 °C, 40 °C, 80 °C in a conditioning cabinet over the entire measuring range. When measuring an inclination the output of the angle will be interpolated across several temperature curves to determine a temperature-independent inclination.

But practice shows that today's market demands cannot be met with the measures above. The currently known inclinometers with a measuring range of ±1 degree have a limit of error of 5 arcsec and 1.4 arcsec/°C over 12 months, which is not precise enough for monitoring tasks, especially for outside measurements with large temperature fluctuations.

Long-term measurements / monitoring with ZEROMATIC

Inclination measuring devices and sensors operate according to Newton's law of gravitation (gravitational acceleration). Thanks to this law, it is possible to identify the absolute zero with a so-called reversal measurement.



Thanks to this reversal measurement, that is due to the calculated zero offset, the sensor can be calibrated. Based on this finding, the so-called automatic reversal probe ZEROMATIC was developed. The determined zero offset is considered for the following measurements.

The biggest challenge in the development phase was the mechanics necessary with regard to repetition accuracy and reliability. The heart of the instrument consists of two digital inclination sensors that constantly output an inclination in X and Y axes.

The limit of error of the entire system with a measurement range of ±1 degree is less than ± 1 Arcsec for several months. The new inclinometer has sucessfully passed an extensive series of tests in varying conditions.

The ZEROMATIC 2/1 and 2/2 instruments are ideal for long-term monitoring of objects such as buildings, bridges, dams, and so on. The principle is based on the just-described reversal measurement to determine the zero offset. The timing and frequency of such a reversal measurement can be defined 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 Y direction.
- **ZEROMATIC 2/2** is equipped with two inclination sensors. This allows continuously receive values in the X and Y direction. After a pre-set time, an automatic reversal measurement is done in order to compensate a possible zero point offset.

The ZEROMATIC instrument is treated in the chapter "Digital Inclinometer Sensors"

Summary

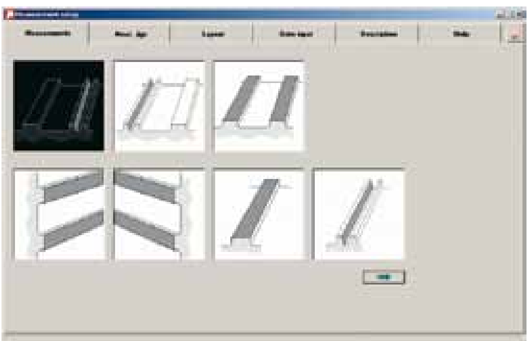
Measurements for which the position of the object is essential must be taken in absolute mode. Absolute mode means that the zero point deviation (also known as ZERO-offset) of the inclination sensor has to be compensated for or eliminated. This compensation is done through a reversal measurement, which is part of the software, before proceeding with the actual measurement.

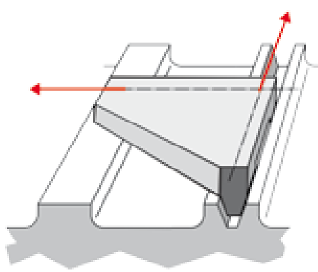
Measuring Software MT-SOFT (Machine Tools Inspection Software)
Overview - Details

As described in the previous chapter, all measurements must be carried out in absolute mode!

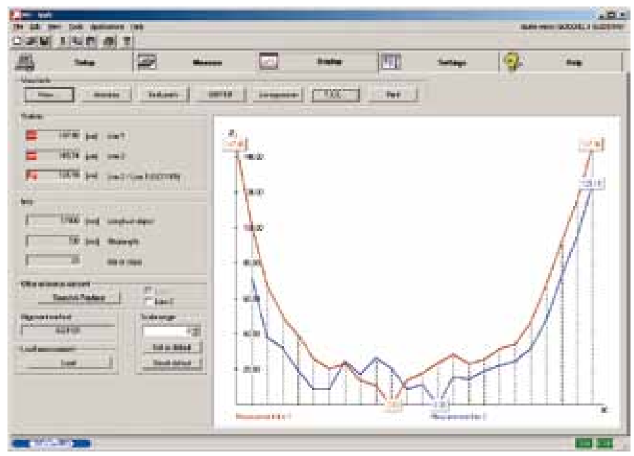
What can be measured with the MT-SOFT software?

- All types of horizontal and vertical guideways



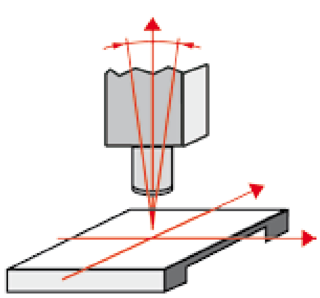


Guideways with measuring device (JIG)

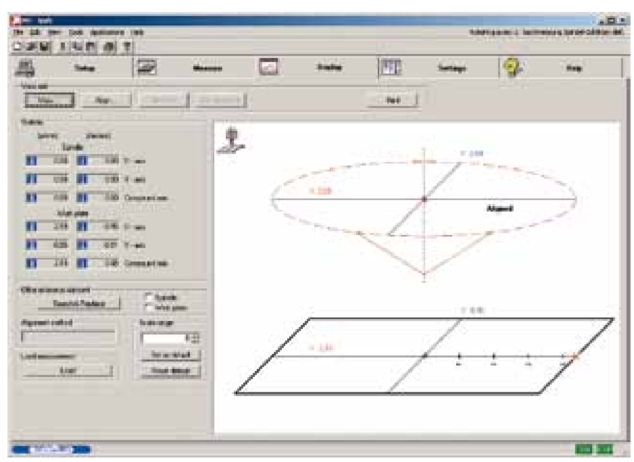


Graphical illustration of a measurement of two guideways of a machine tool

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



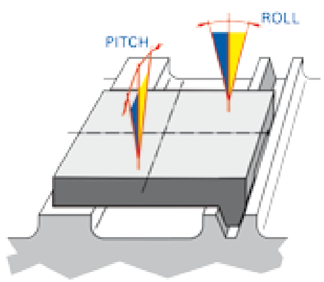
Rectangularity between a working table and a vertical spindle

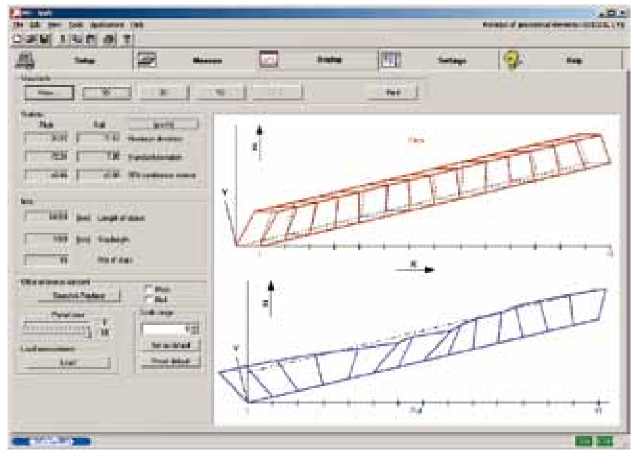


Graphical illustration of a measurement rectangularity between the horizontal surface of a working table and a vertical spindle. The measured objects can be aligned in different modes.

- **Rotation of machine tool elements: PITCH and ROLL**

PITCH and ROLL

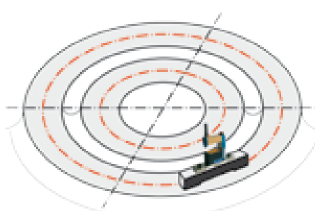


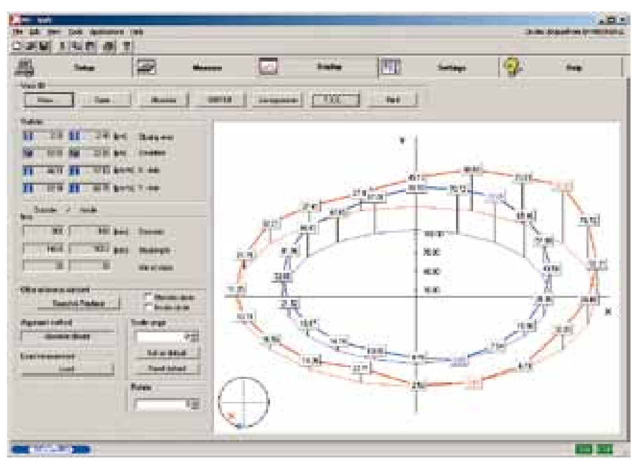


The picture above shows the analysis of "PITCH" and "ROLL" at a glance. Other presentations are possible.

- **Flatness and angular deviations of circular horizontal paths (Circles)**

Circles
Flatness and angular deviations of circular horizontal paths

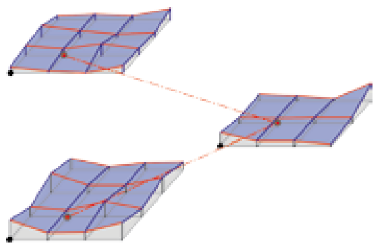


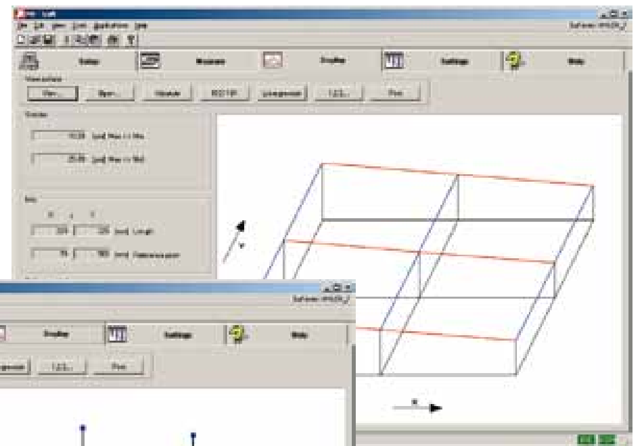


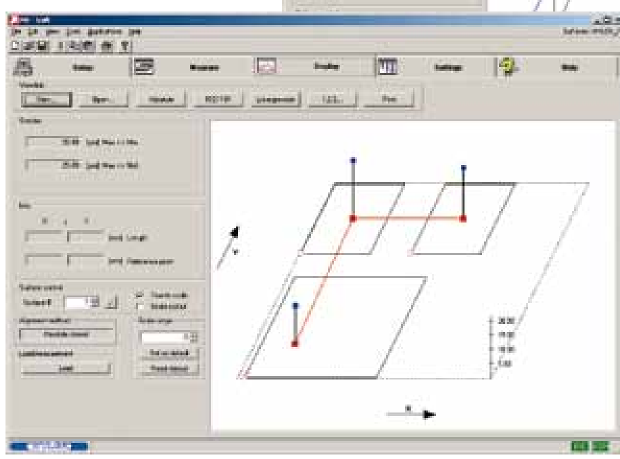
The picture above shows the analysis of the measured double circle

- **Partial surfaces: Flatness and relative position of several independent surfaces (co-planarity).**
  Flatness measurement of horizontal surfaces in space and comparison of the position of various such surfaces (co-planarity). Partial surfaces compared to an overall surface including all partial surfaces

Partial surfaces (co-planarity)







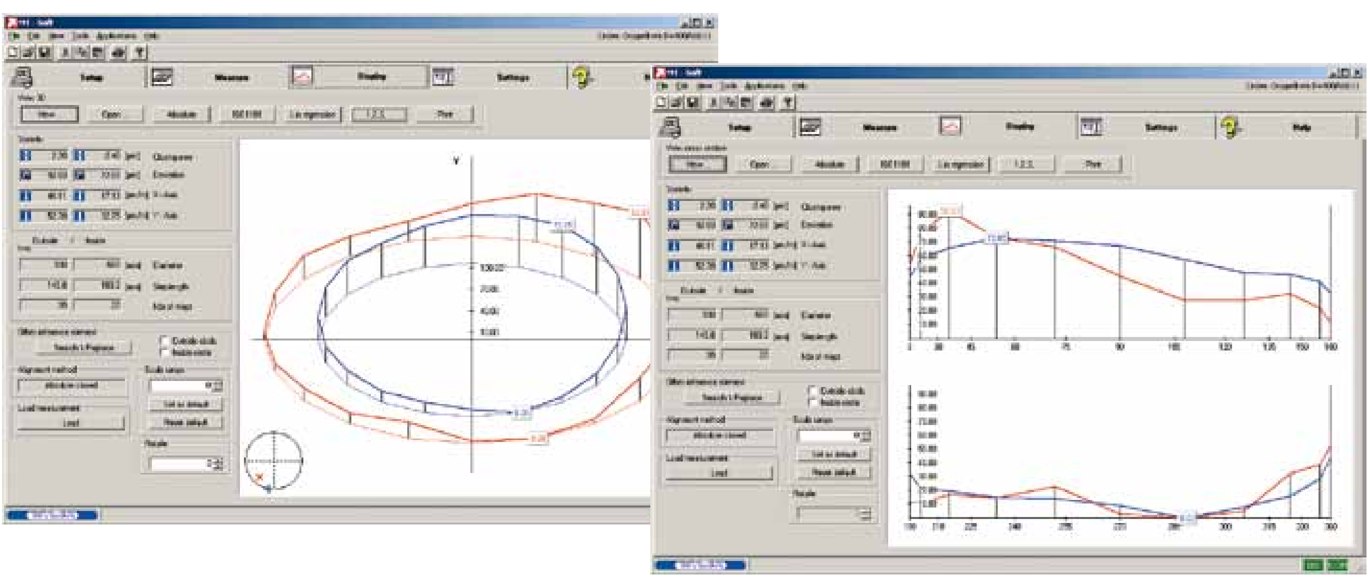
Analysis of variance of the sub-areas to each other and the flatness of the individual sub-areas

Example of an MT-SOFT measuring result

The graphic at the bottom left 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 graphic at the bottom right shows the same measurement in a cross-section.

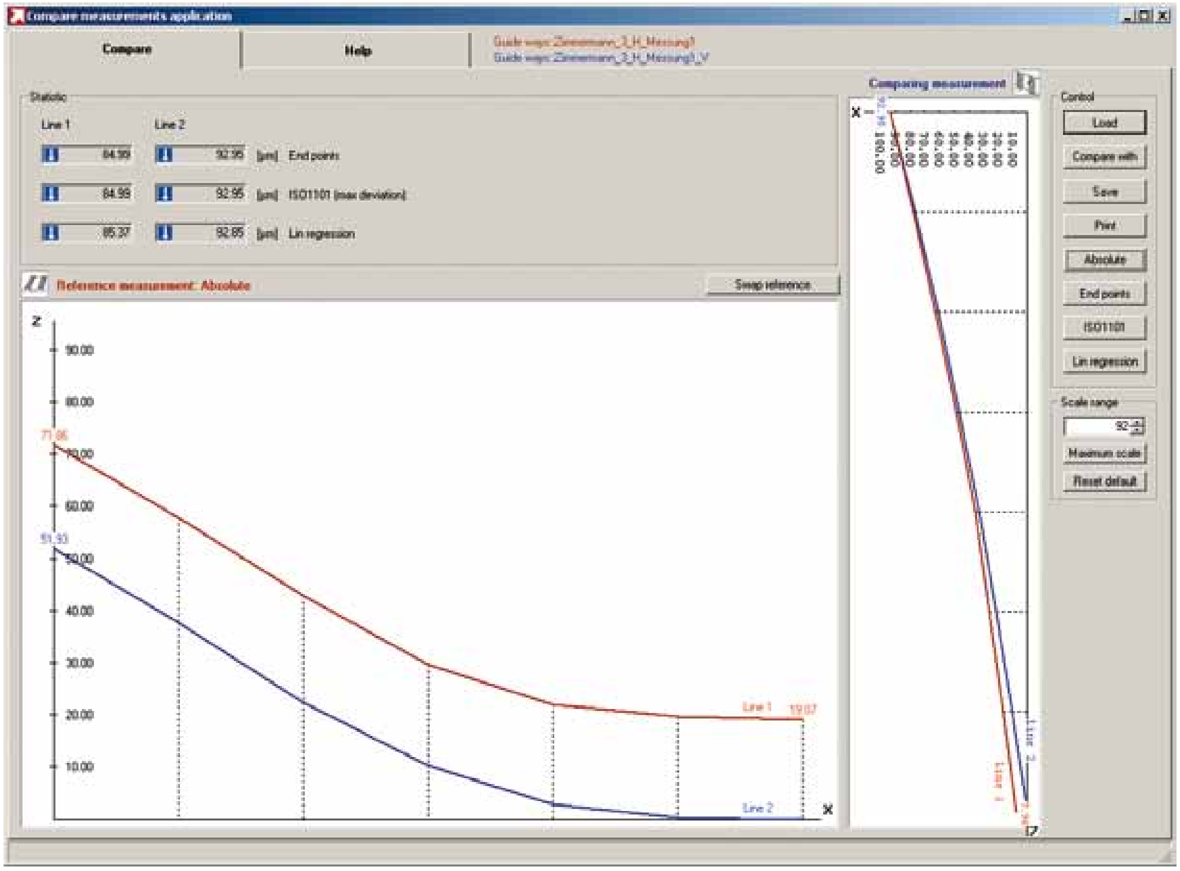
The results can be printed either as a short report with minimal information on measuring values and the perpendicular error or as a detailed complete report.



- **Comparison of Measurements (Applications)**

In order to allow a comparison of several individual measurements, e.g. a horizontal guideway 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 ensures that measurements carried out at different times and stored in a database can be compared with the same "signature".

The reversal measurement to determine the zero point deviation (ZERO-Offset) is part of the software. The calculated zero-offset is automatically taken into account during the measurement at each data acquisition.



Comparison of the horizontal with the vertical guideway of the same machine tool.

- **LEVELSOFT PRO software as a module of MT-SOFT**

The well-proven software for flatness measurement LEVELSOFT PRO is available as part of the MT-SOFT software.

6.3.3 LabEXCEL Measuring Software (LabView® Application)

LabEXCEL software is an easy-to-use package for displaying the measuring values of WYLER inclination measuring instruments and sensors. The core is the WYLER WyBus module. This software ensures the communication between the inclination measuring instruments and sensors and the LabVIEW user interface.

The measuring results can continuously be transferred into a csv file for further treatment, e.g. in EXCEL.

Requirements for the installation of the LabEXCEL software

- Framework 2.0 (Microsoft .NET Framework 2.0)
  Download from [Windows Update] or installation from the CD-ROM delivered with LabEXCEL

Up to 10 WYLER inclination measuring instruments or sensors can simultaneously be read into the LabEXCEL software. In addition there is the ability to display the difference of the measuring values between any pair of different inclination measuring instruments or sensors.

6.3.4 WYLER Software Development Kit

For customers intending to develop their own analyzing software for WYLER instruments, WYLER AG provides several software that explain how to interact with WYLER instruments or sensors either directly or via a software interface developed by WYLER. These examples should allow an experienced programmer to successfully develop their own application software.

WYLER software interface for Microsoft Windows
The software interface developed by WYLER provides a common programming platform to integrate WYLER instruments and sensors and consists of three functional blocks:

1. COM port management
    - Listing of the COM ports
    - Selection of the COM ports to be used
2. Instruments and sensor administration
    - Listing of instruments and sensors
    - Selection of the sensors to be measured by their ID
3. Reading of measuring values
    - Adjustment of measuring parameters
    - Selection of measuring speed / sampling rate
    - Measuring values to be read (displayed angle, temperature)
    - Reading / memorizing of measuring values in the background
    - Reading in / transfer of values measured in the background at any time

Software interfaces are available for the following programming environments:

- Visual C++ 6.0
- C#
- Visual Studio 2008
- LabVIEW™ from version 8.6.1

7 Inclination measuring sensors with analog and digital inclination measuring systems

There is an increasing demand for high-precision inclination sensors to measure the geometry of machines or to monitor machines or objects such as buildings, bridges or dams over longer periods of time.

WYLER AG offers two types of sensors for this purpose:

- The LEVELMATIC 31 analog sensor, which allows an easy integration into any measuring system, as it provides a standard voltage output between –2 V and +2 V proportionate to the inclination
- The digital sensor family ZEROTRONIC. Due to its digital bus, it allows an error free transmission of measurement values over long distances. Furthermore, its special measurement concept allows, within certain limits, users to measure dynamically.

LEVELMATIC 31 analog sensor

The LEVELMATIC 31 sensor is an analog sensor with an analog output signal. The LEVELMATIC sensors are increasingly being replaced by ZEROTRONIC digital sensors. Besides being more accurate, ZEROTRONIC sensors have a more compact design and provide a digital output signal which allows further treatment with various software.

Further details regarding the LEVELMATIC 31 sensor, see next chapter.

Digital sensor group

The sensors of the ZEROTRONIC family have a digital inclination sensor and a digital data transmission. Working digitally, they provide the option to compensate for temperature changes and allow data communication over long distances without any loss of data.

The combination of all these features ensures that these sensors fulfil highest requirements regarding precision, resolution, sensitivity and temperature stability.

LEVELMATIC 31 with LEVELMETER C25

Two ZEROTRONIC sensors mounted inside an X- / Y-mounting block

Two ZEROTRONIC sensors together with an LED CROSS

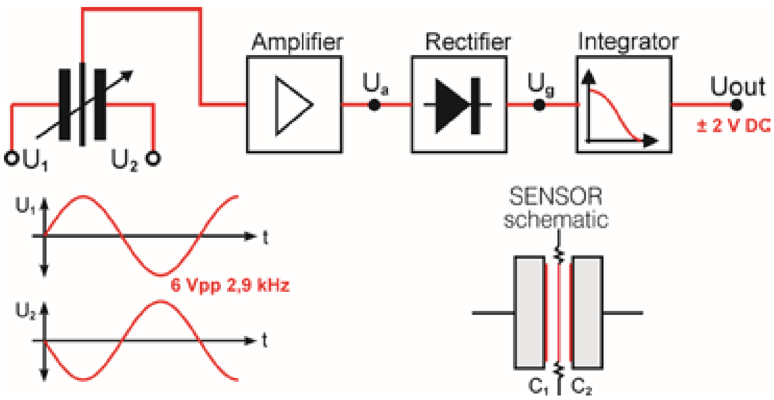
7.1 LEVELMATIC 31 ANALOG SENSOR

The LEVELMATIC 31 is an analog sensor with an anlog output signal (see specification). This sensor has specifically been developed to be mounted on machines. Since the sensor is mounted in a tight, weatherproof and shock-resistant housing, inclination measurements are possible even under difficult conditions. The distance between the sensor and the display unit should not exceed 5 m. The sensor is easy to use.

Measurement principle (similar to MINILEVEL NT + LEVELTRONIC NT):

The LEVELMATIC sensor is based on the pendulum properties of a friction-free supported disc of a 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, and even overhead measurements are possible.

The shielded sensor and the capacitive measuring principle make the system insensitive to magnetic and electric fields.

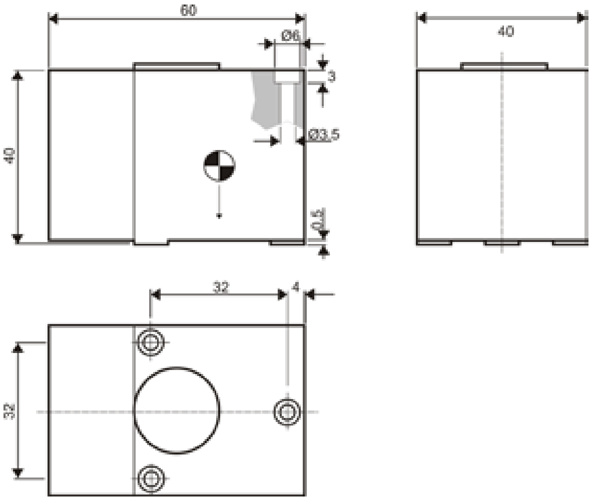


With this pendulum system, extremely accurate results in terms of repetition and hysteresis combined with very short reaction times have been achieved.

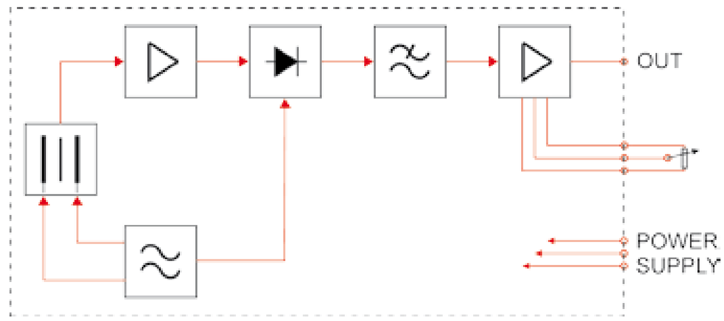
Applications:

- Levelling of a platform
- Inclination measurement on bridges or buildings
- Supervision of machine tools
- Levelling of machines
- etc.

Remark:
Analog LEVELMATIC sensors are increasingly being replaced by ZEROTRONIC digital sensors. Besides being more accurate, ZEROTRONIC sensors have a more compact design and provide a digital output signal which allows further treatment with various software.



Dimensions



Block diagram

LEVELMATIC 31 TECHNICAL SPECIFICATIONS						
Sensitivity	1 mVolt =	1 µRad	2.5 µRad	5 µRad	10 µRad	25 µRad
Full-scale		±2 mRad	±5 mRad	±10 mRad	±20 mRad	±50 mRad
Power supply		±5V DC ±1%, stabilized				
Output		±2000 mV DC at 100 kOhm				
Repetition		<0.025% Full-scale				
Linearity		±0.5% Full-scale				
Operating temperature		0 ... 60 °C				
Temperature coefficient		Zero: ±0.05% Full-scale / deg. Celsius Sensitivity: ±0.05% / deg. Celsius				
Net weight		0.443 kg				
Shock resistance • Measuring axis • Across to the measuring axis		 100 g 20 g				

7.2 Digital inclination measuring sensors

7.2.1 ZEROTRONIC sensor

ZEROTRONIC sensor group

ZEROTRONIC sensors have established themselves in the market as the benchmark when it comes to high-precision inclination measurement in demanding applications.

The ZERTRONIC family of sensors features the following characteristics:

- High resolution and high precision
- Excellent temperature stability
- Measuring ranges of ±0.5 to ±60 degrees
- Synchronized registration of measuring values for several sensors
- High immunity to shock
- High immunity to electromagnetic fields

Choice of two sensor types depending on the application:
Within the ZEROTRONIC family there are two sensor types available which have slightly different physical characteristics:

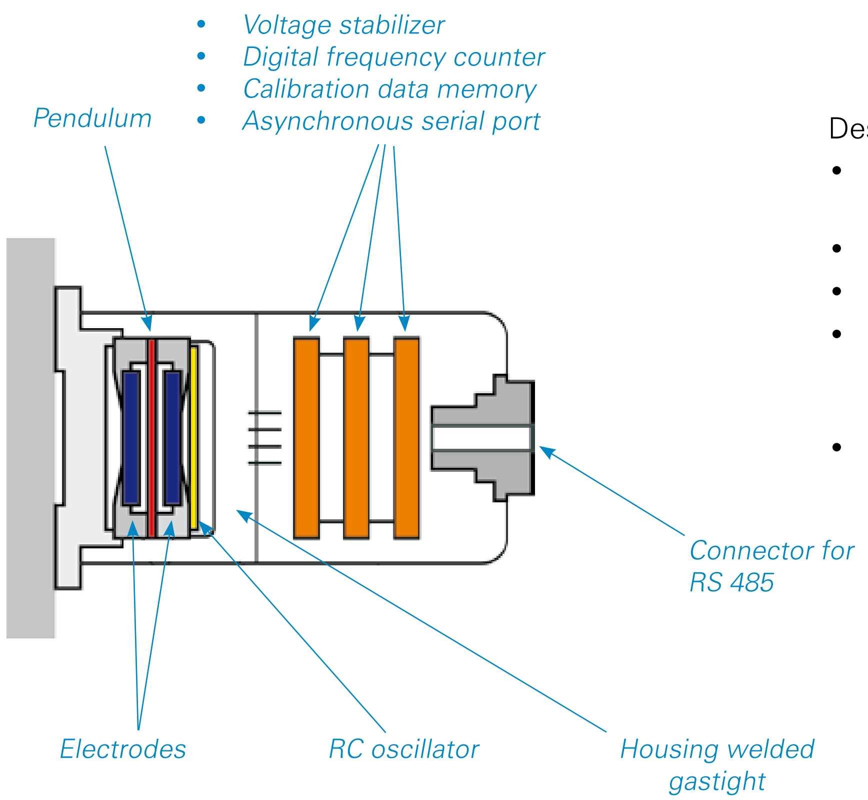
- **ZEROTRONIC Type 3**
- **ZEROTRONIC Type C**

Common characteristics of the two sensors:

- The outer dimensions and the electrical characteristics of the two sensors are identical
- The measuring element in both sensors is based on a pendulum swinging between two electrodes. Depending on the inclined position of the system, the pendulum will change its position in relation to the electrodes and in so doing, the capacitance between the pendulum and the electrodes will change. The change of these capacitances is measured digitally
- The sensor cell is completely encapsulated and thus protected against changes in humidity
- Both sensors are calibrated over the complete measuring range with reference points stored in the EEPROM of the sensor
- Both sensors are equipped with a temperature sensor and are temperature calibrated allowing an excellent compensation for temperature changes

Difference in characteristics of the two Sensors:

- The pendulum of the ZEROTRONIC Type 3 is larger, which provides a significantly better signal-to-noise ratio for smaller inclinations. The ZEROTRONIC Type 3 is therefore better suited for high precision applications where only small inclinations are measured
- The mass of the pendulum of the ZEROTRONIC Type C is smaller than the one of sensor Type 3. This provides a higher stability if the sensor is permanently inclined
- Only ZEROTRONIC Type 3 provides the option of analog output



Design of ZEROTRONIC:

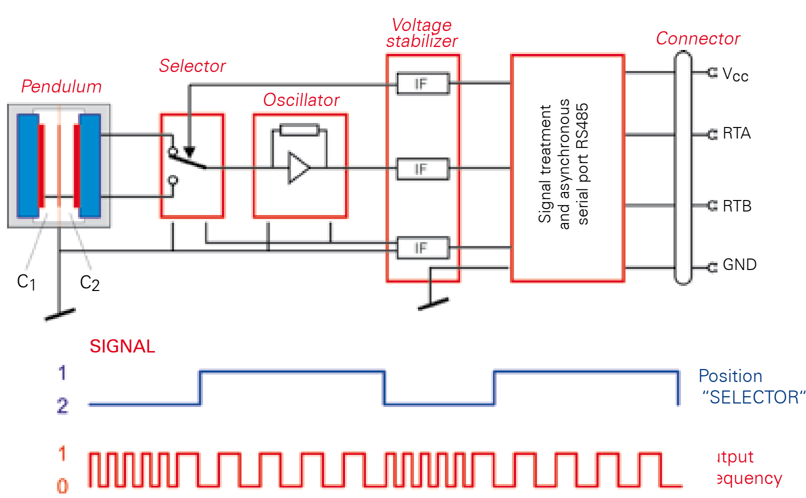
- Sensor including pendulum held by Archimedes helical springs
- RC oscillator
- Voltage stabilizer with level-shifter
- Digital frequency counter with calibration data memory and asynchronous serial port
- Housing and mounting bracket

Measuring principle of digital measuring systems

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 in doing so change the capacitance between the pendulum and the two electrodes. These capacitances are transformed into different frequencies through the RC-oscillator. The ratio of the two frequencies returned is used as the primary signal for detecting the required angle. The system is patent protected in most countries.

Ideally, the mechanical dampening of the pendulum's movements is provided by gases, normally by nitrogen. The viscosity change of gases in the temperature range between -40 °C and +70 °C is marginal. Therefore dampening with gases is superior to dampening with other substances such as liquids. The best possible results in dampening are achieved by the ratio between the surface of the pendulum and the size of 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 highly scalable by adjusting the individual parameters.

Depending on the switched-on electrode and the resulting capacitance, one RC oscillator supplies the required frequency between 250,000 and 350,000 Hz. Because of the alternating engagement of both of the electrodes through a selector switch and always using one oscillator only, it is assured that the temperature influence is limited to a minimum. This configuration has proved to be superior in terms of long-term stability over other existing applications. The short distances between the electrodes and the oscillator and the stable connections between the critical electronic elements further improve the system's capability.



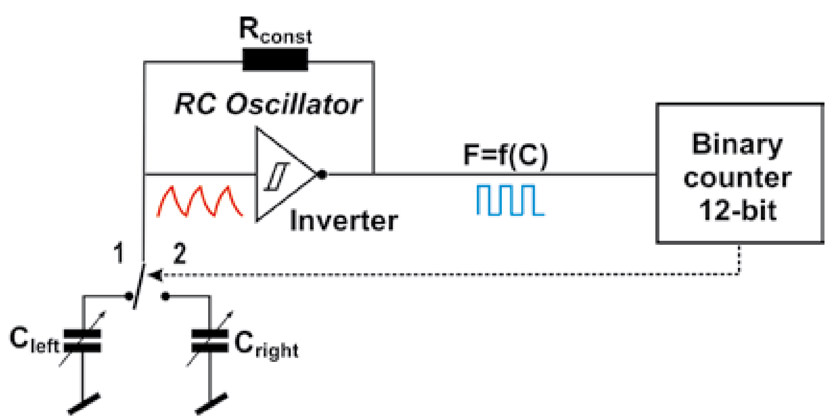
The frequency difference of approx. 100,000 Hz assures that, even when a high measuring rate is applied (numbers of measurements per second), an excellent resolution is available. Most of the existing measuring instruments have an output rate of ±2 volts. This output rate is equal to a possible range of ±2,000 digits. This is certainly not enough for accurate measurements. The implemented calibration curve, stored in the sensor's head allows easy calibrating and leads to excellent results even when using large angles.

The high stability and accuracy of the ZEROTRONIC sensors is, among other things, based on the fact that only one single oscillator is applied which is switched by a SELECTOR alternatingly to the two electrodes. This approach ensures that temperature influences can be minimized and the long-term stability is optimized.

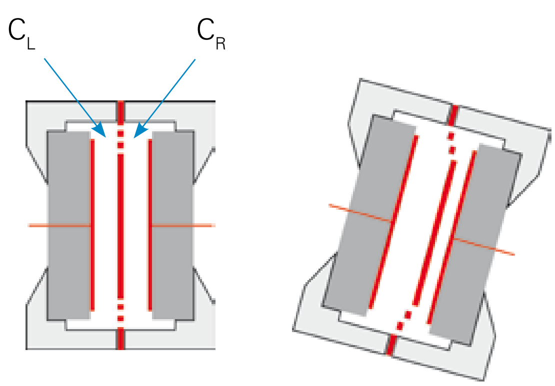
The frequency-differences between the two oscillating circuits are measured digitally and out of these values the inclination is calculated. Thanks to this concept, the signal-to-noise ratio can be optimized and the inclination can be detemined very accurately.

How does the RC-oscillator work with the pendulum system?

The two electrode-sides, consisting of electrode and pendulum, are part of the RC oscillator, which produces, depending on the inclination of the sensor, or deflection of the pendulum, a frequency in the range of 250,000 to 350,000 Hz



The reason for the frequency modulation is based on the change of capacitance left and right by the deflection of the pendulum. If the distance between the pendulum and the electrode becomes smaller, the capacitance increases in inverse proportion to the distance and vice versa.



Sensor horizontal
Capacity $C_L = C_R$

Sensor inclined
Capacity $C_L < C_R$

$$C = \frac{\varepsilon_r \times \varepsilon_0 \times A}{X}$$

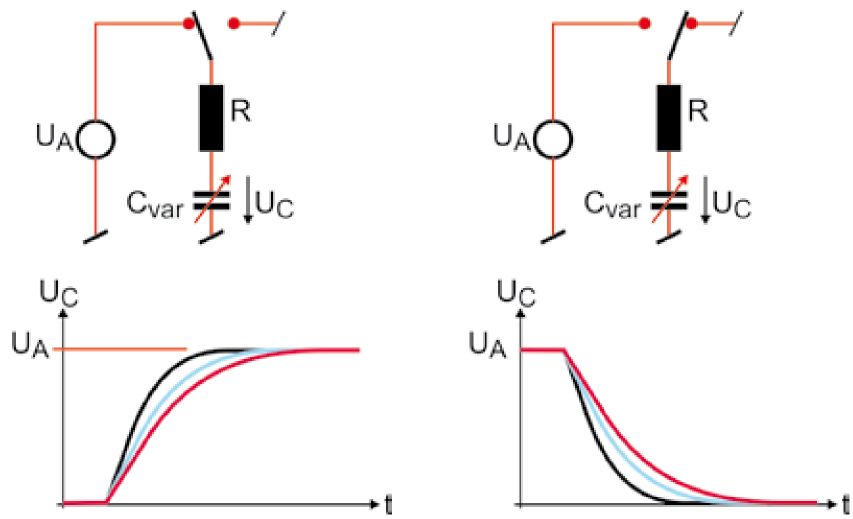
A: Face of the electrode
X: Distance between electrode and pendulum
ε: Permittivity

When a voltage is applied to a capacitor U_A ,it will be charged until $U_A = U_C$.

The charging and discharging time depends on the size of the capacitance of the capacitor.

black curve: small capacity

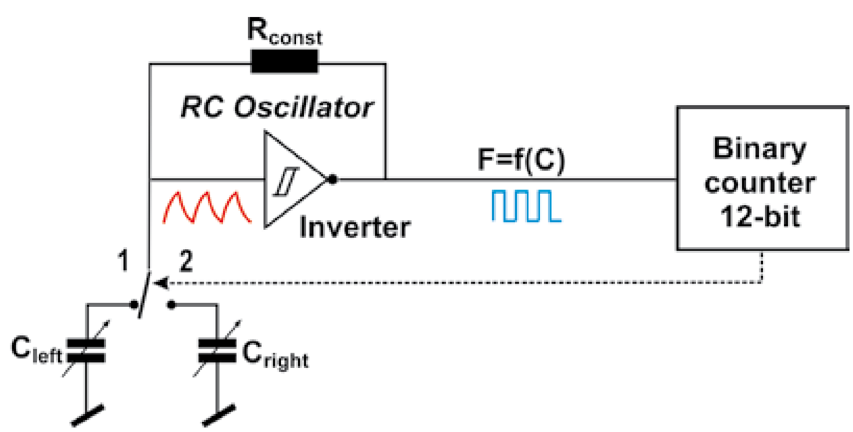
red curve: large capacity



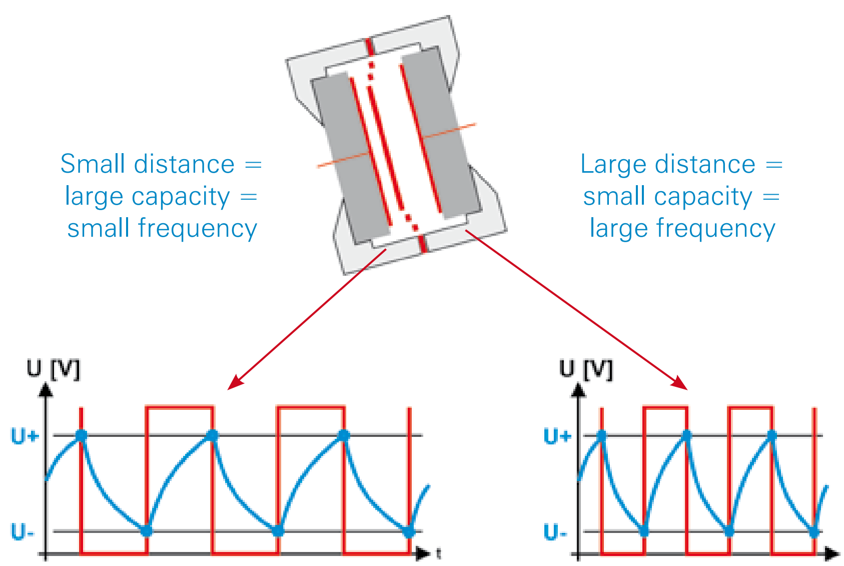
When charging or discharging the capacitor in achieving the upper and the lower threshold voltage, the discharging, or charging procedure begins.

Thus a square wave frequency is visible, which is produced by a so-called inverter. Each loading and unloading process corresponds to the period duration of the frequency F.

Through a 12-bit binary counter, the process switches from the left electrode to the right, and vice-versa.

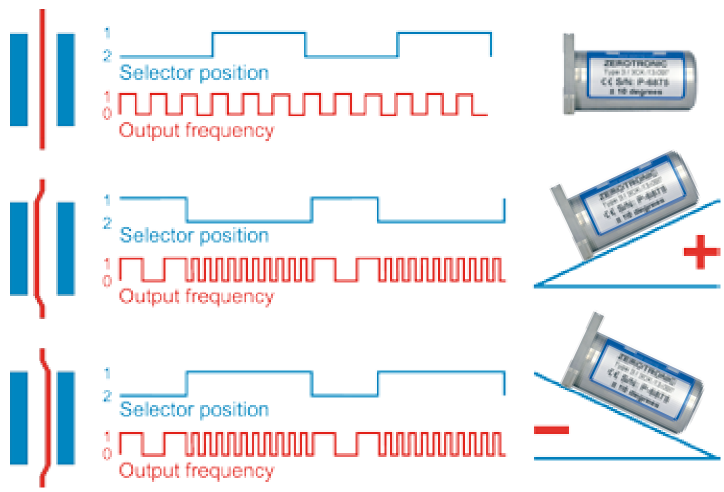


The illustration on the right shows the relationship between the inclination of the sensor, the distance between the electrodes and pendulum, and the resulting frequency.



U+: positive or upper threshold voltage
U-: negative or lower threshold voltage

Inclination of the sensor - Deflection of the pendulum - Characteristic of the frequency

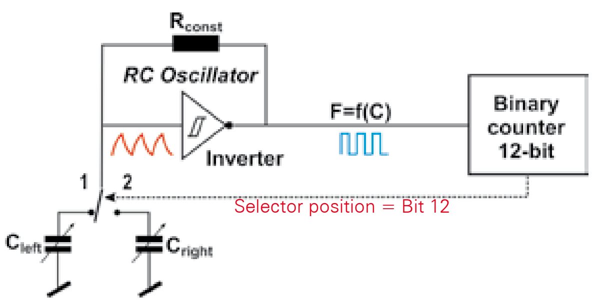


No inclination
left capacity = right capacity

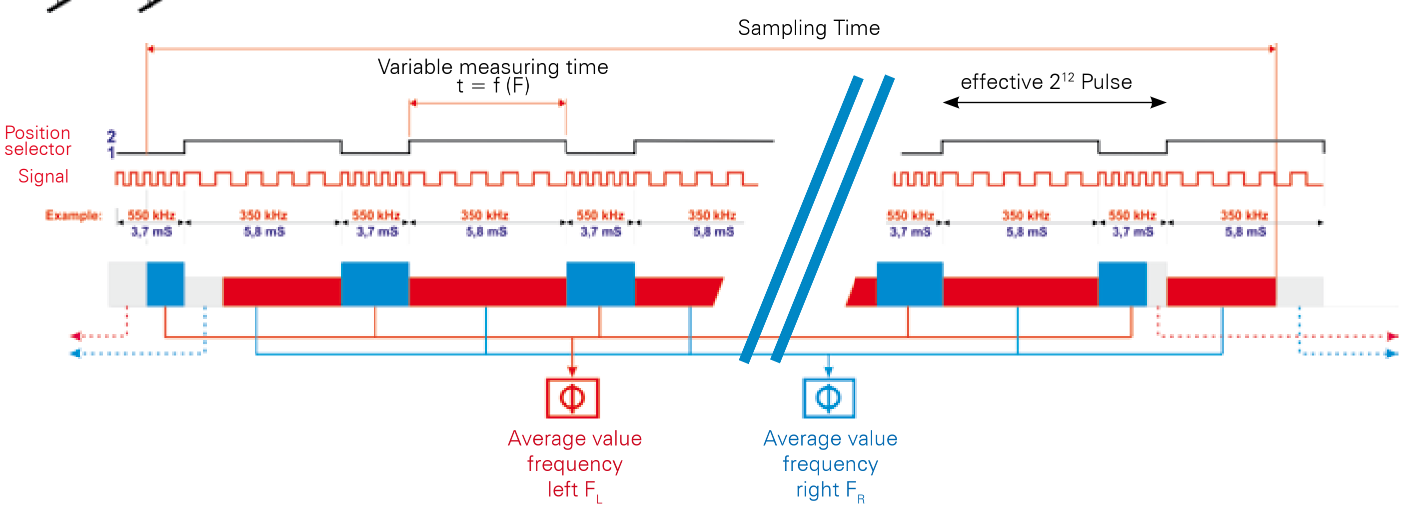
Postive inclination
left capacity > right capacity

Negative inclination
left capacity < right capacity

Relationship between sampling time (sampling time) and variable measuring time of the sensor



"Bit 12" is the signal for the selector position. Therefore, only 2^{11} pulses are counted per side.



$$\text{Inclination} = f(F) = \frac{\phi \ \text{frequency left} \ F_L}{\phi \ \text{frequency right} \ F_R}$$

Example, according to the above illustration

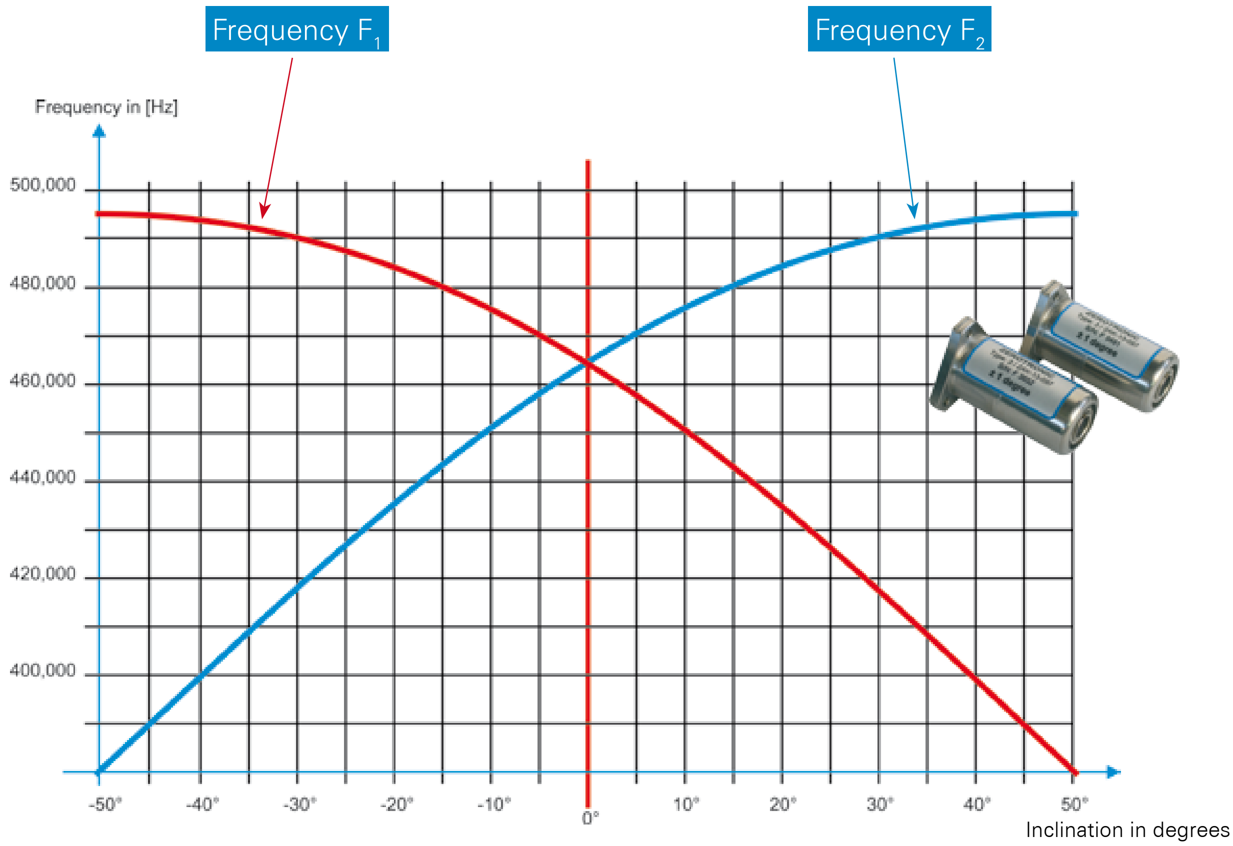
Left side S1:
F = 550,000 Hz: $\mathbf{t_1} = \dfrac{1}{550{,}000\ \text{Hz}} \times \dfrac{4096}{2} = \mathbf{3.7\ ms}$

Right side S2:
F = 350,000 Hz: $\mathbf{t_2} = \dfrac{1}{350{,}000\ \text{Hz}} \times \dfrac{4096}{2} = \mathbf{5.8\ ms}$

Sampling Time:
t_{max} = 8 seconds
t_{min} = 10ms (depending on baudrate)

Calibration of digital systems

Typical frequency response for a digital sensor



Calibration Process of digital systems

Each single sensor is individually calibrated over the complete measuring range as well as over the complete temperature range the sensor is going to be used in. These calibration values are stored as reference points in the EEPROM of the sensor.

Two temperature calibrations are available:

The standard temperature calibration is well suited for sensors that are used in a typical laboratory or a machine shop environment: temperatures around 20 °C and slow temperature changes.

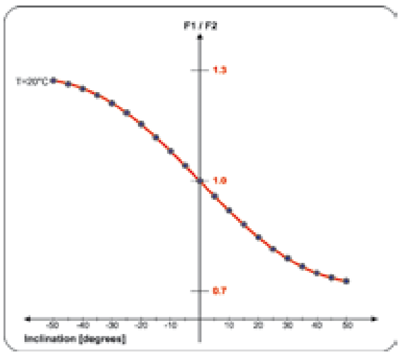
The HTR (High Temperature Range) calibration is suited for those sensors that are exposed to outdoor conditions. These sensors are calibrated at various temperatures, which ensures that they function well across the entire temperature range the sensor can be used in, which is from –40 °C to +85 °C. Thanks to the extended and more elaborate temperature calibration, the HTR sensors show a substantially lower temperature coefficient, which is 1/5 of the value of a standard temperature calibration (see technical specification).

The sensors are calibrated on high-precision calibration equipment as follows:

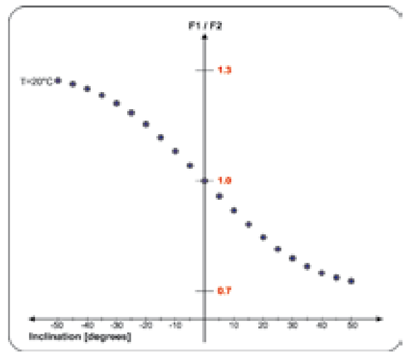
1st: Basic calibration at 20 °C with so-called reference points, which vary according to measuring range

2nd: In addition to the basic calibration, additional calibrations carried out at different temperatures

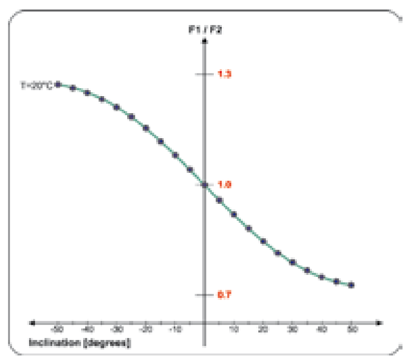
3rd: The calibration is checked for deviations of the reference points from the nominal value



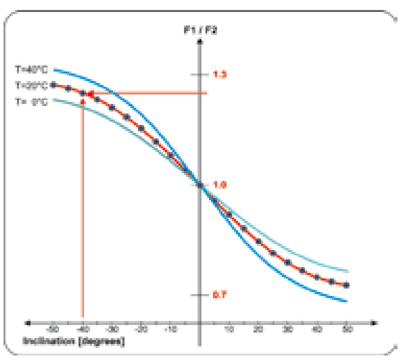
Number of reference points: depending on the measuring range of the sensor



The calibration values are stored as reference points in the EEPROM of the sensor



The values between the reference points are determined by interpolation



Finally, the calibration followed by further temperatures

Dynamic Characteristics of ZEROTRONIC sensors

Inclination sensors are highly sensitive acceleration sensors that measure the deviation from the earth's gravity. Each non-constant movement produces accelerations that will impact the inclination sensor: the stronger these external acceleration components, the lower the resulting accuracy of the inclination measurement will be.

Inclination measurements on moving objects are basically possible if these physical parameters are kept in mind.

Examples of applications that function well:

- Roll measurement on machines that move evenly along one axis
- Inclination measurement on a boat that is in sheltered harbor area
- Inclination measurement on a container that is lifted

By adapting measuring speed and integration time, the accuracy can be optimized.

Examples of applications that do not function:

- Inclination measurement on a train during a turn (the Coriolis acceleration is too large)
- Inclination measurement on a boat on open sea (the accelerations due to the motion of the sea are too large)

The following list of characteristics should allow a proper differentiation and proper application of the two sensors:

ZEROTRONIC Type 3

- High resolution, high precision for inclinations up to 10°
- Excellent signal-to-noise ratio
- Excellent repeatability
- Excellent linearity
- Excellent temperature stability

ZEROTRONIC Type C

- Excellent precision for inclinations between 10° and 60°
- Excellent repeatability
- Excellent long-term stability in inclined position
- Excellent linearity
- Excellent temperature stability

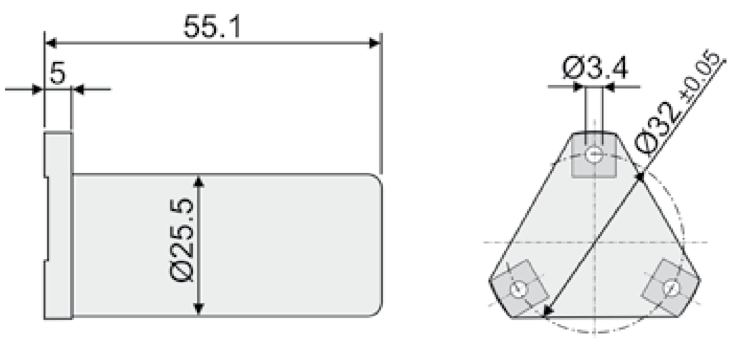
Some typical applications for the ZERPTRONIC Type 3 include those applications in which high resolution is first priority, and where only small inclinations are measured:

- Adjustment of machines (e.g. pitch and roll measurements)
- Precise adjustment of absolute zero
- Precise measurement of small inclinations in a heavy duty environment; e.g. exposure to outside temperature

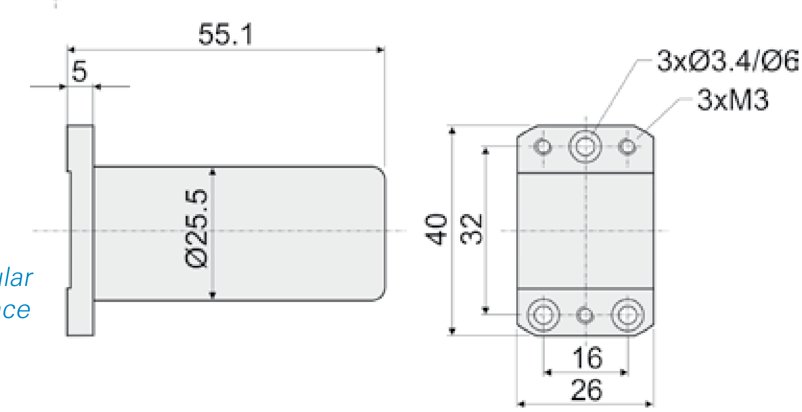
Some typical applications for the ZEROTRONIC Type C include:

- Larger inclinations
- Applications in which the sensor remains in inclined position over a longer period of time

Dimensions ZEROTRONIC SENSOR



ZEROTRONIC sensor with triangular mounting surface



ZEROTRONIC sensor with rectangular mounting surface

ZEROTRONIC SENSOR TYPE 3 TECHNICAL SPECIFICATIONS

The following page lists the technical data of the Type 3 and Type C sensors. The values shown there require a few detailed explanations.

Typical questions related to this table are:

- How should I interpret these values? What is now the accuracy of a ZEROTRONIC sensor?
- How does temperature affect accuracy?
- A blue level has an resolution of 1 μm/m and a measurement range of $\pm$20,000 μm/m, which corresponds to an inclination of $\pm 1°$. Does a ZEROTRONIC sensor with a measuring range of $\pm 1°$ range therefore have the same resolution of 1 μm/m?

In contrast to a BlueLEVEL, which is (typically) used in a controlled environment and for a limited measuring period, applications with ZEROTRONIC sensors are usually different. These range from measurements under laboratory conditions, to long-term measurements of objects, which are exposed to wind, weather and extreme temperatures. It therefore makes little sense to define general "accuracy" for ZEROTRONIC sensors. The table with the technical specifications shows the influence of the various parameters on the total error (limits of error). Some of the most important parameters are:

- Time (measuring time, change of the zero-point)
- Measured value: GAIN
- Temperature, or rather the ambient temperature deviation from reference temperature of +20 °C: Temperature coefficient
- Integration time: sampling-time

ZERO-POINT: The table contains values for the permitted deviation of the zero-point within 24 hours and 6 months. This value is critical if the sensor is fix-mounted and the possible change of the zero-point over a period of time has to be estimated.

Important: The ZERO-POINT deviation can be eliminated at any time by a reversal measurement to zero.

GAIN: This error contribution arises from the change over time of the GAIN. It depends on the reading and has a base value at the same time.

TEMPERATURE: The table shows the temperature coefficient per degree Celsius of temperature difference to 20 °C. That means that the proportion of the error caused by the temperature at -10 °C is in the same range as at +50 °C.

Important: The temperature error can be reduced substantially (to 1/5 of the declared value) by the so-called HTR calibration, in which reference values at low and high temperatures are also stored in the sensor. We recommend the HTR calibration in all applications where the ZEROTRONIC sensor is exposed to high temperature variations.

SAMPLING TIME: These values indicate that the measurement errors can be greatly reduced if the measured values can be integrated over a longer time.

The values also show that the error reduction is in the same order of magnitude when

- a long measuring interval is assigned to the sensor
  or
- when measured faster and the measured values are then integrated.

This means the following: You can specify a measuring interval of 0.1 seconds and then collect 10 readings per second, or you can specify a measuring interval of 1 seconds directly. The result is very similar, but differs when the sensor is mounted on a non-fixed object. For critical applications, the optimal balance of internal and external integration has to be determined.

The total error of a sensor ZEROTRONIC must logically be calculated individually for each application by adding all relevant error contribution. In laboratory conditions, high-precision measurements are possible.

If the application requires, however, measurements at different temperatures and for a long time, these error contributions have to be analyzed in detail to determine whether the required accuracy can be achieved, or whether, for example, mechanical protective measures such as protection from direct sunlight are necessary or whether the temperature influence can be reduced with an insulated housing. Also, the application software and the integration time must be given the necessary attention.

Customized solution with ZEROTRONIC sensors in specially designed adapters using BlueTCs for wireless data transmission

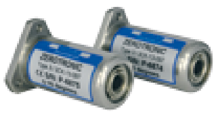
ZEROTRONIC SENSOR TYPE 3 TECHNICAL SPECIFICATIONS				
ZEROTRONIC Type 3	ZERO 0.5	ZERO 1	ZERO 10	ZERO 30
Full-scale	±0.5°	±1°	±10°	±30°
Limits of error within 24 hours (TA = 20°C)				
• ZERO-POINT (Drift)	0.070% F.S.	0.050% F.S.	0.015% F.S.	0.010% F.S.
Limits of error within 6 months (TA = 20°C)*				
• ZERO-POINT (Drift)	0.170% F.S.	0.140% F.S.	0.055% F.S.	0.030% F.S.
• GAIN	0.250% R.O.	0.250% R.O.	0.060% R.O.	0.050% R.O.
	+1 Arcsec	+1.5 Arcsec	+3.6 Arcsec	+5.4 Arcsec
Temperature error / °C (-40°C <= TA <= 85°C)*				
• ZERO-POINT	0.060% F.S.	0.040% F.S.	0.008% F.S.	0.005% F.S.
• GAIN	0.200% R.O.	0.200% R.O.	0.030% R.O.	0.020% R.O.
for ΔT >10 °C ≠ 20 °C, plus	(+2 Arcsec)	(+3 Arcsec)	(+6 Arcsec)	(+6.5 Arcsec)
Resolution (TA = 20 °C)				
(sampling time: 0.1 seconds)				
w/o filter	0.041% F.S.	0.025% F.S.	0.020% F.S.	0.020% F.S.
with filter	0.020% F.S.	0.010% F.S.	0.005% F.S.	0.006% F.S.
(sampling time: 1.0 seconds)				
w/o filter	0.020% F.S.	0.010% F.S.	0.005% F.S.	0.006% F.S.
with filter	0.010% F.S.	0.005% F.S.	0.002% F.S.	0.003% F.S.
(sampling time: 10.0 seconds)				
w/o filter	0.007% F.S.	0.006% F.S.	0.002% F.S.	0.003% F.S.
with filter	0.006% F.S.	0.006% F.S.	0.002% F.S.	0.003% F.S.
Repetition	Repetition is included in "Resolution", see above			
Differential linearity (within 0.1% F.S.)	Differential linearity is included in "Resolution", see above			

ZEROTRONIC SENSOR TYPE C TECHNICAL SPECIFICATIONS				
ZEROTRONIC Type C	ZERO 10	ZERO 30	ZERO 45	ZERO 60
Full-scale	±10°	±30°	±45°	±60°
Limits of error within 24 hours (TA = 20 °C)				
• ZERO-POINT (Drift)	0.015% F.S.	0.008% F.S.	0.005% F.S.	0.005% F.S.
Limits of error within 6 months (TA = 20°C)*				
• ZERO-POINT (Drift)	0.085% F.S.	0.050% F.S.	0.040% F.S.	0.035% F.S.
• GAIN	0.080% R.O.	0.030% R.O.	0.030% R.O.	0.027% R.O.
	+4 Arcsec	+6 Arcsec	+10 Arcsec	+12 Arcsec
Temperature error / °C (-40°C <= TA <= 85°C)*				
• ZERO-POINT	0.011% F.S.	0.005% F.S.	0.005% F.S.	0.004% F.S.
• GAIN	0.015% R.O.	0.020% R.O.	0.025% R.O.	0.030% R.O.
for ΔT >10 °C ≠ 20 °C, plus	(+6.5 Arcsec)	(+7 Arcsec)	(+11 Arcsec)	(+14 Arcsec)
Resolution (TA = 20 °C)				
(sampling time: 0.1 seconds)				
w/o filter	0.050% F.S.	0.022% F.S.	0.018% F.S.	0.025% F.S.
with filter	0.020% F.S.	0.007% F.S.	0.005% F.S.	0.005% F.S.
(sampling time: 1.0 seconds)				
w/o filter	0.015% F.S.	0.006% F.S.	0.005% F.S.	0.004% F.S.
with filter	0.006% F.S.	0.003% F.S.	0.002% F.S.	0.002% F.S.
(sampling time: 10.0 seconds)				
w/o filter	0.008% F.S.	0.003% F.S.	0.003% F.S.	0.003% F.S.
with filter	0.008% F.S.	0.003% F.S.	0.002% F.S.	0.002% F.S.
Repetition	Repetition is included in "Resolution", see above			
Differential linearity (within 0.1% F.S.)	Differential linearity is included in "Resolution", see above			

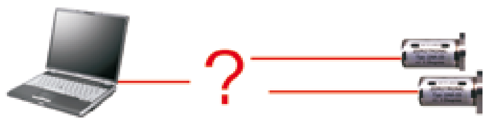
**Remarks*

F.S. = Full-scale (errors related to F.S. are mainly due to drift of zero).
R.O. = Read Out (errors related to R.O. are mainly due to change of gain).
w/o filter = raw values; with filter = floating average over 10 values.
HTR calibration will reduce temperature coefficient by approx. 5 times.

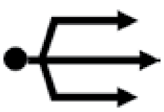
STANDARD CONFIGURATIONS FOR ZEROTRONIC SENSORS



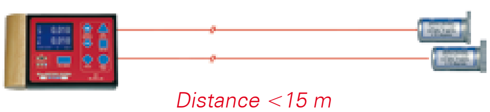
The customer buys the ZEROTRONIC sensor and is responsible for the signal treatment himself. This means the customer uses their own in-house software. In order to be able to do so, the respective sensor specifications are described in this chapter.



Direction PC/laptop

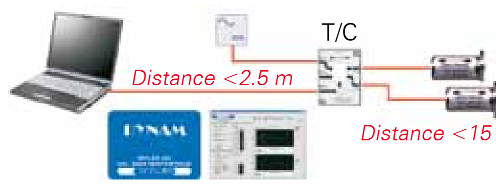


Direction measuring instruments

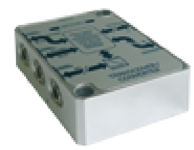


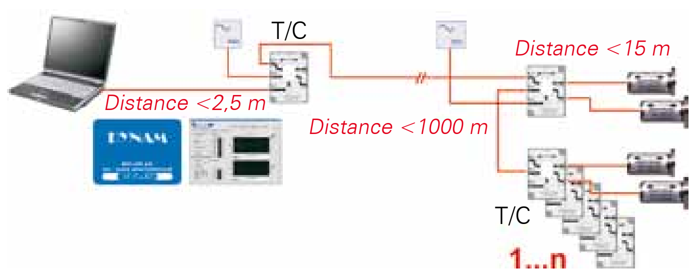
ZEROTRONIC sensors connected to a BlueMETER

Connection to a PC/laptop through a T/C (Transceiver/Converter)

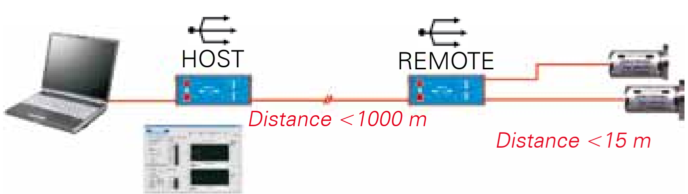


ZEROTRONIC sensors connected to a PC/laptop on RS485-Bus through one or more Transceiver/ Converters (T/C). Analysis of measuring results using DYNAM or LabEXCEL software.
External power supply via Transceiver/Converter.

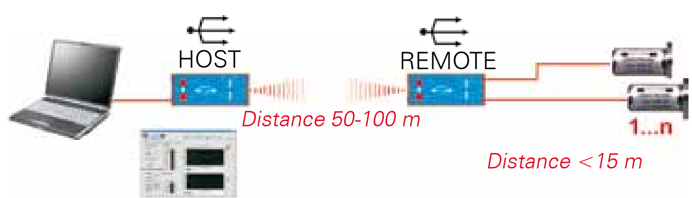




ZEROTRONIC sensors connected to a PC/laptop through two BlueTCs

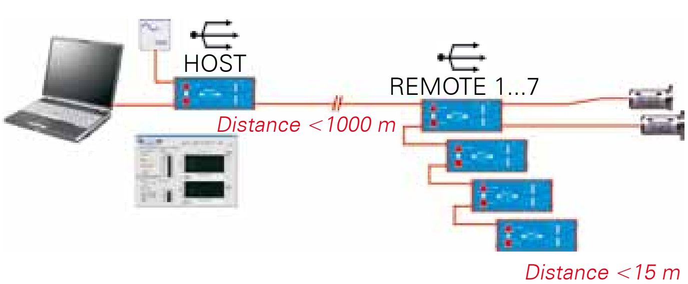


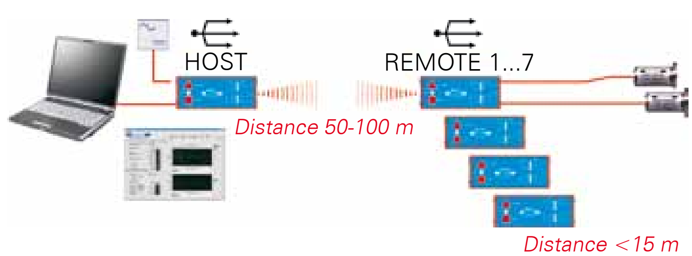
ZEROTRONIC sensors connected to a PC/laptop through BlueTC. The BlueTC is used as an interface for data transmission through a wireless connection



The BlueTC is used as an interface for data transmission through a cable or wireless connection.

To each BlueTC up to eight sensors may be connected. In total, the system can handle 64 units. Because every TC also uses one address, a total of 56 sensors can be connected (64 minus 8 BlueTC addresses). Analysis of measuring results utilizing LabEXCEL software.

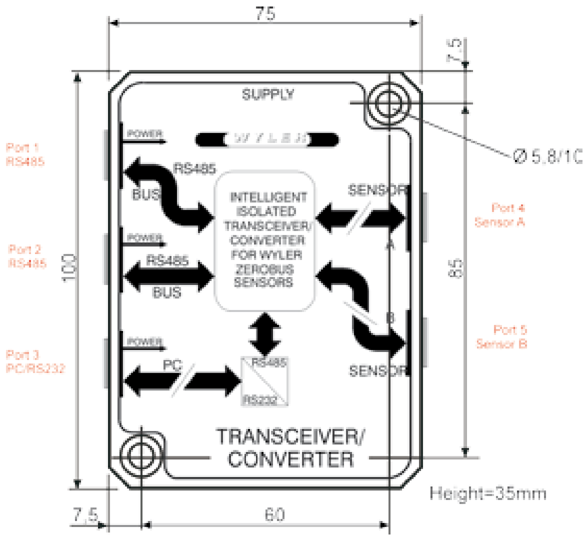




ZEROTRONIC SENSOR TECHNICAL SPECIFICATIONS

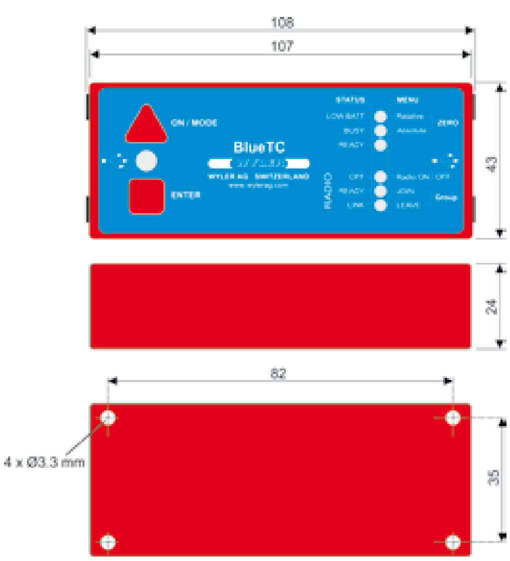
		ZEROTRONIC Sensor Type 3	ZEROTRONIC Sensor Type C
Power consumption ZEROTRONIC sensors		ca. 70 mW	ca. 100 mW
Power supply	Sensor	5V ±10%	5V ±10%
Digital output		RS 485 / asynchronous , 7 DataBits, 2 StopBits, no parity	
	baud rate (automatic adjustment)	2,400 ... 115,000	9,600 ... 57,600
Analog output PWM		0.5V ... 2.5V ... 4.5V @ 5V Supply	---------
Temperature range	Operating	-40 °C to +85 °C	
	Storage	-55 °C to +95 °C	
Net weight sensor		118 gr	100 gr
Shock resistance		practically insensitive	

Dimensions T/C (Transceiver/Converter)

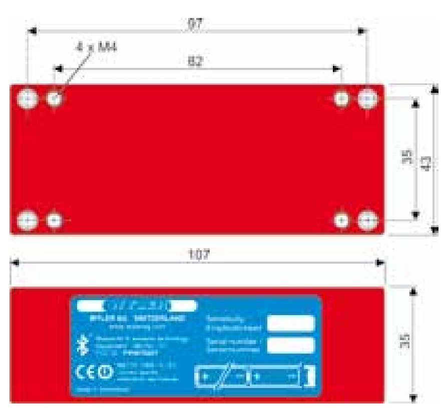


- Automatic baud rate detection 4,800…57,600 baud
- Port 1 and Port 2 = RS 485 bus-connection to and from the aligned T/Cs. Up to 32 sensors can be connected (feeding and transmission of the unregulated power supply (12…48 V DC))
- Port 3 (P/C RS 232): RS 232 interface to PC/ laptop (If not occupied, Port 3 represents a possibility to feed an unregulated power supply (12…48 V DC)
- Ports 3 / 4 / 5 are equipped with galvanic isolation of the bus line

Dimensions of the BlueTC and the battery pack



Digital output	RS 232 / RS 485 / 2 StopBits, no parity, 9600 bps
External power supply	BlueTC: +5V DC, max. 450 mW (PIN 3) or 8…28 V DC (PIN 1)



BlueTC with battery pack

MultiTC (Transceiver/Converter)

The MultiTC is a system component and an interface to connect WYLER-sensors (ZEROTRONIC or ZEROMATIC) with a laptop.

- MultiTC provides an easy way to power the sensors, either through the USB port of a laptop or via a separate 24V power supply.
- The measuring values are transferred from the sensors via the MultiTC to an RS232- or anUSB port of the laptop, where the values can be evaluated with one of the WYLER measuring software like LEVELSOFT PRO, MT-SOFT or LabEXCEL.

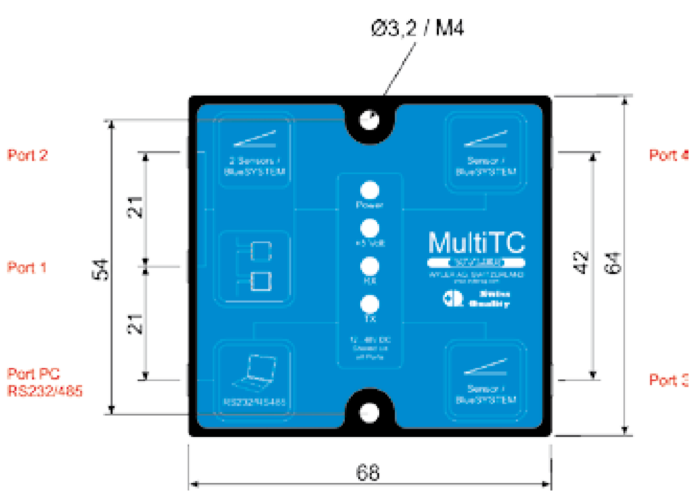
MultiTC TECHNICAL SPECIFICATIONS	
External power supply	+ 5V DC, max. 450 mW (USB) or 12-48V DC (external Powersupply)
Format of transmission	RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 57'600 bps
Dimensions	L x W x H 68 x 64 x 23mm
Operating temperature range	0 ... + 40 °C
Storage temperature range	0 ... + 70 °C
Net weight	190 g

- MultiTCs can be cascaded, that means, several MultiTCs can be connected to each other allowing wide area system configuration with several sensors.
- With baud rates up to 57'600 bps the MultiTC allows fast data acquisition
- Four LEDs allow simple monitoring of the status of the communication as well as of the power supply

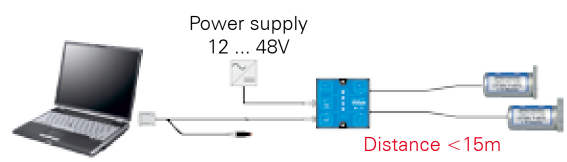
Advantages compared to BlueMETER:
- Simple configuration
- Reduced costs

Disadvantages compared to BlueMETER:
- No display of the measuring values on the measuring instrument [A] and reference instrument [B]
- Change of address of a measuring instrument not possible
- PC with software LEVELSOFT PRO or LabEXCEL is indispensable

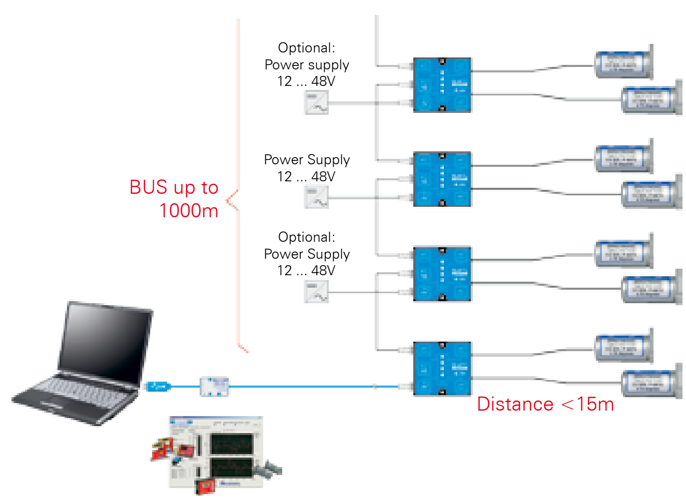
Dimensions of the MultiTC



Possible configurations with MultiTC



Configuration with 2 ZEROTRONIC sensors, connected to a RS232-port of a laptop, via a MultiTC. Power is supplied from an external power supply 24V.

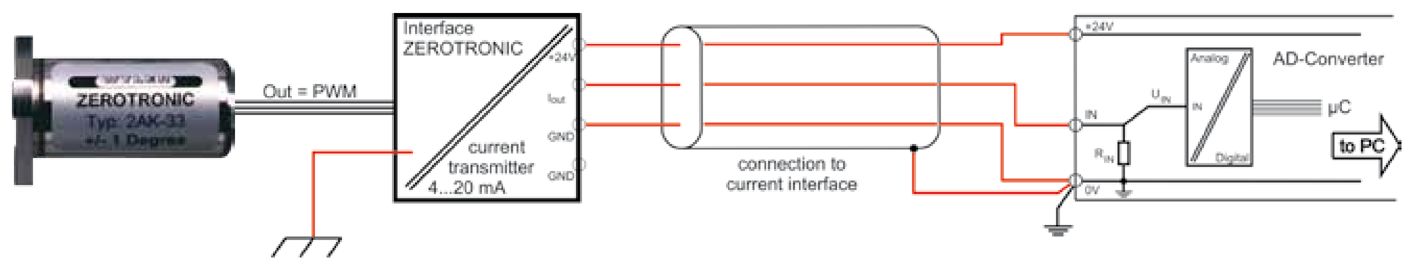


Configuration with 8 ZEROTRONIC sensors, connected to an RS232- or an USB port of a laptop, via 4 MultiTC. Power is supplied from one or several 24V power supplies.

7.2.2 ZEROTRONIC SENSOR WITH ANALOG OUTPUT (PC INTERFACE WITH CURRENT TRANSMITTER)

The ZEROTRONIC sensor has a digital output. In order to integrate this sensor in an analog measuring system, there is a separate interface with a current transmitter (4-20 mA), connectable to a standard A/D converter card on a PC, available (for ZEROTRONIC sensor Type 3 only).

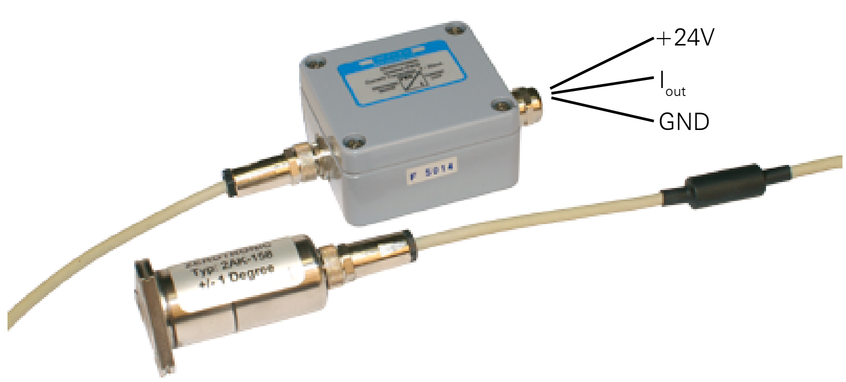
Current Transmitter 4...20mA for ZEROTRONIC sensors



CURRENT TRANSMITTER TECHNICAL SPECIFICATIONS			
Power supply		18...36 V DC (50 mA at 24V)	
Operating temperature range		0...70 °C	
Settling time (selectable)	7.5 mS	75 mS	750 mS
Accuracy	LOW	MEDIUM	HIGH
Output currents		+FS 1)	20 mA
		Zero Point	12 mA
		-FS 1)	4 mA
Weight, incl. cable to sensor		260g	
Dimensions		65 x 48 x 35 mm	

Remarks 1)

MEASURING RANGE ZEROTRONIC SENSORS	Fullscale (FS)	Output current / °
±1°	±2°	4 mA
±10°	±10.5°	0.7619 mA
±30°	±33°	0.2424 mA



7.2.3 Special applications with ZEROTRONIC sensors

The ZEROTRONIC sensors are already very compact. Nevertheless, it is often necessary to mount the sensor in an even more limited space. Thanks to its modular design, special solutions can be developed.

The example to the left shows ZEROTRONIC sensors, which are mounted in a vertical cylindrical form. In order to achieve this, the sensor unit and the electronic unit have been mounted separately on top of each other. One sensor is mounted along the X axis,, the other one along the Y axis.

Both sensors have a common electrical interface to the RS 485 bus.

Two ZEROTRONIC sensors mounted on top of each other
One sensor measures the X axis, the other sensor the Y axis.

Diameter of the unit is less than Ø 35 mm

Another example is shown in the next picture. A ZEROTRONIC sensor is mounted in a special mounting block onto a standard WYLER base. With this configuration, the sensor can be used as a hand tool.

Measurement values can be read on a LEVELMETER 2000 or a BlueMETER/BlueMETER BASIC and can be further treated with software

- **DYNAM**
- **LEVELSOFT PRO**
- **LabEXCEL**

on a PC/laptop.

The picture shows a 2D-sensor, which has been developed to be supported by the vertical spindle of a machine tool. The measuring fixture is suited for analyses of rotation **"PITCH"** and **"ROLL"** (both X and Y axes can be measured at the same time).

When it comes to heavy duty applications a special housing, like on the picture to the right can be used to protect the 2D sensor completely.

This picture shows a 2D-sensor in a special housing with switchable magnetic fixing. The device is suitable for measuring the rotation "PITCH" and "ROLL" in tight spaces.It can also be mounted on vertical surfaces.

Customized solution with ZEROTRONIC sensors in specially designed adapters using BlueTCs for wireless data transmission

For heavy duty applications all system components can be equipped with increased IP protection

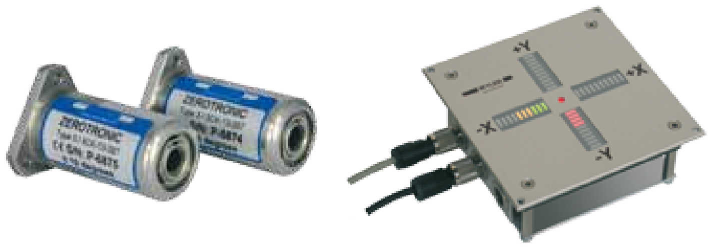
The above examples show that the application of ZEROTRONIC sensors is very flexible. Our engineers are interested in discussing your special applications and defining customer specific solutions for you.

TWO DIMENSIONAL LED-CROSS WITH ZEROTRONIC SENSORS

The two-dimensional LED-CROSS is very suitable for providing a visual representation of the inclination of a platform.

Typical applications are:

- Supervision of a crane for goods that are sensitive to inclinations
- Optical aid for manual hydraulic levelling of objects or platforms
- Supervision of working platforms: preventing the platform from tilting with the help of programmable alarms

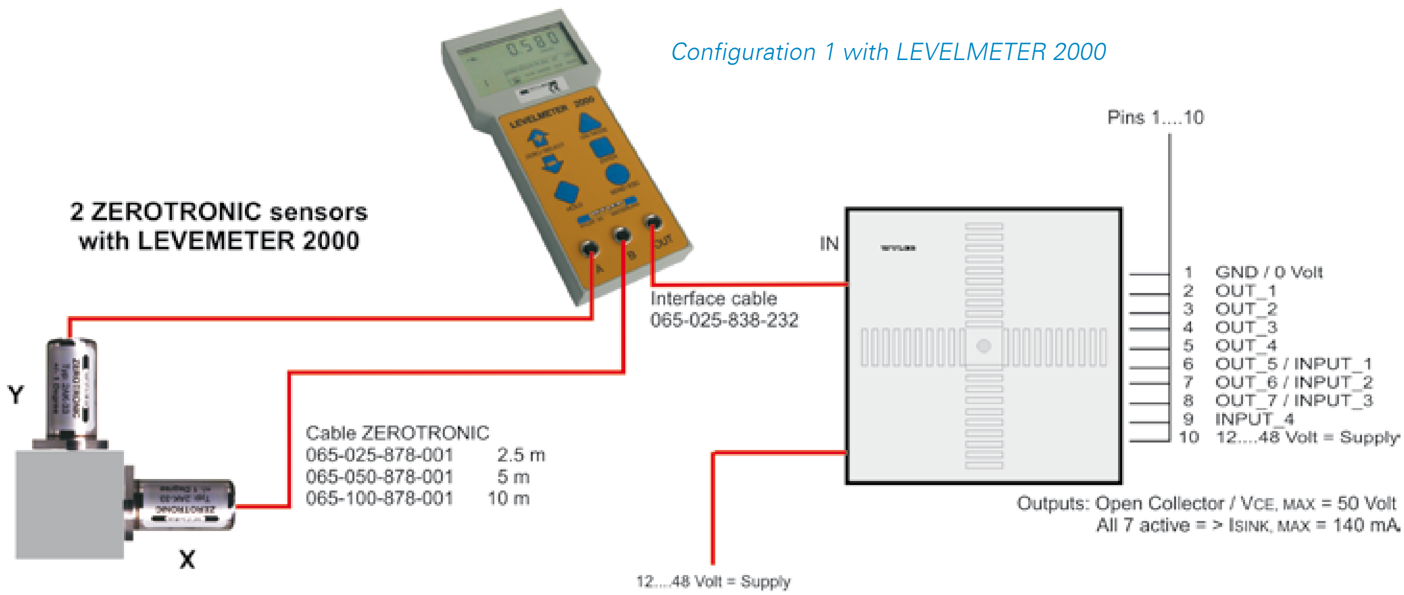


The instrument has the following features:

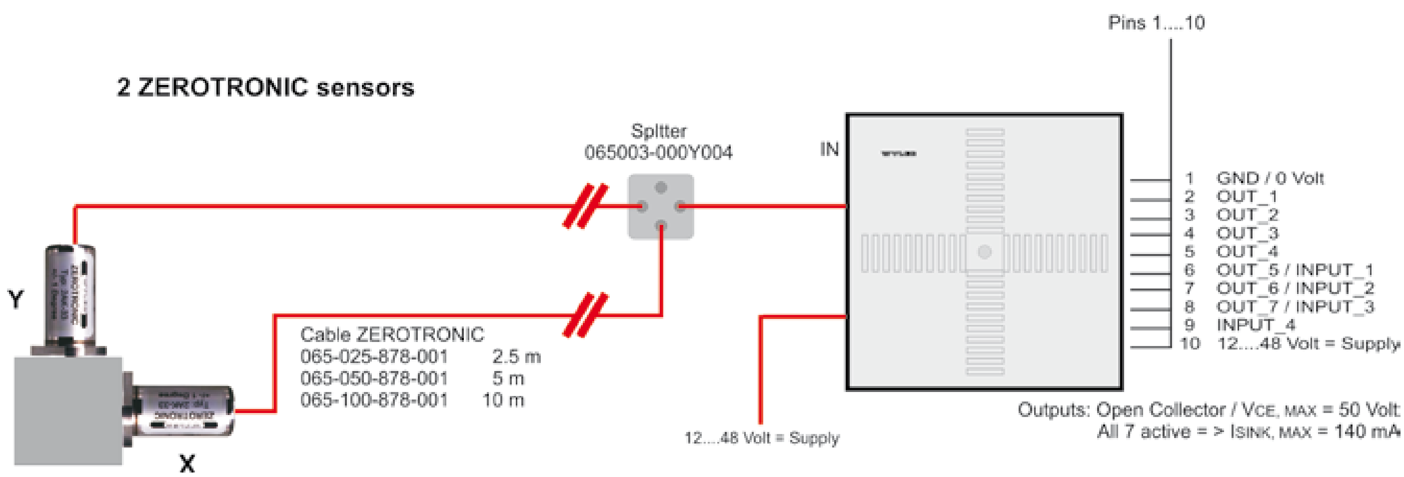
- Inputs for two ZEROTRONIC sensors; typically two 10° sensors are used
- Resolution of ten LEDs per direction. Logarithmic resolution to allow very precise reading around zero
- Four alarms can be set (one alarm per direction)
- Seven alarm outputs (open-collector outputs) are programmable with logical functions
- The functionality of the unit and the cables are controlled, and can be assigned to one of the alarm outputs. Unit can be panel-mounted or mounted in a housing. Box available on request
- Connection for an additional LED-cross with slave function

TECHNICAL SPECIFICATIONS LED-CROSS	
Power supply	12 - 48 V DC (200 mA / 24V DC)
Operating temperature range	-20° ... +85°
Update speed of the display	2 - 3 Hz
Communication protocol for X- and Y-axis sensors	According to our "WYBUS" specification: RS 485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Interface for X- and Y-sensors	According to our "WYBUS" specification: RS 485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Dimensions	Plate: 96 x 96 mm / Height: approx. 40 mm
Hole center distance	89 x 89 mm / M3
Net weight (without housing and cables)	171 g

Configuration 1 with LEVELMETER 2000



Configuration 2



7.3 DYNAM Software for ZEROTRONIC sensors

DYNAM / The measuring software for ZEROTRONIC sensors

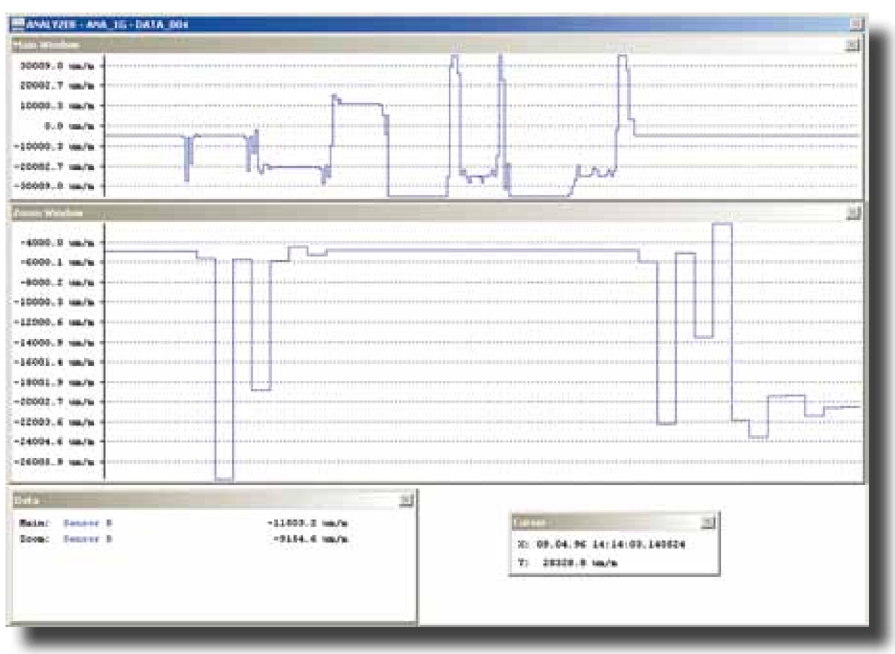
The DYNAM software was developed for calculating and displaying static and dynamic inclinations and profiles under MICROSOFT WINDOWS. The ZEROTRONIC family of sensors can be operated with the DYNAM software. With this software, the data of the connected sensors can be sampled, computed and displayed in forms or it can be transmitted. Each of the connected sensors is a so called "sensor measuring channel" which has to be named, and can be addressed correspondingly.

The integrated software modules allow the performing of a number of measuring tasks without knowledge of software programming. Simple tasks like computing the difference between two sensors or sophisticated jobs such as the compensation of an acceleration from the measured angle can be performed easily.

The measured data can be displayed in numerical or graphical form on a computer monitor, sent to a connected printer, saved in files on hard disc or a storage device or sent to a serial output port.

The software module ANALYZER allows users to open the files with the saved data and display the data again in numerical or graphical form on the monitor.

Requirement Hardware/PC:	RS 232 interface. Adapter solutions can not be used. Only T/C (transceiver/converter) can be used as an interface.



The SW ANALYZER module allows access to stored data and display in graphical or numerical form on the screen

7.4 LabEXCEL Software (LabVIEW®-Application)

LabEXCEL is an easy-to-use software package for displaying the measurement values of WYLER inclination measuring instruments and sensors. The core is the WYLER WyBus-module. This software ensures the communication between the inclination measuring instruments and sensors and the user interface of LabVIEW. The measuring results can continuously be transferred into a csv file for further treatment, e.g. in EXCEL.

Requirements for the installation of "LabEXCEL" software

- Framework 2.0 (Microsoft .NET Framework 2.0).
  Download from [Windows Update] or installation from the CD-ROM delivered

Up to 10 WYLER inclination measuring instruments or sensors can simultaneously be read into "LabEXCEL". In addition, users can choose to display the difference of the measuring values between any pair of inclination measuring instruments or sensors.

SYSTEM REQUIREMENTS:

- Microsoft Windows 2000 / XP, Service Pack 2 / VISTA / WIN 7
- Pentium III
- Minimum 32 MB RAM
- Graphic card 800x600 pixels
- CD-ROM

Activation (license) of the software by means of a USB dongle

7.5 WYLER SW Development Kit

For customers intending to develop their own analyzing software for WYLER instruments, WYLER AG provides several software examples that explain how to interact with WYLER instruments or sensors either directly or via a software interface developed by WYLER. These examples should allow experienced programmers to successfully develop their own application software.

WYLER software interface for Microsoft Windows:
The software interface developed by WYLER provides users with a common programming platform to integrate WYLER instruments and sensors and consists of three functional blocks:

1. COM port management
    - Listing of the COM ports
    - Selection of the COM ports to be used
2. Instruments and sensor administration
    - Listing of instruments and sensors
    - Selection of the sensors to be measured by their ID
3. Reading of measuring values
    - Adjustment of measuring parameters
    - Selection of measuring speed / sampling rate
    - Measuring values to be read (displayed angle, temperature)
    - Reading / memorizing of measuring values in the background
    - Reading in / transfer of values measured in the background at any time

Software interfaces are available for the following programming environments:

- Visual C++ 6.0
- C#
- Visual Studio 2008
- LabVIEW™ from version 8.6.1

  System requirements for the WYLER software interface:
  Microsoft .NET framework 2.0

8 Handheld Inclination measuring instruments with digital measurement evaluation

8.1 Inclination measuring instrument BlueLEVEL-2D

The BlueLEVEL-2D is a high precision and compact inclination measuring instrument for 2 axes. In spite of its small outer dimensions the instrument contains 2 inclination sensors one in X- and one in Y-direction together with a full graphical and color 2D-display.

Thanks to its precision and its size the BlueLEVEL-2D is perfectly suited for the alignment of machines and machine parts. It can be used as a stand-alone unit, but also in combination with a WYLER measuring software.

BlueLEVEL-2D has the following features:

- Rugged, rust-protected housing made of aluminium
- High precision bases with three inserts made of sintered carbide Ø20 mm with one M4 thread each
- Large and very easy-to-read color display
- Various display methods can be chosen
- All current units can be indicated
- The instrument is compatible with the full range of WYLER digital sensors
- Powered by standard 1.5V batteries, rechargeable batteries or main adapters
- The internal software allows a simple zero setting, together with a reversal measurement
- Fulfils the strict CE- / FCC requirements (immunity / emission of electromagnetic smog)
- Options:
  - External power supply 24V
  - Wireless communication, based on Bluetooth technology
  - Cable to connect the instrument to a PC
  - Software to collect measuring data
  - Various attachable measuring bases on special request, like e.g. prismatic

Graphical 2D-display

The 2D-display shows graphically the position of an object in space, respectively the change of its position and makes the information easily understandable.

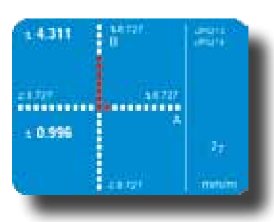
This substantially facilitates the alignment of e.g.

- a machine
- a reference plate

  etc.

The following parameters (among others) can be set and changed at the BlueLEVEL-2D:

- Units
- Display of measuring range
- Type of display
- Filter settings

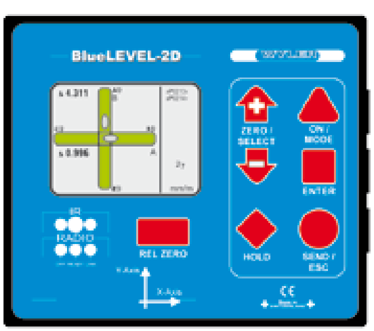


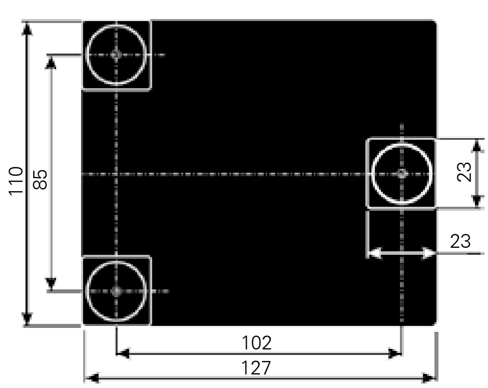
It is possible to send the measured data via an RS232 port to a PC/laptop and therewith to the WYLER software LEVELSOFT PRO, MT-SOFT and LabEXCEL software.

BlueLEVEL-2D TECHNICAL SPECIFICATIONS

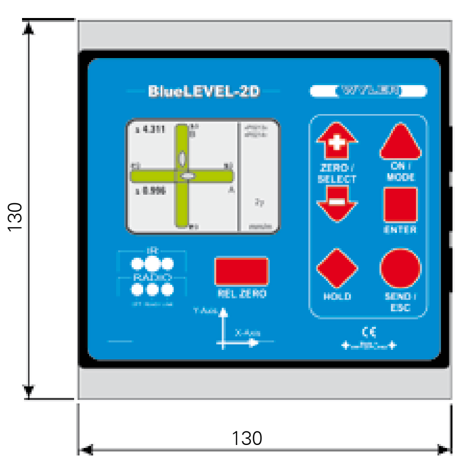
Measuring range (both axis)	BlueLEVEL-2D ±20 mm/m (±1°)	BlueLEVEL-2D ±100 mm/m (±5°)
Settling time (DIN 2276) / Value available after	<5 seconds	
Resolution	1 μm/m	5 μm/m
Limits of error according to DIN 2276 <0.5 full-scale (DIN 2276)	max. 1% of measured value + min. 1 digit	
Limits of error according to DIN 2276 >0.5 full-scale (DIN 2276)	max. 1% of (2 x measured value - 0.5 x full-scale)	
Data connection	RS232 / RS485, asynchr., 7 DataBits, 2 StopBits, no parity, 9600 bps	
Wireless option	Bluetooth® ISM Band / 2,4000 – 2,4835 GHz	
Temperature error • 20 °C±5 °C • 0...40 °C / DIN 2276	up to 2'000 μm/m: max. 2 μm/m up to 20'000 μm/m: max. 4 μm/m	up to 10'000 μm/m: max. 10 μm/m up to 100'000 μm/m: max. 20 μm/m
Power supply with batteries (lifetime with Bluetooth)	2 x size C, total Voltage 3V maximum primary types, NiMH, NiCd, NiZn (ca. 12 hrs)	
External power supply	5V DC (USB) / 24V DC (external power supply)	
Dimension housing + net weight	L x W x H / L X B X H : 127 mm x 110 mm x 48 mm 1.4 kg	
Temperature range Operating Storage	0 °C to + 40 °C - 20 °C to + 60 °C	
CE conformity	Meets emission and immunity requirements	

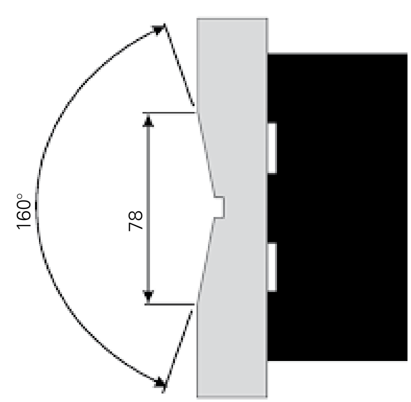
Dimensions of the BlueLEVEL-2D





3 inserts made of sintered carbide
Ø20 mm, with one M4 thread each

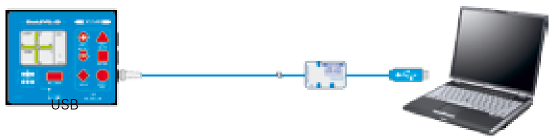




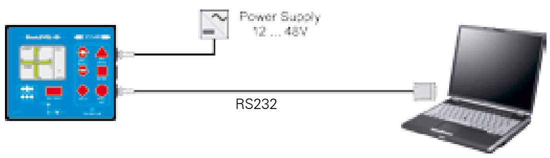
Primatic base made of cast iron for shaft Ø80 ... 370 mm

Primatic base made of aluminium hard anodised for shaft Ø80 ... 370 mm

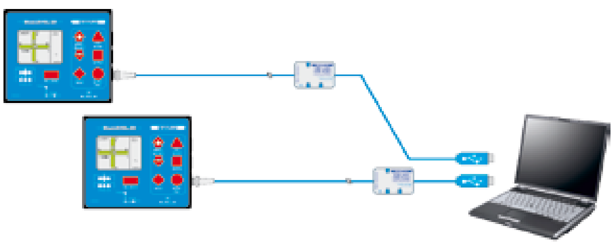
Possible configurations with BlueLEVEL-2D



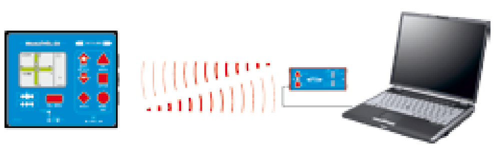
BlueLEVEL-2D connected to a laptop with an USB cable. The instrument is powered from the USB port.



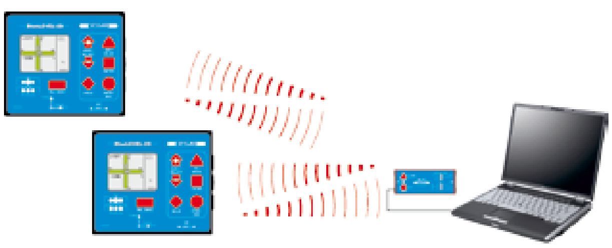
BlueLEVEL-2D connected to a laptop with the RS232 cable. The instrument is powered from an external power supply.



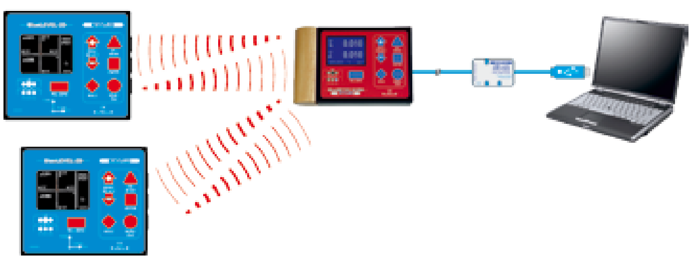
Two BlueLEVEL-2D connected to a laptop with USB cables allowing simultaneous differential measurement in 2 directions. The instruments are powered from the USB ports.



BlueLEVEL-2D connected via Bluetooth to a BlueTC and to a laptop.



Two BlueLEVEL-2D connected via Bluetooth to a BlueTC and to a laptop.



Two BlueLEVEL-2D connected via Bluetooth to a BlueMETER SIGMA and to a laptop.

Graphical 2D-display

The 2D-display shows graphically the position of an object in space, respectively the change of its position and makes the information easily understandable.

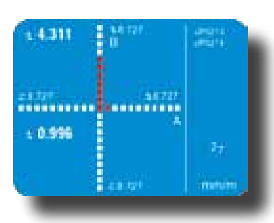
This substantially facilitates the alignment of e.g.

- a machine
- a reference plate

etc.

The following parameters (among others) can be set and changed at the BlueLEVEL-2D:

- Units
- Display of measuring range
- Type of display
- Filter settings



It is possible to send the measured data via an RS232 port to a PC/laptop and therewith to the WYLER software LEVELSOFT PRO, MT-SOFT and LabEXCEL.

8.2 Inclination measuring instrument CLINOTRONIC PLUS

The CLINOTRONIC PLUS provides a measuring capacity of ±45 degrees or alternatively ±10 degrees and ±30 degrees respectively. Four precisely machined exterior reference surfaces assure accuracy and repeatability of measurements in any quadrant. Selected by push-button, any units suitable for inclination measurement may be applied to the display. Even slope indication based on a relative base of selectable length is possible. Simple push-button operation automatically sets absolute as well as relative zero. The RS 485 interface allows the connection to other WYLER instruments or directly to a PC using a special cable.

All indicated values are, by interpolation of calibration values stored, computed prior to display. If required, an integrated calibration mode may be actuated in order to replace the stored calibration data. For this purpose, the CLINOTRONIC PLUS ±45° must, with the aid of suitable equipment, be accurately inclined, using five-degree steps over the range of ±50 degrees.

The measuring principle is based on a differential capacitance measurement of a pendulum providing excellent repetition, hysteresis as well as start-up behaviour. Combined with a complex evaluation algorithm, this forms the base of a high-quality handheld tool.

This reliable inclination measuring instrument has a number of interesting advantages. The most important of them are:

- Aluminium housing, hard anodised, with heavy walls for more stability. Fulfils the strict CE requirements (immune to electromagnetic smog)
- For recalibration, a so-called Clinomaster is available (for CLINOTRONIC PLUS ±45° only)
- Powered by standard 1.5V batteries, allowing cost-efficient reliability all over the world
- Various connecting possibilities to a PC
- Further features of the instrument:
    - Easy zero-point adjustment
    - Wide variety of different units displayed
    - Absolute and relative measurement

The corresponding software LabEXCEL CLINO based on LabView®

The following measuring units may be selected:

mm/m (2 Dec)	00.00 mm/m
Inch / 10 Inches	.00 00 ‘‘/10“
Inch / 12 Inches	.00 00 ‘‘/12“
artillery per mille	00 00

Milliradian (2 Dec)	00.00 mrad
Milliradian	00 00 mrad
Degrees (2 Dec)	00.00°
Degrees (4 Dec)	.00 00°

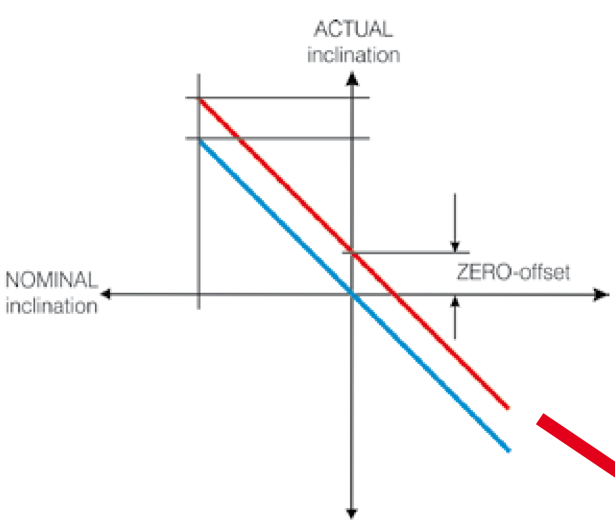
Degrees / Arcmin	00° 00’
Arcmin / Arcsec	00’ 00‘‘
GON Grad (2 Dec)	00.00 gon
GON Grad (4 Dec)	.00 00 gon

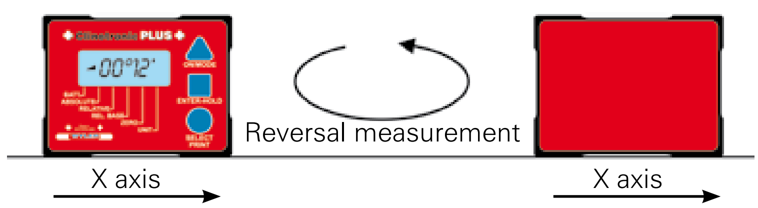
mm / rel.Basis	00.00 mm/m
mm / rel.Basis	.00 00 mm/m
Inch / rel.Basis	.00 00 ‘‘/10“

CLINOTRONIC PLUS TECHNICAL SPECIFICATIONS				
Measuring range		±45 degrees **STANDARD**	±30 degrees	±10 degrees
Calibration	Built-in software	21 setting points manual 25 factory-set calibration points		
Settling time	Value available after	approx. 2 seconds		
Resolution	Depending on units set	>5 Arcsec (0.025 mm/m)		
Limits of error		<2 Arcmin + 1 Digit	<1.5 Arcmin + 1 Digit	<1 Arcmin + 1 Digit
Interface		RS 485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps		
Power supply with batteries (lifetime)	**STANDARD** Option	1 x 1,5V, Alakaline, size AA / 25 hrs 1 x 3V, MnO2-Lithium, size AA / 55 hrs		
Dimension Housing + Net weight	Aluminium hard anodised	100 x 75 x 30 mm / 400 g		
Temperature range	Operating Storage	0 °C to +40 °C -20 °C to +70 °C		
CE conformity	Fulfils emission and immunity standards			

Zero-point correction offset (ZERO-offset) with the handheld instrument CLINOTRONIC PLUS

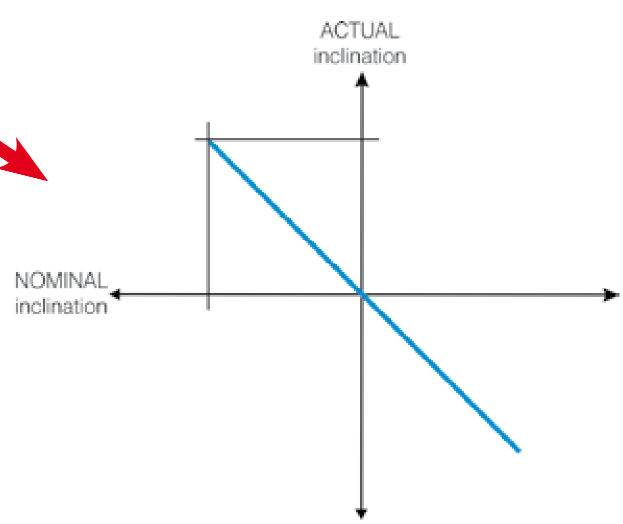
Each instrument has, with increasing duration of use, a so-called drift and a ZERO-offset. This “error“ may be compensated for by a reversal measurement on a CLINOTRONIC PLUS. If the ZERO-OFFSET as well as the linearity are out of tolerance, the instrument must be recalibrated.





Zero-point deviation (ZERO-offset) instrument $= \frac{A + B}{2}$

Inclination of the measured surface in direction X $= \frac{A - B}{2}$



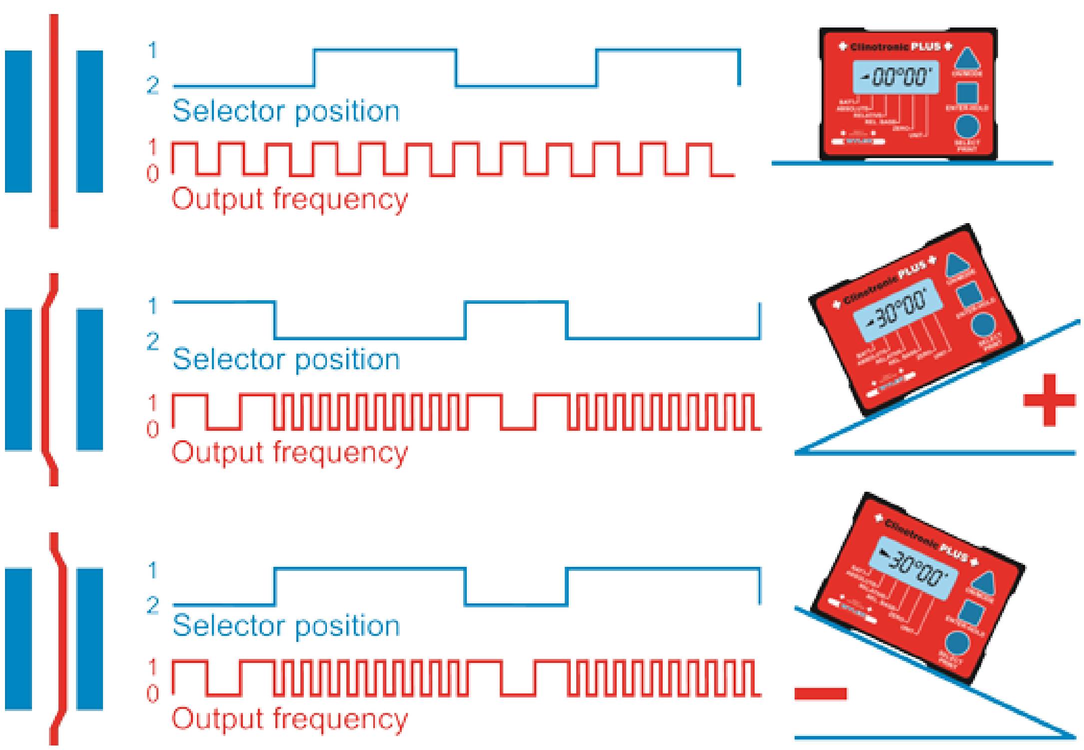
The zero-deviation (ZERO-offset) can be eliminated and compensated for with a reversal measurement. The compensation value is stored in the device.

CLINOMASTER FOR THE CALIBRATION OF THE CLINOTRONIC PLUS WITH MEASURING RANGE OF ±45°

Thanks to the integrated calibration software and the CLINOMASTER, the measuring instruments CLINOTRONIC PLUS can be calibrated very easily. By means of the CLINOMASTER, traceability can be ensured.

Note: Traceability is the ability to chronologically interrelate uniquely identifiable entities in a way that is verifiable.

INCLINATION OF THE INSTRUMENT - DEFLECTION OF THE PENDULUM - CHARACTERISTIC OF THE FREQUENCY

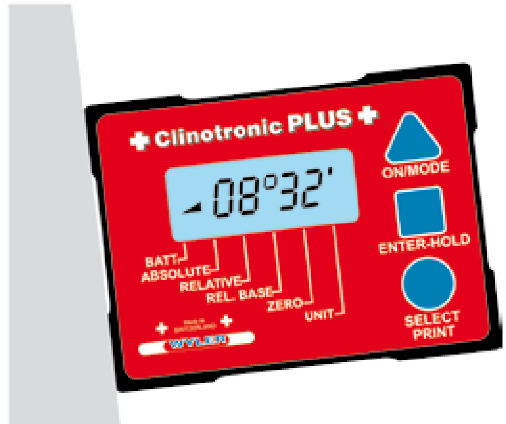


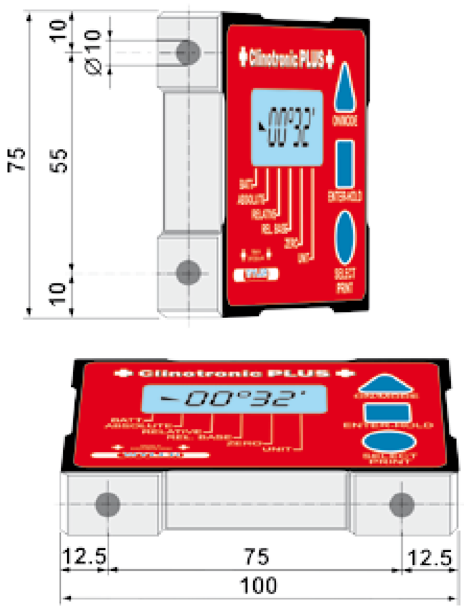
No inclination
Pendulum in
ZERO Position

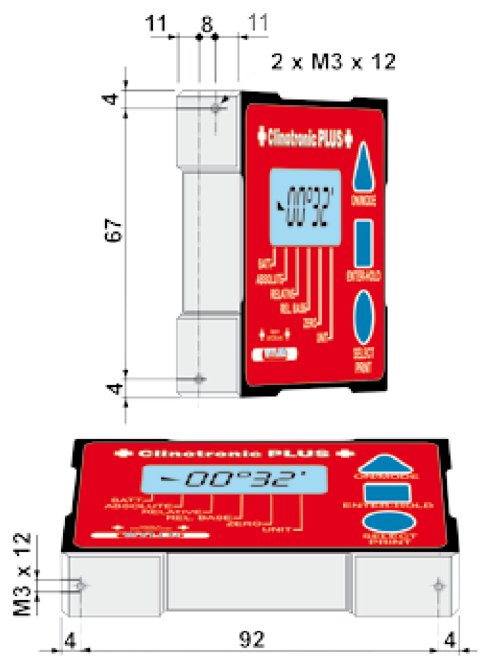
Positive inclination
Pendulum closer to
the left electrode

Negative inclination
Pendulum closer to
the right electrode

Examples of special options for CLINOTRONIC PLUS







Left:
CLINOTRONIC PLUS with magnetic inserts left and bottom

Right:
CLINOTRONIC PLUS threaded holes M3 left and bottom

8.2.1 LabEXCEL Clino Software

LabEXCEL Clino is an easy-to-use software for displaying the measuring values of WYLER handheld measuring instruments belonging to the CLINOTRONIC PLUS series. The software is based on the programming environment of LabVIEW™ by National Instruments. The core is the WYLER WyBus module. This module ensures the communication between the inclination measuring instruments and the user interface of LabVIEW™.

The measuring results can continuously be transferred into a csv file for further treatment, e.g. in EXCEL.

Requirements for the installation of LabEXCEL Clino software

- Framework 2.0 (Microsoft .NET Framework 2.0). Download from (Windows Update) or installation from the CD-ROM delivered

Up to two inclination measuring instruments from the CLINOTRONIC PLUS series can simultaneously be read into the LabEXCEL software. In addition, there is the possibility of displaying the difference of the measuring values between two different CLINOTRONIC PLUS devices.

8.3 Inclination measuring instrument CLINO 2000

The CLINO 2000 is a precision handheld inclination measuring instrument fulfilling the highest standards.

The CLINO 2000 is designed as a standalone unit, but it can also be used together with a second instrument for measurements where a reference is required. Furthermore, it can be connected to a PC / laptop via a built-in RS 232 interface.

The measured primary values are compared to a stored reference curve in the CLINO 2000. This allows a very accurate calculation of the inclination.

This top-level inclinometer with large measuring range brings a great many advantages to the metrologist.

The most important of them are:

- A highest possible precision over the large measuring range of ±45° / ±60° / ±30° / ±10°, with integrated temperature compensation
- Effortless zero adjustment by using the integrated software and a reversal measurement
- Easy calibration due to implemented software guidance and the calibration aids as part of the delivery (for the CLINO 2000 / ±45° only)
- Large digital display with the advantage to set all commonly used measuring units
- Built-in possibility to connect an additional instrument for differential measurement or ZEROTRONIC sensors by using the serial port
- Rugged housing, rust-protected, with prismatic bases
- Built-in cross vial for easy alignment of the secondary vertical setting direction in order to eliminate “twist error“
- State-of-the-art digital technology
- The instrument is fully compatible with the entire range of WYLER AG digital sensors
- Powered by standard 1.5V batteries, rechargeable batteries or with mains adapter
- Fulfils the strict CE requirements (immunity against electromagnetic smog).
- As an option, magnetic inserts are available

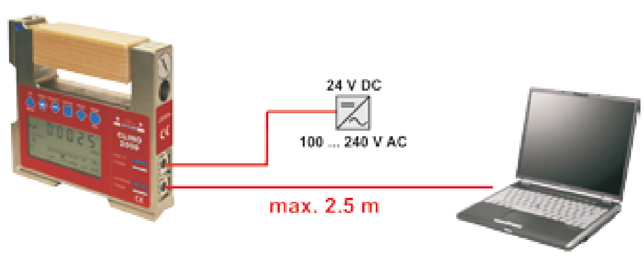
The following measuring units may be selected:

mm/m (2 Dec)	xxxx.xx mm/m	mm/ relative basis	xxx.xx mm/REL	Degrees/Arcmin/ Arcsec	xx° xx′ xx′′	GON / Grad (3 Dec)	xx.xxx gon
Inch / 10 Inches	xx.xxxx′′/10′′	Zoll/ relative basis	xx.xxxx ′′/ REL	Arcmin / Arcsec	xxx′ xx′′	per mille	xxx.xx‰
Inch / 12 Inches	xx.xxxx′′/12′′	Degrees/ Arcmin	xxx° xx′	Degrees (3 Dec)	xx.xxx°	artillery per mille	xxx.xx
Milliradian (2 Dec)	xxxx.xx mRad						

CLINO 2000 TECHNICAL SPECIFICATIONS		
Measuring range		±45° **STANDARD** ±10° ±30° ±60°
Calibration	Built-in software and calibration aids	Correction of gain by simple three-point-method
Settling time	Value available after	<5 seconds
Resolution	Depending on units set	5 Arcsec (approx. 0.025 mm/m)
Limits of error within 6 months / Gain (TA = 20°C)*		<12 Arcsec +0.027% R.O.
Limits of error at -45°, 0°, +45° right after quick calibration, using the calibration aids / Gain		Limits of error as above, but <30 Arcsec (CLINO 2000 ±45° only)
Data connection		RS 232 / RS 485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Power supply with batteries (lifetime)	Batteries Option, rechargeable batteries	2 x size AA 1.5V (35 - 50 hrs) 2 x size AA 1.2 V NiMH rechargeable (25 - 45 hrs)
External power supply		+12 ... +48 V DC / 200 - 500 mW
Dimension of housing + Net weight	Cast iron, rust-protected	150 x 150 x 35 mm / 2.600 kg
Temperature range	Operating Storage	0 °C ... +40 °C -20 °C ... +70 °C
CE conformity	Fulfils emission and immunity requirements	

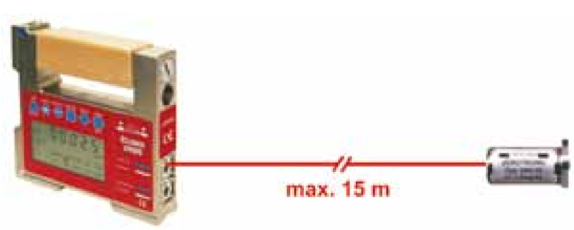
Technical drawing CLINO 2000

Possible configurations with the handheld measuring instrument CLINO 2000



CLINO 2000 connected to a PC / RS 232

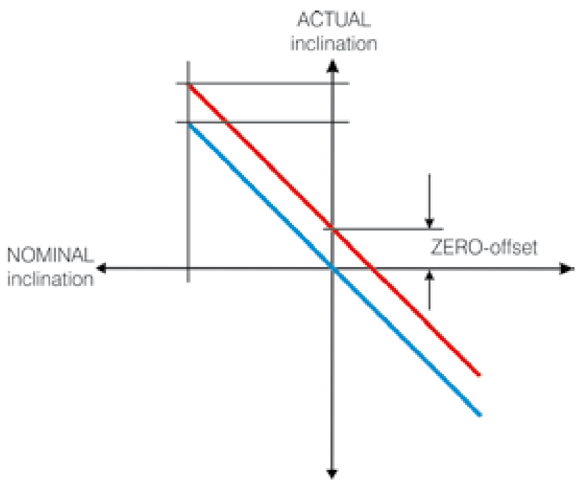
Two CLINO 2000 connected to each other; one instrument used as measuring instrument, the other as reference instrument



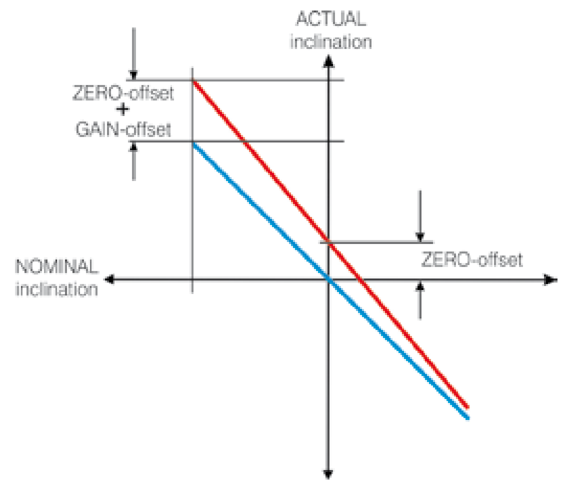
CLINO 2000 connected with ZEROTRONIC sensor / max. 15 m

Correction zero and gain error (ZERO-Offset and Gain-offset) for handheld instrument CLINO 2000

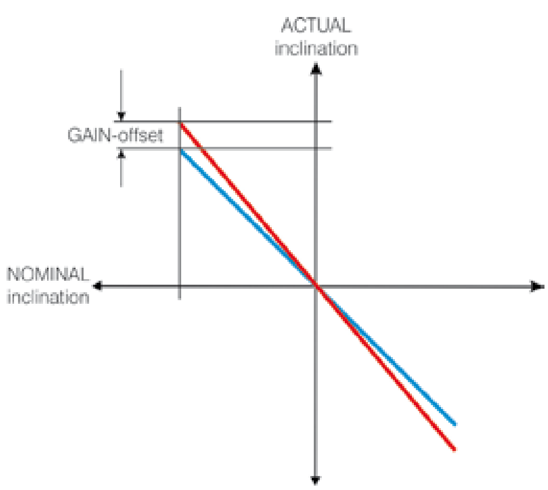
Each instrument has, with increasing duration of use, a so-called drift and a ZERO-offset. This “error“ may be compensated for by a reversal measurement on a CLINO 2000. If the ZERO-offset as well as the linearity are out of tolerance, it is easy to calibrate the CLINO 2000 ±45° thanks to implemented software guidance and the calibration aids. The devices with a measuring range of ±10°, ±30° and ±60° have no calibration aids - only a factory calibration is possible.



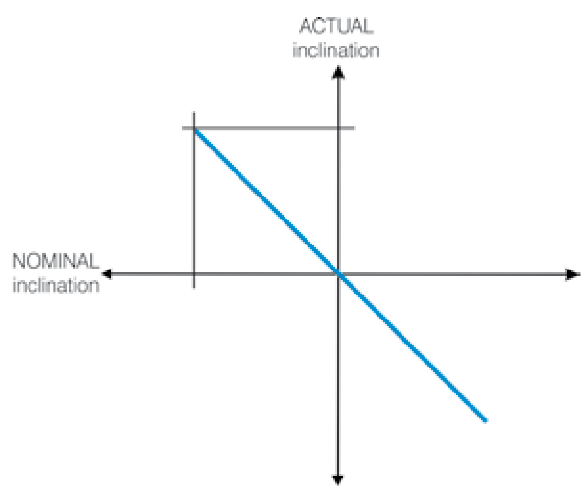
The zero-deviation (ZERO-offset) can be eliminated, or compensated for with a reversal measurement.



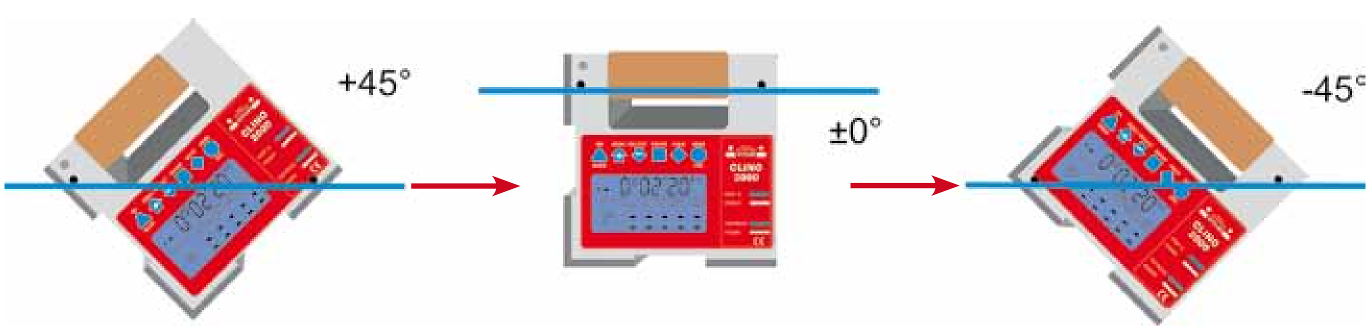
If the ZERO-offset as well as the linearity (GAIN-error) are out of tolerance, only the ZERO-offset can be compensated by a reversal measurement. The GAIN-error will remain.



The GAIN-error will remain. This error can be corected thanks to implemented software guidance and the calibration aids.



After the calibration, the device is ready for accurate measurements again.



Calibration procedure with the handheld instrument CLINO 2000 ±45°.

8.4 Inclination measuring instrument BlueCLINO

8.4.1 instrument BlueCLINO

The BlueCLINO is based on the well-proven CLINO2000 and has the following features:

- Large and very easy-to-read color display
- Various color profiles can be chosen
- Various display methods such as bar graphs or spirit levels can be chosen
- All current units can be indicated
- High precision over the entire measuring range of ±60° with integrated temperature compensation
- The internal software, together with a reversal measurement, allows a simple zero setting
- Rugged housing, with prismatic bases made of either aluminum hard anodized or cast iron, rust-protected
- The base on the right hand side can be used as a measuring base as well
- Built-in cross vial for easy alignment of the vertical axis in order to avoid "twist errors"
- The instrument is compatible with the full range of WYLER digital sensors
- Powered by standard 1.5V batteries, rechargeable batteries or with mains adapter
- Fulfils the strict CE requirements (immunity against electromagnetic smog)
- The instrument can be adjusted to local gravitation
- Options:
    - Wireless communication, based on Bluetooth technology
    - The instrument can be recalibrated with the help of simple calibration tools that are supplied together with the instrument (option). This process is supported by the internal software
    - Magnetic inserts in the left hand vertical and bottom horizontal base possible
    - A fourth measuring base may be attached to the top of the instrument
    - External power supply
    - Cable to connect the instrument to a PC
    - Software to collect measuring data

The following measuring units may be selected:

mm/m (2 Dec)	xxxx.xx mm/m	mm/ relative Basis	xxx.xx mm/REL	Degrees (3 Dec)	xxx.xxx°	Arcmin / Arcsec	xxxx' xx''
mm/m (3 Dec)	xxxx.xxx mm/m	mm/ relative Basis	xxx.xxx mm/REL	Degrees/Arcmin	xxx° xx'	Arcsec	xxxxxx''
Inch / 10 Inches	xx.xxxx''/10''	Inch/ relative Basis	xx.xxxx ''/ REL	Degrees/Arcmin/ Arcsec	xx° xx' xx''	Arcsec	xxxxxx.x''
Inch / 12 Inches	xx.xxxx''/12''	artillery per mille	xxx.xx	GON / Grad (3 Dec)	xx.xxx gon		
Milliradian (2 Dec)	xxxx.xx mRad	per mille	xxx.xx‰				

The BlueCLINO is available in two versions:

BlueCLINO with prismatic bases made of cast iron

BlueCLINO with prismatic bases made of hard anodized aluminum

BLUECLINO TECHNICAL SPECIFICATIONS		
Measuring range		±60 degrees STANDARD
Settling time	Value available after	<5 seconds
Calibration OPTION	Built-in software and calibration aids	Correction of gain by simple three-point method
Resolution	Depending on units set	5 Arcsec (approx. 0.025 mm/m)
Limits of error within 6 months / Gain (TA = 20°C)		<12 Arcsec + 0.027% R.O. R.O. = Read-out / measurement value
Limits of error at -45°, 0°, +45° right after quick calibration, using the calibration aids / gain	Limits of error as above in the range of ±45°, but <30 Arcsec	
Data connection	RS 232 / RS 485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps	
Wireless option	Bluetooth®	ISM Band / 2.4000 – 2.4835 GHz
Power supply with batteries (lifetime)	2 x size C, total voltage 3V maximum; primary types, NiMH, NiCd, NiZn (ca. 25 hrs)	
External power supply	+12 ... +48 V DC / 200 - 500 mW	
Dimension housing + net weight	Cast iron, rust-protected	150 x 150 x 40 mm / 3.450 kg
	Aluminium, black hard anodized	150 x 150 x 40 mm / 1.500 kg
Temperature range	Operating Storage	0 °C to +40 °C -20 °C to +60 °C
CE conformity	Fulfils emission and immunity requirements	

Technical drawing BlueCLINO

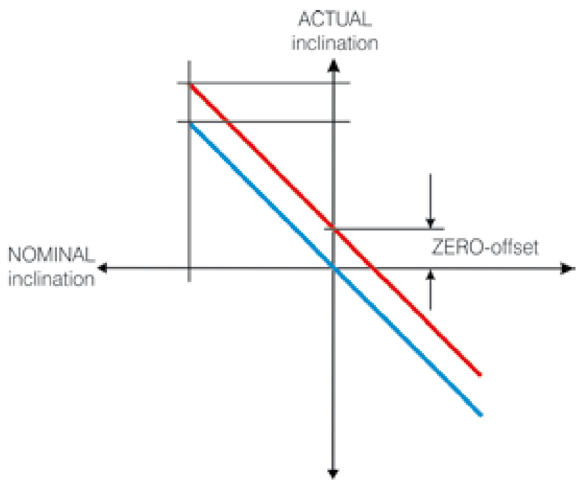
Easy to calibrate (option)
thanks to implemented software guidance and optional calibration aids (with two calibration pins)

The following display types are available in the BlueCLINO:

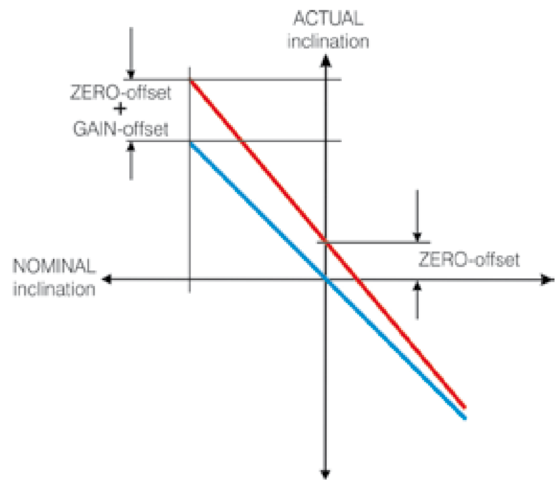
The style on the display can be changed by the user as desired. The background can be represented in different colors.

Correction zero and gain error (ZERO-Offset and Gain-offset) for handheld instrument BlueCLINO

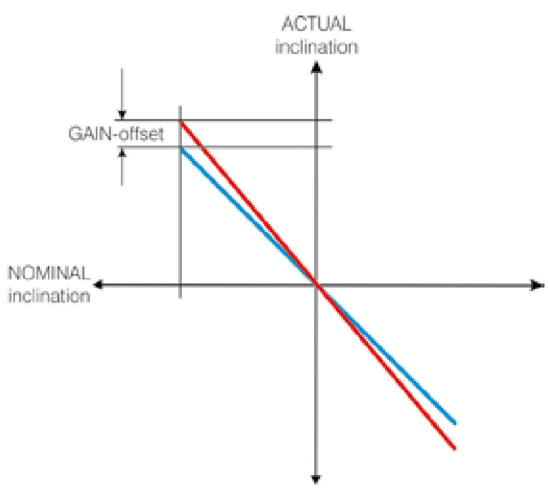
Each instrument has, with increasing duration of use, a so-called drift and a ZERO-offset. This "error" may be compensated for by a reversal measurement on a BlueCLINO. If the ZERO-offset as well as the linearity are out of tolerance, it is easy to calibrate the BlueCLINO (option) thanks to implemented software guidance and the calibration aids. For devices without a calibration system, only a factory calibration is possible.



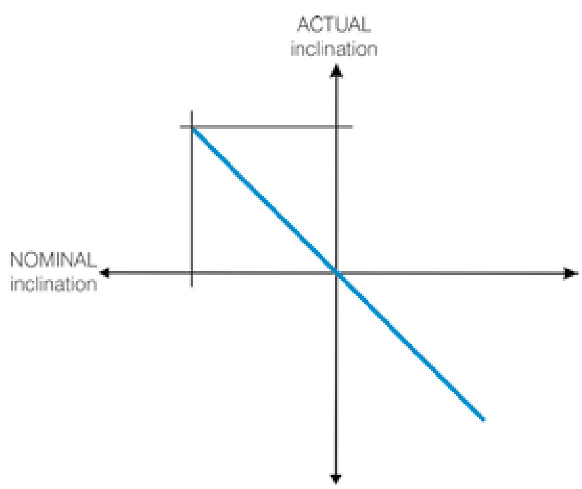
The zero-deviation (ZERO-offset) can be eliminated, or compensated for with a reversal measurement.



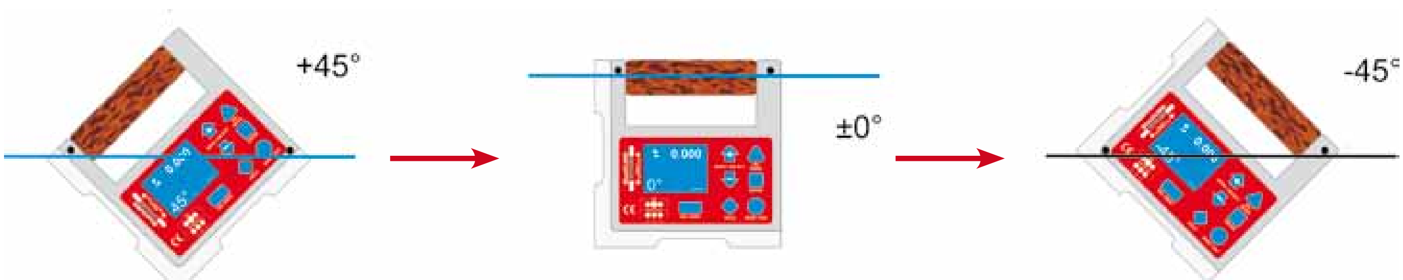
If the ZERO-offset as well as the linearity (GAIN-error) are out of tolerance only the ZERO-offset can be compensated for by a reversal measurement. The GAIN-error will remain.



The GAIN-error will remain. This error can be corected thanks to implemented software guidance and the calibration aids.



After the calibration, the device is ready for accurate measurements again.



Calibration procedure with the handheld instrument BlueCLINO.

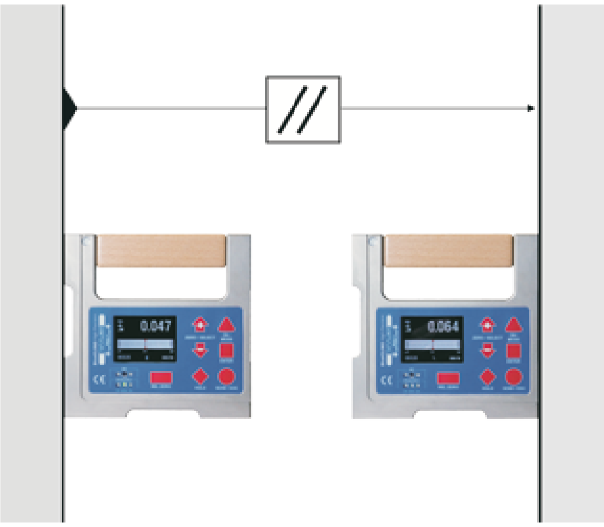
8.4.2 BlueCLINO *High Precision*

The **BlueCLINO *High Precision*** combines the accuracy of an angular based BlueLEVEL with the flexibility of a BlueCLINO. The BlueCLINO *High Precision* is therefore well suited for the following applications:

- Measurement and alignment of vertical guideways
- Measurement and alignment of horizontal and vertical machine parts
- Comparison of horizontal and vertical guideways. The comparison of a left and a right vertical guideway is particularly useful with the help of the additional vertical base on the right hand side of the instrument
- Squareness measurement
- The **BlueCLINO *High Precision*** can be integrated in any BlueSYSTEM by cable or by using the optional wireless connection with Bluetooth®

BlueCLINO *High Precision* has the following functions and features:

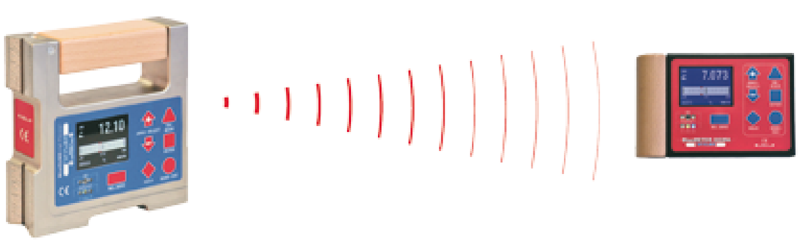
- Large and very easy-to-read color display
- Various color profiles can be chosen
- Various display methods, such as bar graphs or spirit levels can be chosen
- All current units can be indicated
- Measuring range of ±1° (corresponds to approximately ±18mm/m)
- High precision due to the rugged, rust-protected housing made of cast iron with prismatic and scraped bases on the left hand and lower side of the housing, combined with an integrated temperature compensation
- Right hand base is precision ground
- Simple zero-adjustment with the integrated software and a reversal measurement
- Built-in cross vial for easy alignment of the vertical axis in order to avoid twist errors
- The **BlueCLINO *High Precision*** is compatible with the full range of WYLER digital sensors
- Powered by standard 1.5V batteries, rechargeable batteries or with mains adapter
- Fulfils the strict CE requirements (immunity against electromagnetic smog)
- The instrument can be adjusted to local gravitation



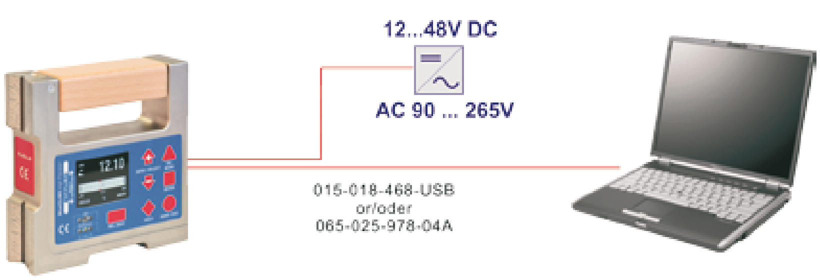
Simple comparison of a left and a right vertical guideway

TECHNICAL SPECIFICATIONS BlueCLINO *High Precision*		
Measuring range		±1°
Settling time	Value available after	< 5 seconds
Resolution	Depends on units set	1 Arcsec (approx. 0.005 mm/m)
Limits of error according to DIN 2276		up to 0.5°: 1% R.O. >0.5°: 0.1 x (2 x R.O. - 0.5°) at least 1 Arcsec, or 0.005 mm/m (R.O. = Read-out)
Data connection	RS 232 / RS 485, asynchr., 7 DataBits, 2 StopBits, no parity, 9600 bps	
Wireless Option	Bluetooth®	ISM Band / 2.4000 – 2.4835 GHz
Power supply with batteries (lifetime)	2 x size C, total voltage 3V maximum; Primary types: NiMH, NiCd, NiZn (ca. 25 hrs)	
External power supply		+24V DC
Dimension housing + net weight	Cast iron, rust-protected	150 x 150 x 40 mm / 3.450 kg
Temperature range	Operating Storage	0 °C bis +40 °C** -20 °C bis +60 °C
CE conformity	Meets emission and immunity requirements	

*** Specifications are valid for 20 °C ±10 °C*



BlueCLINO *High Precision* connected to BlueMETER SIGMA through wireless data transmission (Option)



BlueCLINO *High Precision* connected to BlueMETER SIGMA or BlueTC and a laptop through wireless data transmission (Option)

9 ZEROMATIC 2/1 + 2/2

TWO-DIMENSIONAL PRECISION INCLINATION SENSOR WITH AUTOMATIC REVERSAL MEASUREMENT

The two-dimensional inclination measurement sensors ZEROMATIC 2/1 and 2/2 are perfectly suited for any application where monitoring of the smallest changes in absolute inclinations over a longer period of time is required. The extremely high accuracy is achieved by measuring and compensating for any drift of the absolute "zero" by applying an automatic reversal measurement at defined intervals.

The ZEROMATIC 2/1 has one inclination sensor. Each reversal measurement will provide one set of precise and absolute inclination values in X and Y direction.

The ZEROMATIC 2/2 has two inclination sensors. It can therefore provide continuous values for the inclination in X and Y axes. At defined intervals it will perform a reversal measurement and compensate for any offset.

Typical applications are:

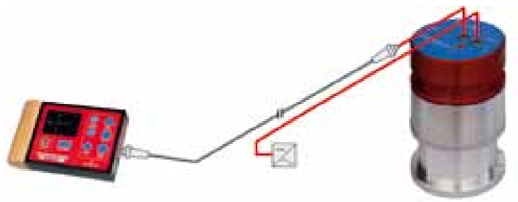
- Monitoring of critical machines
- Monitoring of buildings, bridges or dams
- Defining absolute zero references e.g. for radars

The instruments have the following features:

- High-precision mechanics for the automatic reversal measurement
- Rugged precision aluminum housing for protection against external influences
- LEDs showing the status of the instrument
- Data transmission to PC/laptop
- Optional connection to a portable BlueMETER display unit

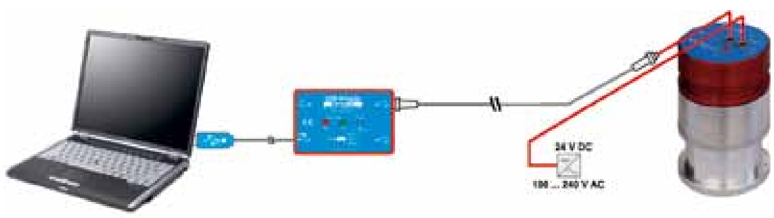
ZEROMATIC TECHNICAL SPECIFICATIONS			
		1° Sensor	
Stability of Zero	Limits of error	±1 Arcsec	
Linearity	Limits of error	0.5% R.O.	
Temperature coefficient		0.08% R.O. / °C	
Operating temperature range		-10 °C - +60 °C	
Time for one reversal measurement		<2 minutes	
Interval between 2 reversal measurements		Definable by the user >2 min	
Power supply		24V DC	
Power consumption	ZEROMATIC 2/1 ZEROMATIC 2/2	1.5 W (standby mode); 2.4 W (measuring); 7.2 W (reversal measurement)	
Dimensions	Height Diameter	ZEROMATIC 2/1: ZEROMATIC 2/2:	H: 193 mm Ø 120 mm
IP Protection		63: Connector inserted, or with cover	
Net weight	ZEROMATIC 2/1 ZEROMATIC 2/2	4.030 kg 4.150 kg	

Possible configurations with the ZEROMATIC sensors

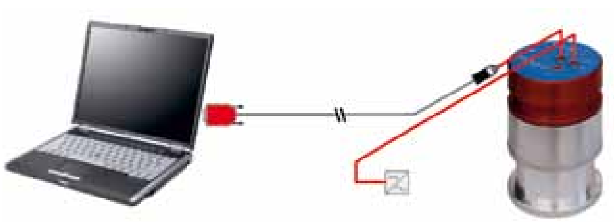


ZEROMATIC connected to a BlueMETER SIGMA

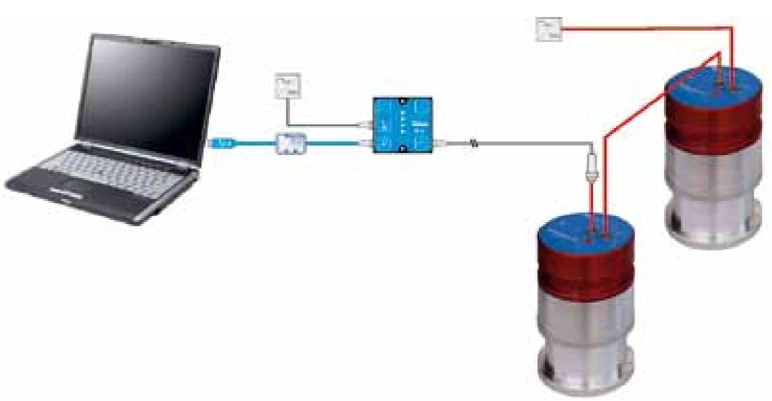
ZEROMATIC connected throuh a USB cable to a PC/laptop, distance from the measuring instrument to the PC/laptop max. 1.8 m



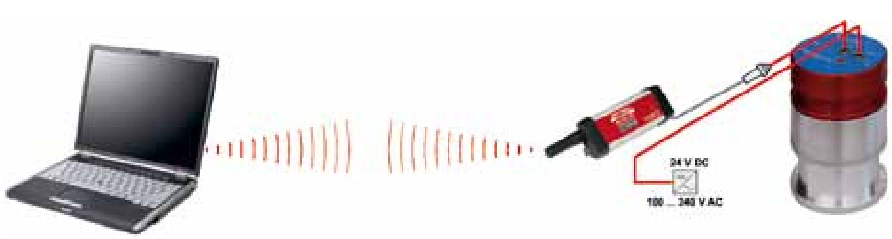
ZEROMATIC connected through an USB-Adapter to a laptop or PC, distance from the measuring instrument to the PC/laptop max. 1000 m



ZEROMATIC connected through a RS 232 cable to a laptop or PC, distance from the measuring instrument to the PC/laptop max. 2.5 m



Several ZEROMATIC devices connected through a MultiTC to a laptop or PC, distance from the measuring instrument to the PC/Laptop max. 1000 m



Data transmission of the ZEROMATIC device by means of a data logger. Reading the data from the datalogger into the PC / laptop via wireless data transmission.

ZEROMATIC CONFIGURATOR SOFTWARE AND THE MEASURING PRINCIPLE OF THE ZEROMATIC SENSOR

ZEROMATIC 2/x:

After a programmable interval, a reversal measurement is triggered for the ZEROMATIC 2/x. The calculated inclination values can be read either with a BlueMETER or with a PC and corresponding software.

ZEROMATIC 2/1:

The ZEROMATIC 2/1 is equipped with one inclination sensor with a measuring range of ±1°.

During the reversal measurement the inclination is measured in all four directions (270°, 180°, 90°, 0°) with the same sensor.

After the reversal measurement, the new calculated absolute inclinations in the X and Y axes can be read including the current sequence number. This sequence number is incremented by 1 after each new reversal measurement.

ZEROMATIC 2/2:

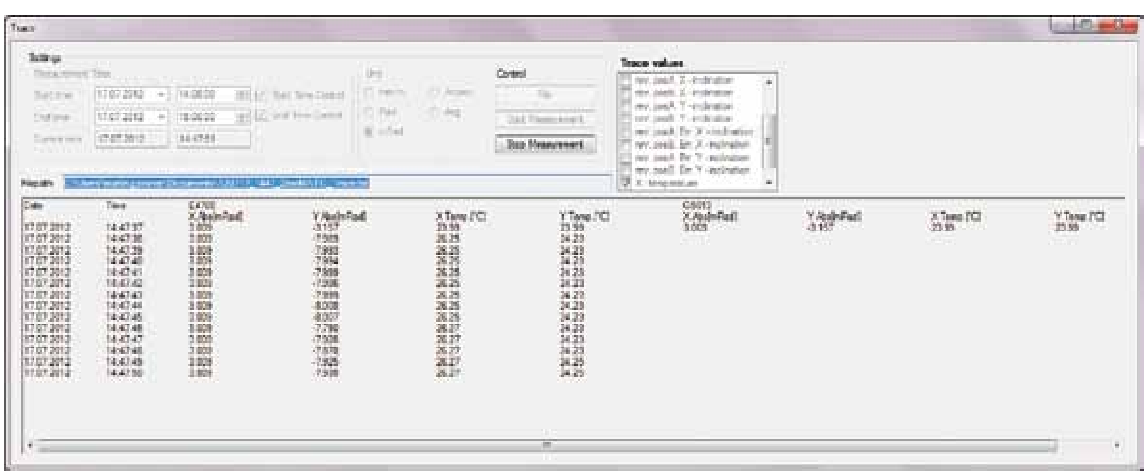
The ZEROMATIC 2/2 is equipped with two inclination sensors with a measuring range of ±1°.

Since the ZEROMATIC 2/2 has two sensors with orthogonal orientation, it is sufficient for a reversal measurement to carry out two measurements only at the positions 180° and 0°.

After the reversal measurement, the new calculated absolute inclinations in the X and Y axes can be read including the current sequence number. Afterwards the continuous measurement starts and after the programmable measuring interval a new set of measurement values can be read. A new set of values can be identified with the corresponding sequence number which is incremented by 1 each time.

ZEROMATIC CONFIGURATOR SOFTWARE

ZEROMATIC Configurator software allows an easy configuration and commissioning of the ZEROMATIC 2/X sensors. The two parameters “interval between two reversal measurements“ and “measurement interval“ as well as the individual RS 485 address can be programmed. Furthermore, it provides a way to register inclination as well as the temperature in the sensor manually or automatically (time-based).



The measuring principle of the ZEROMATIC sensor

Sequence of the reversal measurement / continuous measurement / measuring axis reversal measurement / definition of the zero-offset

ZEROMATIC 2/1:

The interval between two reversal measurements can be freely chosen with any value larger than two minutes and depends on how many measuring values are required per day or per hour. The chosen interval can be programmed by software or with the help of a BlueMETER and is stored in the ZEROMATIC. A typical value for long-term monitoring is one reversal measurement every hour.

Alternatively a reversal measurement can be triggered by a software command. After each reversal measurement the sensor provides a new set of the current absolute inclination values in both axes. These values will be kept until the next reversal measurement.

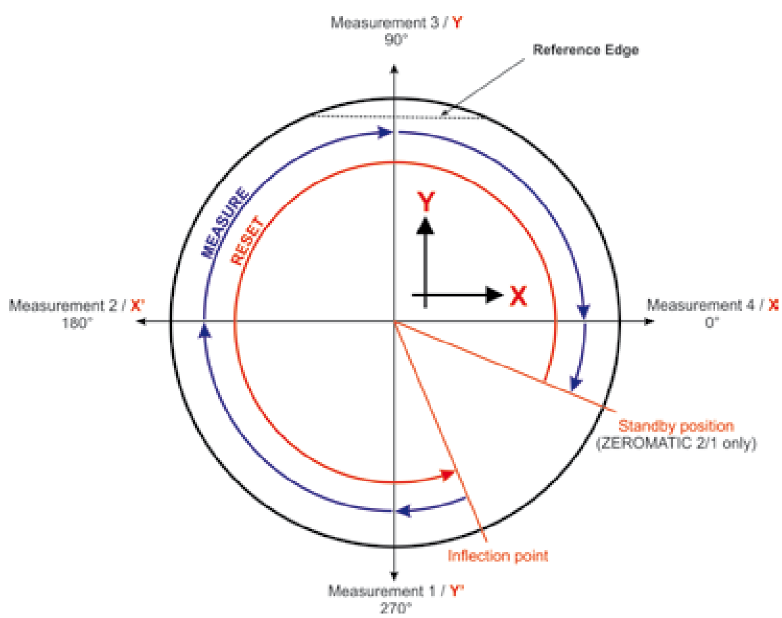
ZEROMATIC 2/2:

The stability of the environment defines the frequency required to recalculate the zero-offset by executing a reversal measurement. The interval can be chosen between a few minutes (at least two minutes) up to several hours. The chosen interval can be programmed by software or with the help of a BlueMETER and is stored in the ZEROMATIC. Furthermore, a reversal measurement can be triggered at any time with a software command. During a reversal measurement, the continuous measurement of the ZEROMATIC 2/2 is interrupted

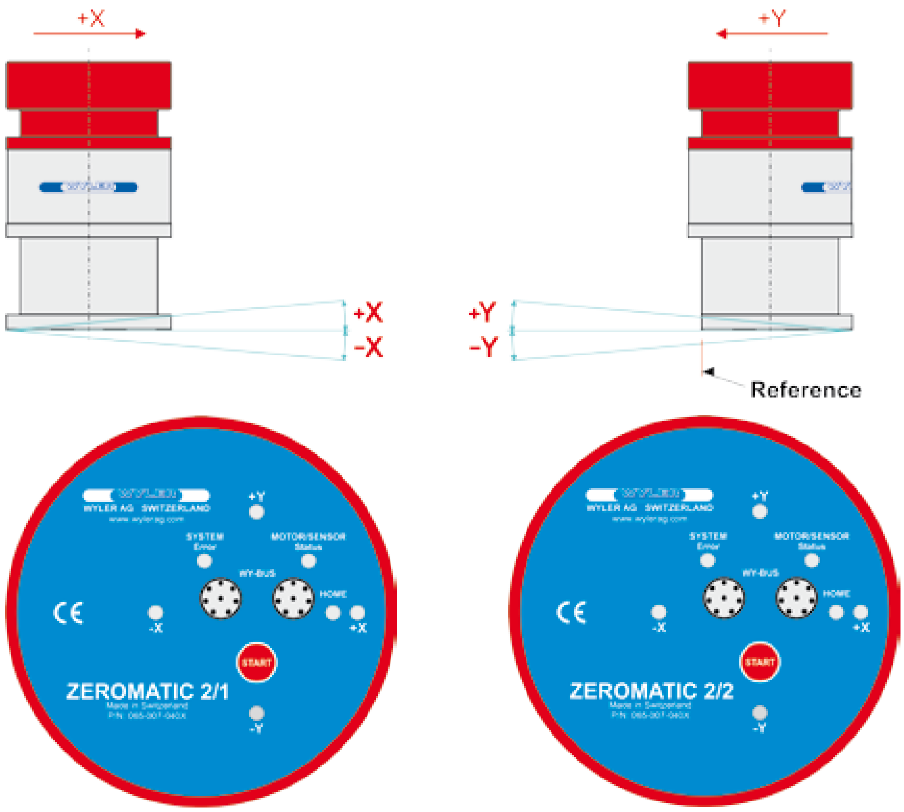
When starting a reversal measurement, the rotor first seeks the standby position. Then it turns to the measuring positions:

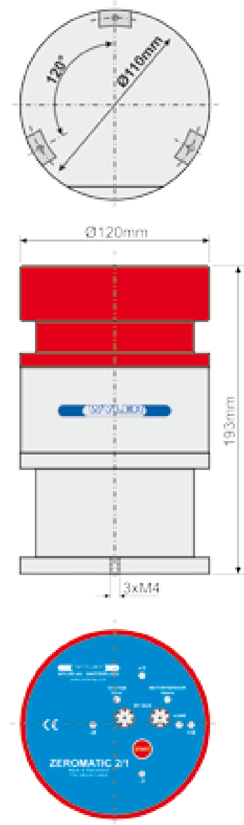
ZEROMATIC 2/1:
270°/ 180° / 90°/ 0°. After the last measurement, the rotor moves to the standby position and remains there until the next reversal measurement starts.

ZEROMATIC 2/2:
180° / 0°. The rotor remains (afterwards) in the 0° position. Sensors start to measure continuously.

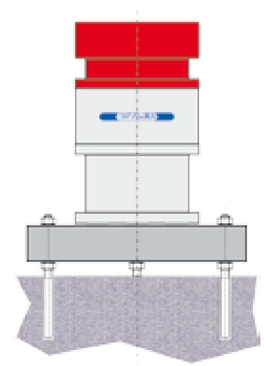


Dimensions and mounting of ZEROMATIC 2/1 and 2/2



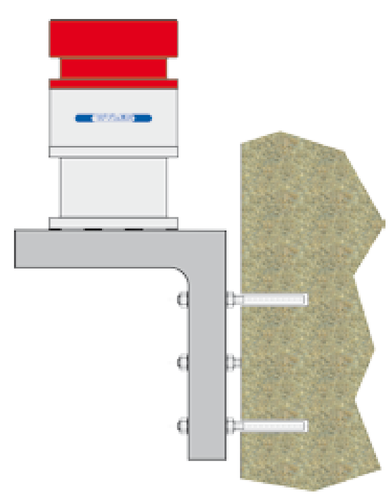


ZEROMATIC high-precision instruments make inclination measurements possible. It is however important to consider the following recommendations:



TEMPERATURE:
Uneven temperature changes may have a great influence on the measured results. It has therefore to be ensured that the temperature is distributed evenly around the sensor.

MECHANICAL TENSION:
Mechanical tension between the ZEROMATIC and the mounting bracket and/or the anchorage must be avoided, as these tensions are often the cause of unstable values.

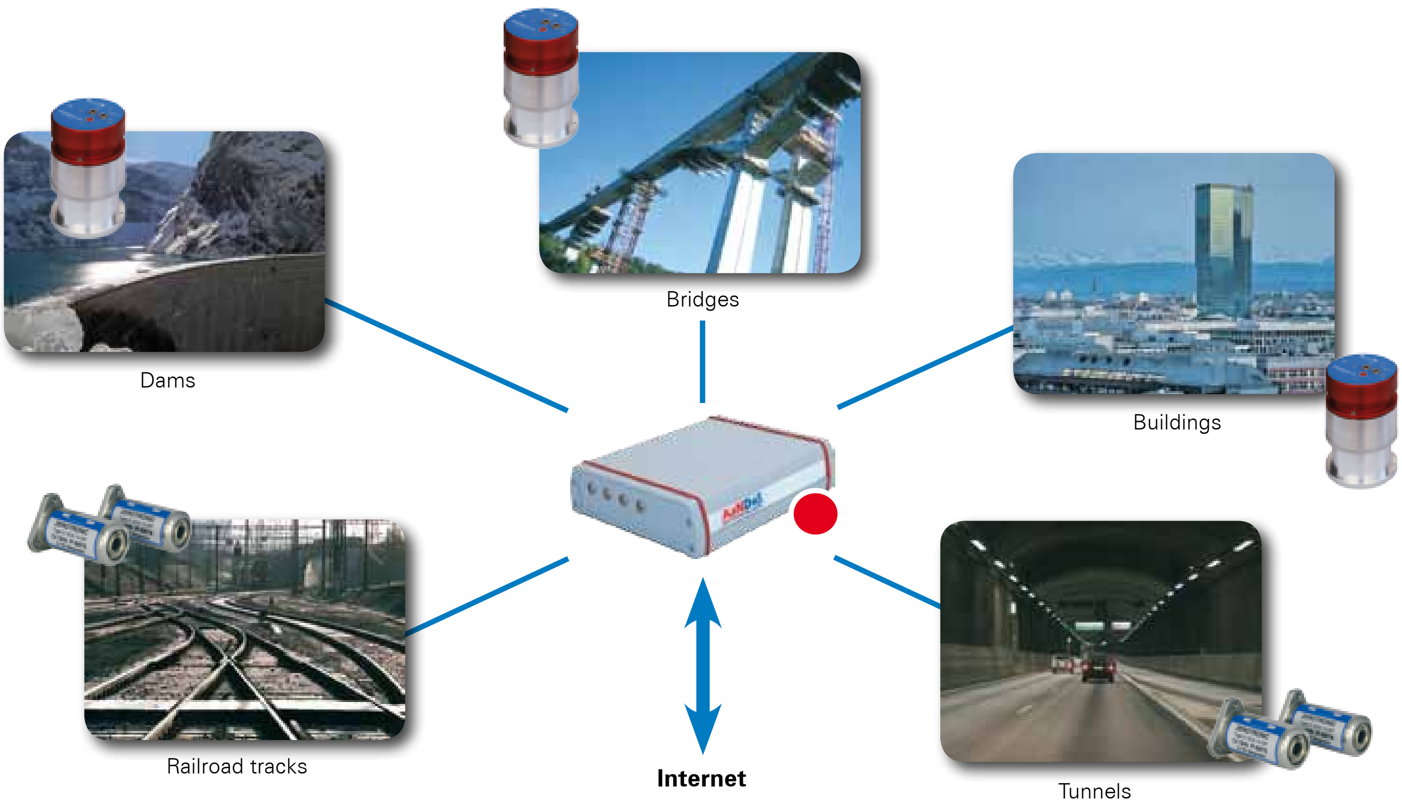


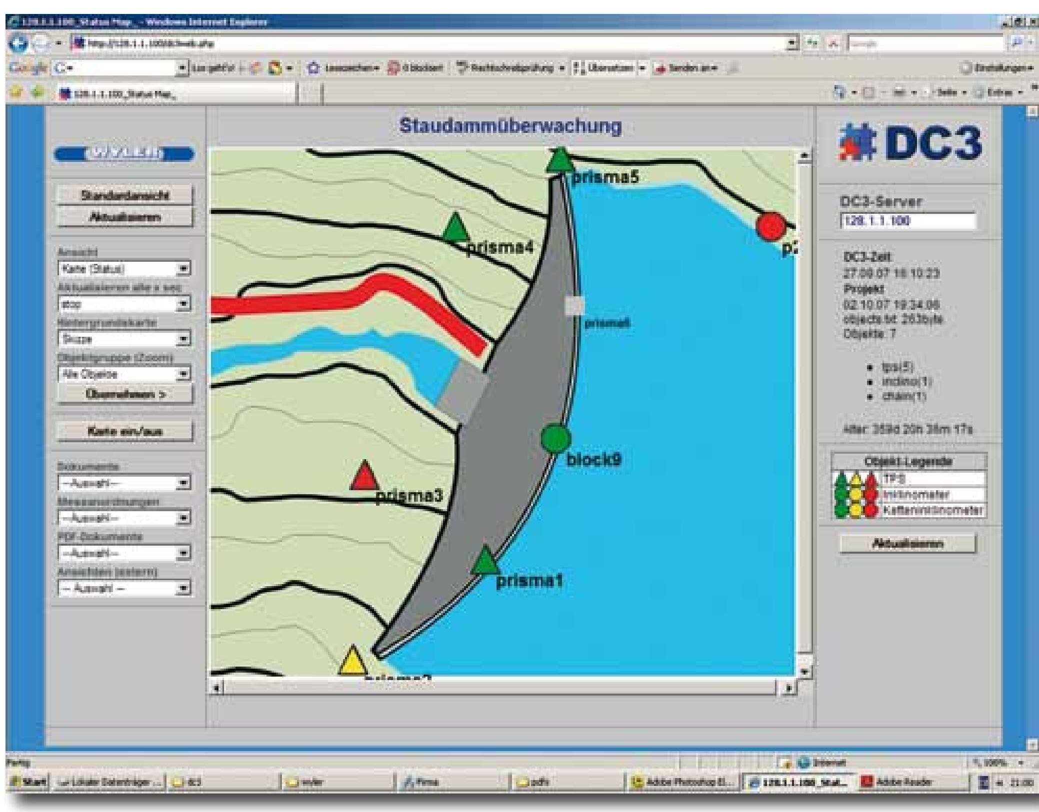
The following may be used to verify proper mounting of the instrument: Install the ZEROMATIC on the mounting bracket (bolted down). After an acclimatization time, start measurements. Now the mounting bolts are carefully loosened while the measurements are running without touching the instrument (temperature change). If the measured values change, the support is under tension. In that case, the design is not suitable for accurate measurements.

THREE-POINT MOUNTING / DESIGN
Whenever possible, use a three-point mounting jig.
Use the same geometry and homogenous material everywhere. Make a "center symmetrical" design.

Monitoring of Dams, Bridges or Buildings / AaNDoS-System

The **AaNDoS-System** allows the gathering of various types of sensors such as GPS receivers and inclination sensors. The data is then transmitted by internet or wirelessly to a central monitoring station.





9.1 DATA LOGGER

DATA LOGGER SPECIFICALLY ADAPTED TO WYLER INSTRUMENTS

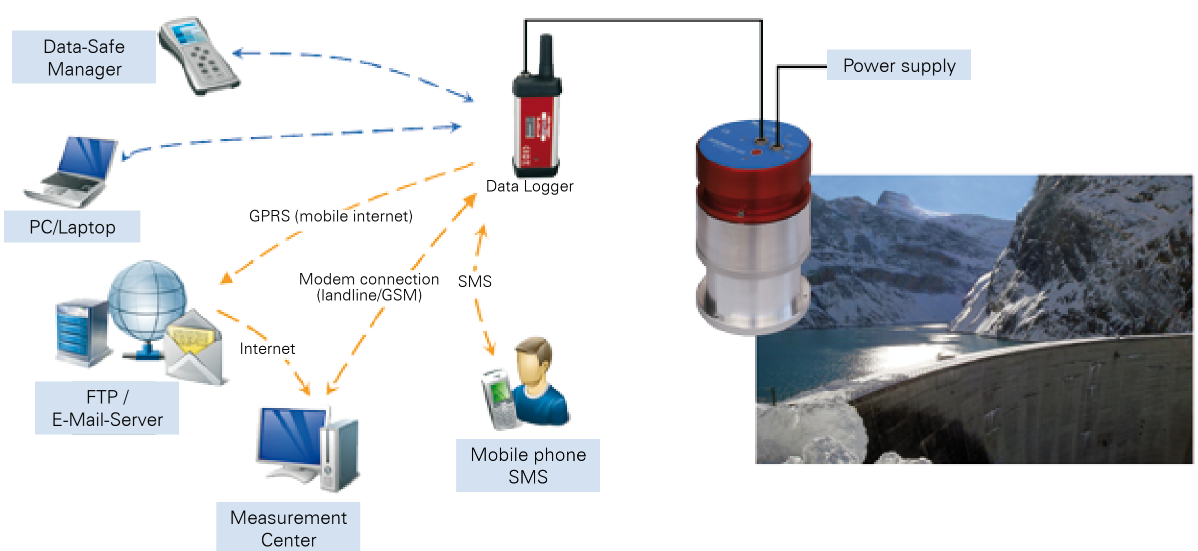
To meet the increasing demand for long-term monitoring, WYLER AG offers a data logger specifically adapted to WYLER instruments. High autonomy and integrated Bluetooth and GSM technology allows users to handle even complex monitoring tasks:

- Long-term monitoring of dams, bridges or buildings:
  - Continuous data collection of various WYLER sensors
  - These measuring values can then be sent once a day to the office via GSM
- Monitoring of correct inclination of an object:
  - Process-technology
  - Sluices
- Monitoring of machines:
  - Monitoring of machines running 24 h a day
  - Monitoring of machines during commissioning
  - Measuring of errors on a machine

Key features:

- Low current consumption, allowing long-term monitoring
- SMS messages e.g. when surpassing alarm limits
- Wide temperature range from –40 to +85 °C
- Small and robust housing with IP 66

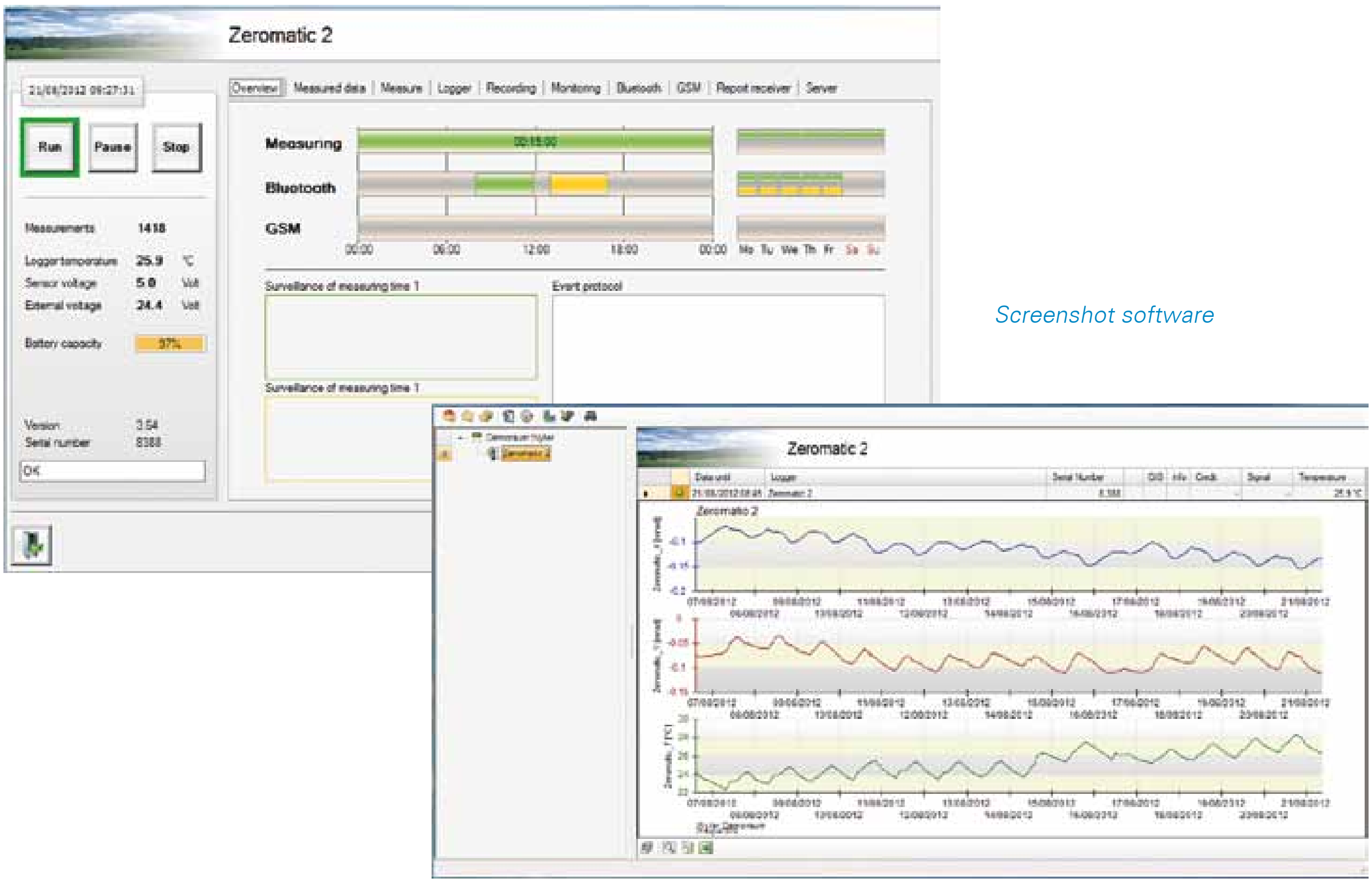
Possible configuration:
Dam monitoring with data transmission via GSM



Data analysis:
The data logger is supplied with setup and analysis software, which allows an easy setting of all parameters for the data collection as well as the analysis of the data.

Options:
The Bluetooth module is standard; the GSM module is optional.

Using a data logger with ZEROTRONIC sensors



Screenshot software

WYLER DATA DATA LOGGER TECHNICAL DATA	
Memory	max. 60,000 points
Measuring frequency	max.: 1 Hz; min.: 1 measurement per day
Operating temperature	Without GSM: -40..+85 °C
Dimensions	Ø x L : 41 x 100/137 mm
Weight	160 g
GSM Module	Functions with SIM card • PIN code has to be disabled • Data transfer has to be enabled
Remote access via GSM	Up to 3 time slots per day can be defined
Bluetooth	Bluetooth 2.0
IP	66

10 Digital displays and Interfaces

10.1 BlueMETER SIGMA

BlueMETER Sigma is a further enhancement of the well known BlueMETER, and has been developed as an intelligent display unit for the electronic inclination measuring instruments

- BlueLEVEL
- BlueCLINO and BlueCLINO *High Precision*
- MINILEVEL NT and LEVELTRONIC NT (by means of cables only)
- Clinotronic Plus
- ZEROMATIC
  and
- ZEROTRONIC sensors

BlueMETER SIGMA

Besides the excellent measuring accuracy, the measuring instruments BlueLEVEL, BlueCLINO, Clinotronic Plus and ZEROTRONIC sensors supply a fully digital signal for transmitting these values over long distances without any loss of quality.

BlueMETER Sigma is

- a display unit
  and
- an interface between instrument and PC/laptop

The following new functions and features distinguish the BlueMETER Sigma from the BlueMETER:

- large and very easy-to-read color display
  - Various color profiles can be chosen
  - Various display methods are available: the new graphical 2D-display allows very useful new applications!
- Measured values from up to four instruments can be displayed simultaneously. Users can choose which instrument is displayed as A, B, C or D.
- Furthermore the following options are available:
  - Display of the difference of two instruments (A-B)
  - Display of the difference of four instruments (A-B and C-D). The values can then be displayed as a 2D-graphic: A-B for the X-axis, and C-D for the Y-axis.
- The connectors for the cables are now on the right side of the instrument, allowing adjustment of the instrument to the optimal reading angle with a built-in bracket on the back of the BlueMETER Sigma.

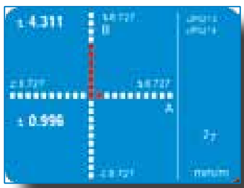
Graphical 2D-display

The 2D-display shows graphically the position of an object in space, and the change of its position and makes the information easily understandable.
This substantially facilitates the alignment of e.g.

- a machine
- a truck
- a container hanging on a crane
- a reference plate
  etc.

The following parameters (among others) can be set and changed at the BlueMETER Sigma:

- Units
- Filter settings
- Relative base length
- Physical address of the Zerotronic sensors



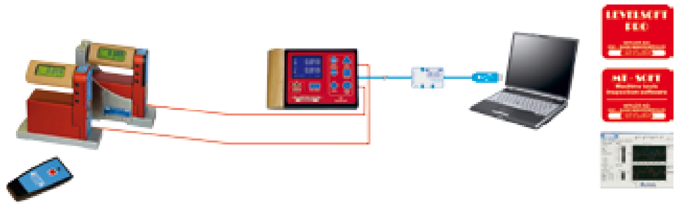
It is possible to send the measured data via an RS232 port to a PC/laptop and therewith to the WYLER software LEVELSOFT PRO, MT-SOFT and LabEXCEL software.

Additional functions and features of the BlueMETER Sigma:

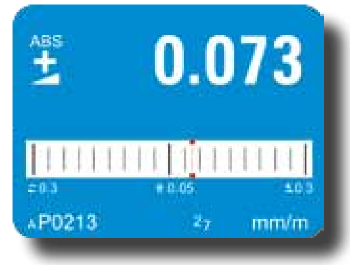
- New design with aluminum housing and latest technology
- Optional wireless communication based on Bluetooth® technology: a single worldwide standard
- Display of measuring values in various measuring units, such as
  - µm/m or mm/m to three decimal places
  - inches/10 inches
  - Milliradian
  - degress/Arcmin/Arcsec
  - mm/relative base length

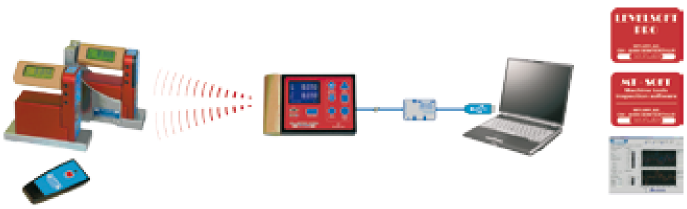
    etc.
- Absolute measurements
- Relative measurements
- Evaluation and storage of the zero-offset of instruments/sensors
- Battery voltage indicator
- Powered by standard 1.5V batteries type C
- CE compatible

BlueMETER SIGMA TECHNICAL SPECIFICATIONS	
Range to choose	depends on the measuring instruments / sensors connected
External power supply	+24V DC
Digital output	RS232, asynchronousous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Power supply with batteries	2 x size C, max. 3 volt (for ca. 20 hrs)
Resolution	depends on the measuring instruments / sensors connected
Dimensions	Length: 150 mm / Height: 34/40 mm / Width: 96 mm
Net weight	
• with batteries	835 g
• without batteries	684 g
Operating temperature range	0 ... + 40 °C
Storage temperature range	- 20 ... + 70 °C

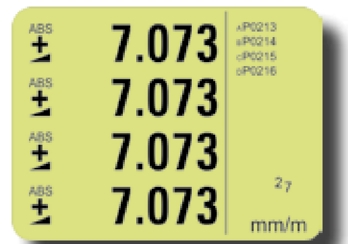


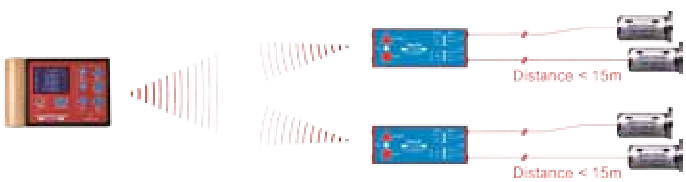
Two BlueLEVEL units connected to a BlueMETER SIGMA by means of cables and linked to a PC



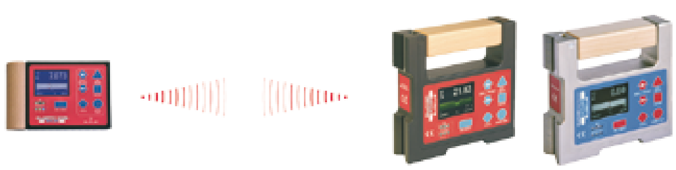


Two BlueLEVEL units connected to a BlueMETER SIGMA by means of wireless data transmission and linked to a PC

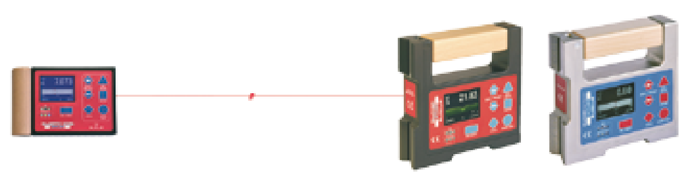




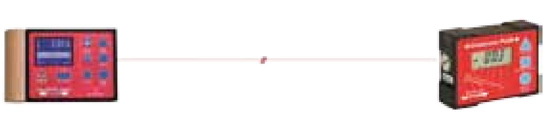
Four ZEROTRONIC sensors connected to a BlueMETER SIGMA by means of two BlueTC



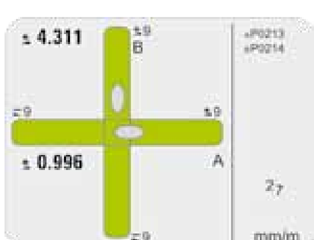
BlueCLINO or BlueCLINO High Precision connected to a BlueMETER SIGMA by means of wireless data transmission

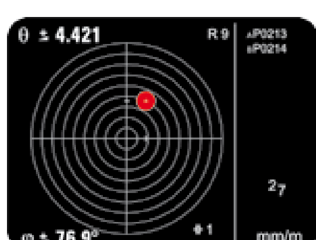


BlueCLINO or BlueCLINO High Precision connected to a BlueMETER SIGMA by means of cables



CLINOTRONIC PLUS connected to a BlueMETER SIGMA by means of cables





10.2 BlueMETER / BlueMETER BASIC

The BlueMETER and BlueMETER BASIC are intelligent digital display units developed by WYLER AG for the BlueLEVEL inclination measuring instrument and the ZEROTRONIC sensors.

Besides the excellent measuring accuracy the BlueLEVEL instruments and the ZEROTRONIC sensors supply a fully digital signal for transmission over long distances without any loss of quality.

The BlueMETER and BlueMETER BASIC is

- A display unit
- An interface between instrument and PC/laptop
- Programming station for the ZEROMATIC instruments

On the BlueMETER and BlueMETER BASIC various parameters may be set or changed, such as:

- Measuring units
- Port definition (port)
- Filter-settings
- Relative base length, etc.

It is possible to send measured data via an RS 232 port to a PC/laptop or the WYLER LEVELSOFT PRO, MT-SOFT and LabEXCEL software.

- Compact and pleasant design in aluminium housing and state of the art technology.
- Wireless data transmission based on the internationally approved Bluetooth™ standard (option)
- Large and easy-to-read LCD display
- Display showing the automatically recognized instruments connected (serial number and type)
- Powered by standard 1.5V batteries type "C"
- In compliance with CE regulations and all applicable EMC regulations

The BlueMETER and BlueMETER BASIC offer the possibility of displaying the measuring value of single sensors or measuring instruments or also the difference between two sensors or instruments.

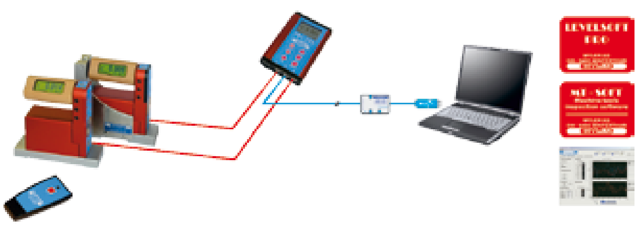
The following display settings are basically possible:

- Measuring with one of several instruments connected to port "A"
- Measuring with one of several instruments connected to port "B"
- Differential measurement between two instruments
- Simultaneous display of one each of several instruments connected to the ports "A" and "B"

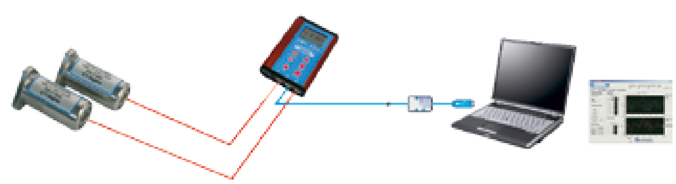
BlueMETER + BlueMETER BASIC TECHNICAL SPECIFICATIONS

Range to choose	depends on the measuring instruments / sensors connected
External power supply	8…28 V DC
Digital output	RS 232 / RS 485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Display available	within 3 seconds
Power supply with batteries	3 x 1.5V, Size "C" ALKALINE
Resolution	depends on the measuring instruments / sensors connected
Dimensions	Length: 178 mm / Height: 32/37 mm / Width: 118 mm
Net weight	
• with batteries	784 g
• without batteries	558 g
Operating temperature range	0 ... +40 °C
Storage temperature range	-20 ... +70 °C

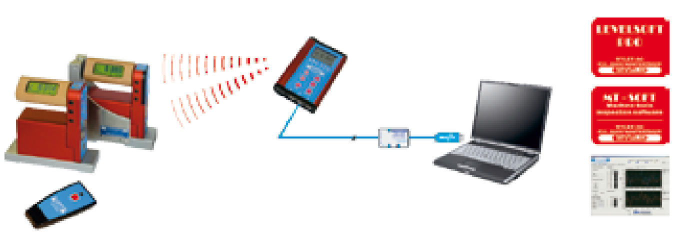
Configurations with BlueMETER and BlueMETER BASIC (examples)



2 BlueLEVEL units connected to a BlueMETER by means of cables and linked to a PC



2 ZEROTRONIC sensors connected to a BlueMETER by means of cables and linked to a PC



2 BlueLEVEL units connected to a BlueMETER by means of wireless data transmission and linked to a PC

10.3 BlueTC with/without wireless data transmission for BlueLEVEL / BlueLEVEL BASIC / ZEROTRONIC sensors

Introduction:

The BlueTC with or without radio transmission can be used as an alternative interface to the BlueMETER and BlueMETER BASIC for using the inclination measuring instruments BlueLEVEL and BlueLEVEL BASIC.

It is possible to send measured data via an RS 232/485 port to a printer, a PC/laptop or the WYLER LEVELSOFT PRO and MT-SOFT software or to other software such as LabEXCEL

Advantage compared to the BlueMETER/BlueMETER BASIC connected to BlueLEVEL/BlueLEVEL BASIC instruments are:

- Simple configuration; BlueTC is only an interface between instruments and PC/laptop
- Cost effectiveness (in case of wireless data transmission)

BlueTC

Disadvantage compared to the BlueMETER/BlueMETER BASIC connected to BlueLEVEL or BlueLEVEL BASIC instruments are:

- No display of the measured values of the connected instruments [A] and [B]
- Menu less extensive and less comfortable due to missing display

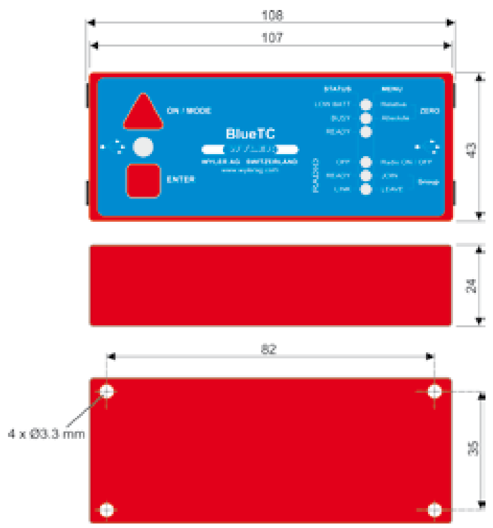
BlueTC TECHNICAL SPECIFICATIONS	
External power supply	+5V DC, max. 450 mW (PIN 3) or 8…28 V DC (PIN 1)
Format of transmission	RS 232 / RS 485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Dimensions without battery pack Dimensions with battery pack	L: 108 mm / W: 43 mm / H: 24 mm L: 108 mm / W: 43 mm / H: 59 mm
Operating temperature range Storage temperature range	0 ... +40 °C -20 ... +70 °C
Net weight without battery pack Net weight, incl. battery pack and incl. batteries	150 g 500 g

BlueTC with battery pack

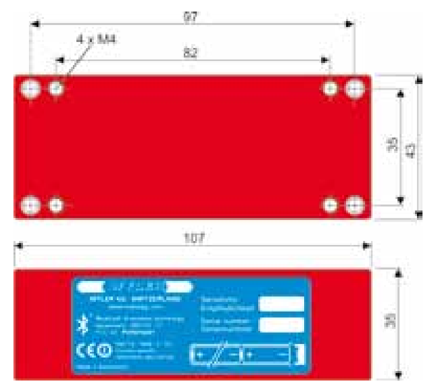
Top view

Side view

Bottom view hole pattern



Battery pack for BlueTC

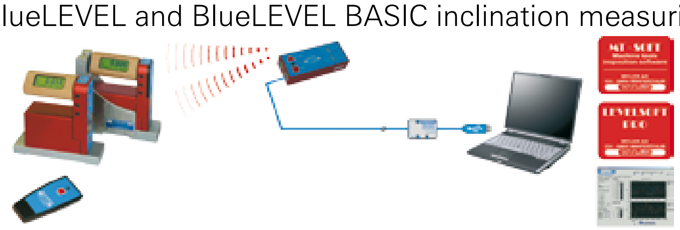


Bottom view hole pattern

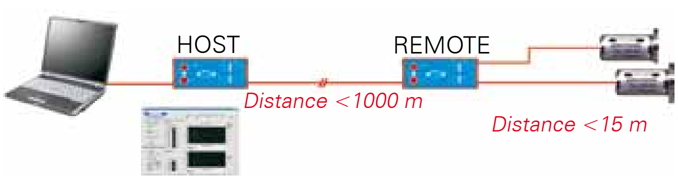
Side view

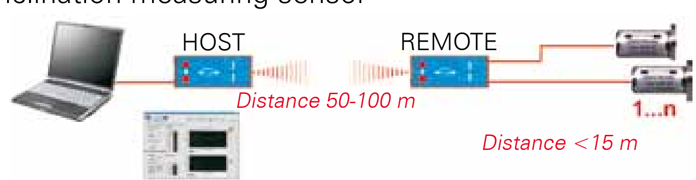
Possible configurations with BlueTC with and without wireless data transmission

BlueTC with BlueLEVEL and BlueLEVEL BASIC inclination measuring instruments



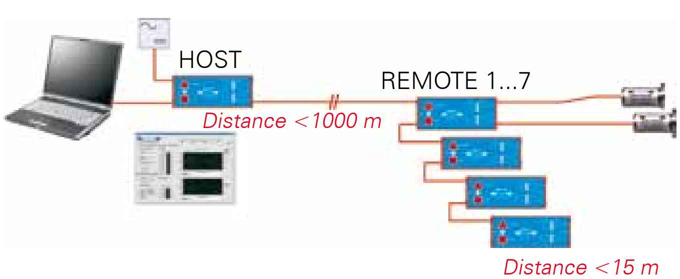
BlueTC with ZEROTRONIC inclination measuring sensor





Configuration with two or more BlueTCs, connected to ZEROTRONIC sensors and to a PC/laptop whereas the BlueTC works as an interface, and with data transmission through cable: Up to a total of 64 units can be connected, whereas the HOST BlueTC, each REMOTE BlueTC and each sensor count as one unit.

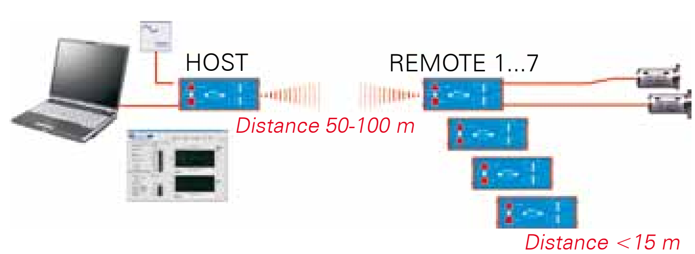
Distance PC - BlueTC <2.5 m / Distance BlueTC - BlueTC <1000 m / Distance BlueTC - sensors <15 m



Configuration with two or more BlueTCs, connected to ZEROTRONIC sensors and to a PC/ laptop whereas the BlueTC works as an interface, and with wireless data transmission: Up to a total of 16 wireless units can be joined via Bluetooth, whereas the HOST BlueTC and each REMOTE BlueTC count as one unit. Up to 7 remote units can be read in simultaniously.

Regarding the configuration set-up of the sensors, there is only the limitation that the total number of units connected may not exceed 64, whereas the HOST BlueTC, each REMOTE BlueTC and each sensor count as one unit.

Distance PC - BlueTC <2.5 m / Distance BlueTC - BlueTC <50...100 m / Distance BlueTC - sensors <15 m



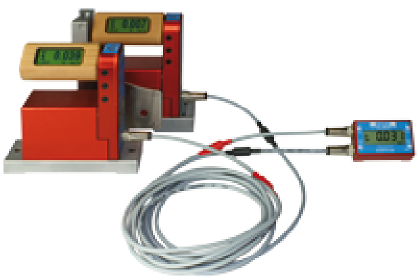
10.4 BlueMETER LIGHT for BlueLEVEL / BlueLEVEL BASIC / ZEROTRONIC sensors

Introduction:

The BlueMETER LIGHT has been developed as an alternative to the well proven BlueMETER for

- The digital sensors in the ZEROTRONIC family
- The digital inclinometers BlueLEVEL and BlueLEVEL BASIC

The displayed measuring values are automatically sent to the serial interface every 0.3 seconds.



The BlueMETER LIGHT serves as display unit for all sensors in the ZEROTRONIC family as well as for the BlueLEVEL and BlueLEVEL BASIC measuring instruments.

The BlueMETER LIGHT can be considered a simplified version of the BlueMETER and the BlueMETER BASIC.

The BlueMETER LIGHT serves as

- Display unit
- Interface between the measuring instrument(s) and a PC
- 5V supply for the connected sensors and measuring instruments, provided it is powered with external power supply

Contrary to the BlueMETER, the BlueMETER LIGHT does not allow any settings or modifications, such as

- Measuring unit displayed
- Connection of sensor (port)
- Filters
- Relative base length

  etc.

The BlueMETER LIGHT can be used in combination with all digital WYLER instruments. All the relevant data, such as

- Calibration data
- Address of instrument
- Zero-offset

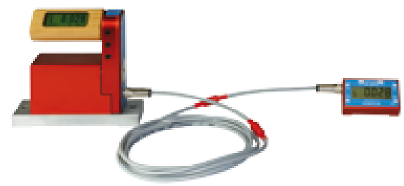
  etc.

are memorized in the respective measuring instruments. The BlueMETER LIGHT can be connected to a serial port (RS 232) of a PC. The measuring data can be treated by software, e.g. LEVELSOFT PRO, MT-SOFT or LabEXCEL and transferred to a printer.

BlueMETER LIGHT TECHNICAL SPECIFICATIONS	
Range to choose	depends on the measuring instruments / sensors connected
External power supply	24V from external power supply or +5V from measuring instrument
Resolution	depends on the measuring instruments / sensors connected
Format of transmission	RS 485/RS 232, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Dimensions / net weight	L: 72 mm / W: 44 mm / H: 20 mm / 125 g
Operating temperature range Storage temperature range	0 ... +55 °C -10 ... +60 °C

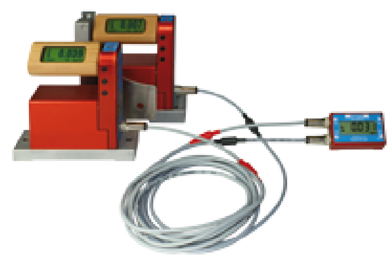
Possible configurations with the BlueMETER LIGHT

The BlueMETER LIGHT can be used in combination with BlueLEVEL or BlueLEVEL BASIC as a remote display. It allows the display of measuring values of one single instrument or the difference between two instruments. When connecting the BlueMETER LIGHT (OUT-port - RS 232) to a PC, the measuring value displayed is automatically transmitted every 0.3 seconds.

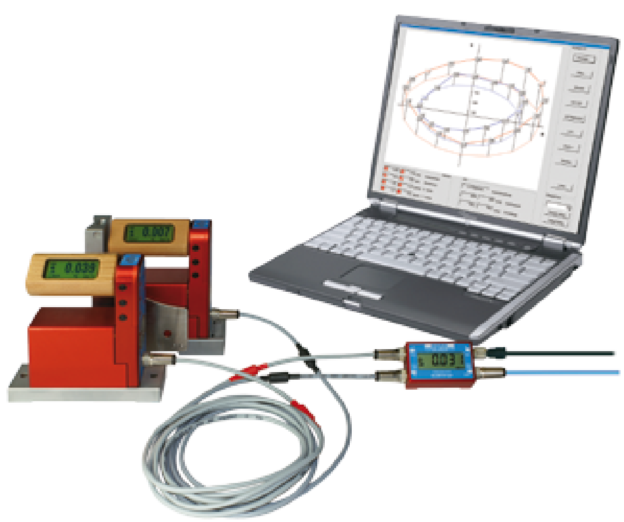


When using it in combination with a BlueLEVEL or BlueLEVEL BASIC, the later must be powered by batteries, or an external power supply must be used.

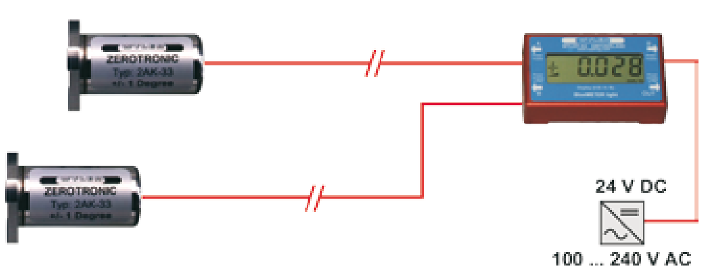
Display:
As soon as BlueLEVEL are connected to both ports (A + B) of the BlueMETER LIGHT, the display will automatically show the difference of the two signals. The measuring unit is identical to the format of the instrument(s) connected [mm/m] or [Arcsec].



When the BlueMETER LIGHT is directly connected to ZEROTRONIC sensors (type 3 and type C), the display will be in Radian [mRad].



Possible configurations with the BlueMETER LIGHT / ZEROTRONIC sensors



Display in [mRad]

Connection to ZEROTRONIC sensor

In combination with one or two ZEROTRONIC sensor(s) you have the possibility of directly displaying the measured value, respectively the difference between the two.

However, this configuration requires an external power supply of 24V (as shown on the sketch at the left).

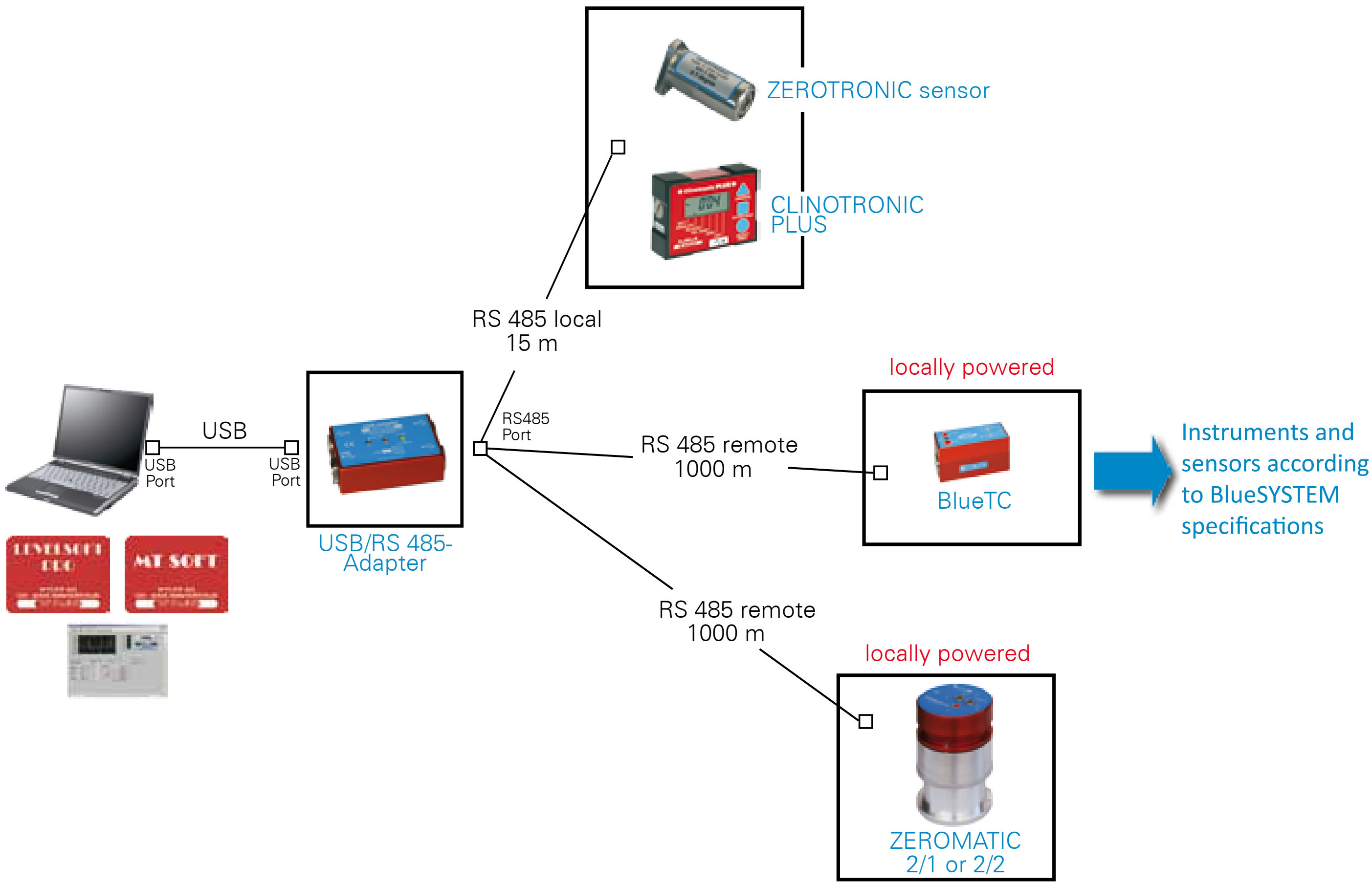
10.5 USB / RS 485 Adapter

With this USB / RS 232 adapter you can easily
(without additional power supply)

- Overcome longer distances using the integrated USB to RS 485 interface
- Connect measuring instruments and sensors to a PC

Note:
The 5-volt supply for the instruments connected is taken from the USB port. The power consumption is limited to 250 mA. This allows the connection of two ZEROTRONIC sensors or two CLINOTRONIC PLUS devices, for example.

Possible configurations with the USB / RS 485 adapter



USB-/RS 485-Adapter TECHNICAL SPECIFICATIONS	
Interface:	USB 2.0 compatible VirtualComPort-driver (VCP) for Windows XP or Vista: <www.ftdi-chip.com>
Communication	9,600 / 57,600 Baud, asynchronous, 7 Databits, 2 Stoppbits, no parity, no handshake
Power supply	+5V from USB-interface (PC), limited to 250mA (Suspend_mode= Off) Power Supply +24V (optional) to supply connected instruments
LED display	green = +5V from PC yellow = serial information, Tx= Transmitter/ Rx= Receiver
Operating temperature	0° ... +60 °C
Dimensions/weight	Length=63 mm; Width=40 mm; Height=20 mm / 110 gr

APPENDIX

INFLUENCE OF GRAVITY ON THE MEASURED INCLINATION

Gravitational force is known to be fairly constant all over the world. This is the foundation of the measuring principle applied in WYLER sensors. However, gravitational force does vary by up to 0.5%. To utilize the full precision of the sensors, which are among the most accurate inclinometers, the local gravity must be taken into account. The measured values have to be interpreted accordingly.

The electronic sensors use a capacitive measuring system as shown in Fig. 1. A friction-free supported disc is placed in between two electrodes, forming a differential capacitor. Rotational symmetric springs hold the disc in the middle of the gap. When the sensor is inclined, the gravitational force moves the disc to the lower side, reducing the distance to one electrode, whereas on the other side the distance to the other electrode increases. This leads to an increase of the capacitance on the lower and to a decrease on the upper side. From these changes, the electronics in the sensor calculate the angle of the inclination.

The equilibrium of the resilient and the gravitational force can be described as follows:

$$cx = mg \sin(\alpha) \qquad (1)$$

where

x	displacement of the disc
c	spring constant
m	mass of the disc
g	gravity
α	inclination angle

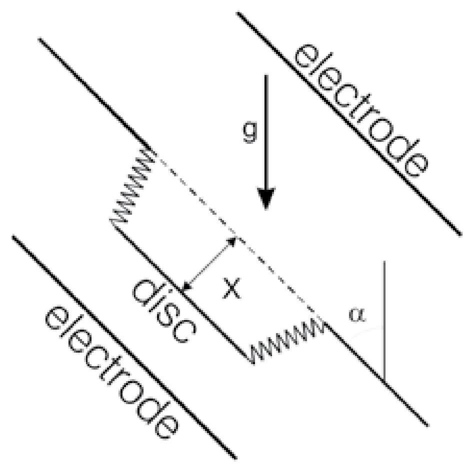


Fig. 1 Schematic representation of the capacitive measuring system

This measuring principle relies on gravity to be constant. However, gravitational force varies by about 0.5% around the Earth's surface. Because the Earth is rotating and its shape is not a perfectly uniform sphere, the strength of Earth's gravity changes with latitude, altitude, local topography and geology. The International Union of Geodesy and Geophysics (IUGG) defined the international gravity formula, which relies on the reference ellipsoid, a mathematically-defined surface. It describes gravity sufficiently accurately:

$$g(\phi, h) = 9.780327\left(1 + 0.0053024\sin^2(\phi) - 0.000058\sin^2(2\phi)\right) - 3.086\times10^{-6} h \qquad (2)$$

where

ϕ	latitude
h	altitude

Table 1 shows the gravitational acceleration in various cities around the world; amongst these cities, it is lowest in Mexico City (9.779 m/s²) and highest in Oslo and Helsinki (9.819 m/s²).

Amsterdam	9.813	Istanbul	9.808	Paris	9.809
Athens	9.807	Havana	9.788	Rio de Janeiro	9.788
Auckland	9.799	Helsinki	9.819	Rome	9.803
Bangkok	9.783	Kuwait	9.793	San Francisco	9.800
Brussels	9.811	Lisbon	9.801	Singapore	9.781
Buenos Aires	9.797	London	9.812	Stockholm	9.818
Calcutta	9.788	Los Angeles	9.796	Sydney	9.797
Cape Town	9.796	Madrid	9.800	Taipei	9.790
Chicago	9.803	Manila	9.784	Tokyo	9.798
Copenhagen	9.815	Mexico City	9.779	Vancouver	9.809
Nicosia	9.797	New York	9.802	Washington	9.801
Jakarta	9.781	Oslo	9.819	Wellington	9.803
Frankfurt	9.810	Ottawa	9.806	Zurich	9.807

Since gravity depends on the latitude and the altitutde, the measured inclination is precise only at the location where the measuring device was calibrated, i.e. at WYLER AG in Winterthur, Switzerland. In Singapore, for example,, where the gravitational force is smaller, the displayed angle will be below the actual one.

The displacement of the disc can be calculated using formula (1):

$$x_m = \frac{1}{c} m g_m \sin\left(\alpha_{eff}\right) \qquad (3)$$

where

x_m displacement of the disc at location of measurement

g_m gravity at the location of measurement

α_{eff} effective angle

The electronics of the sensor calculate the angles according to the place where it was calibrated. Therefore the same formula used for the displayed angle can be used:

$$\alpha_m = \arcsin\left(\frac{c x_m}{m g_c}\right) \qquad (4)$$

where

g_c gravity at the place of calibration

α_m displayed angle at place of measurement

Combining formula (3) and (4) allows forecasting which angle the sensor will show at a location with changed gravity. Solving for the effective angle the correction factor for the displayed angle can be calculated:

$$\alpha_{eff} = \arcsin\left(\frac{g_c}{g_m}\sin\left(\alpha_m\right)\right) \qquad (5)$$

The diagram in Fig. 2 shows the deviation of the measured angle from the effective one as a function of the gravitational force and of the effective angle itself. With increasing angles, the deviation increases as well. In Singapore, where the gravitational force is with 9.781 m/s² one of the lowest, the deviation at 45° is 0.1525°. Horizontally no deviation occurs.

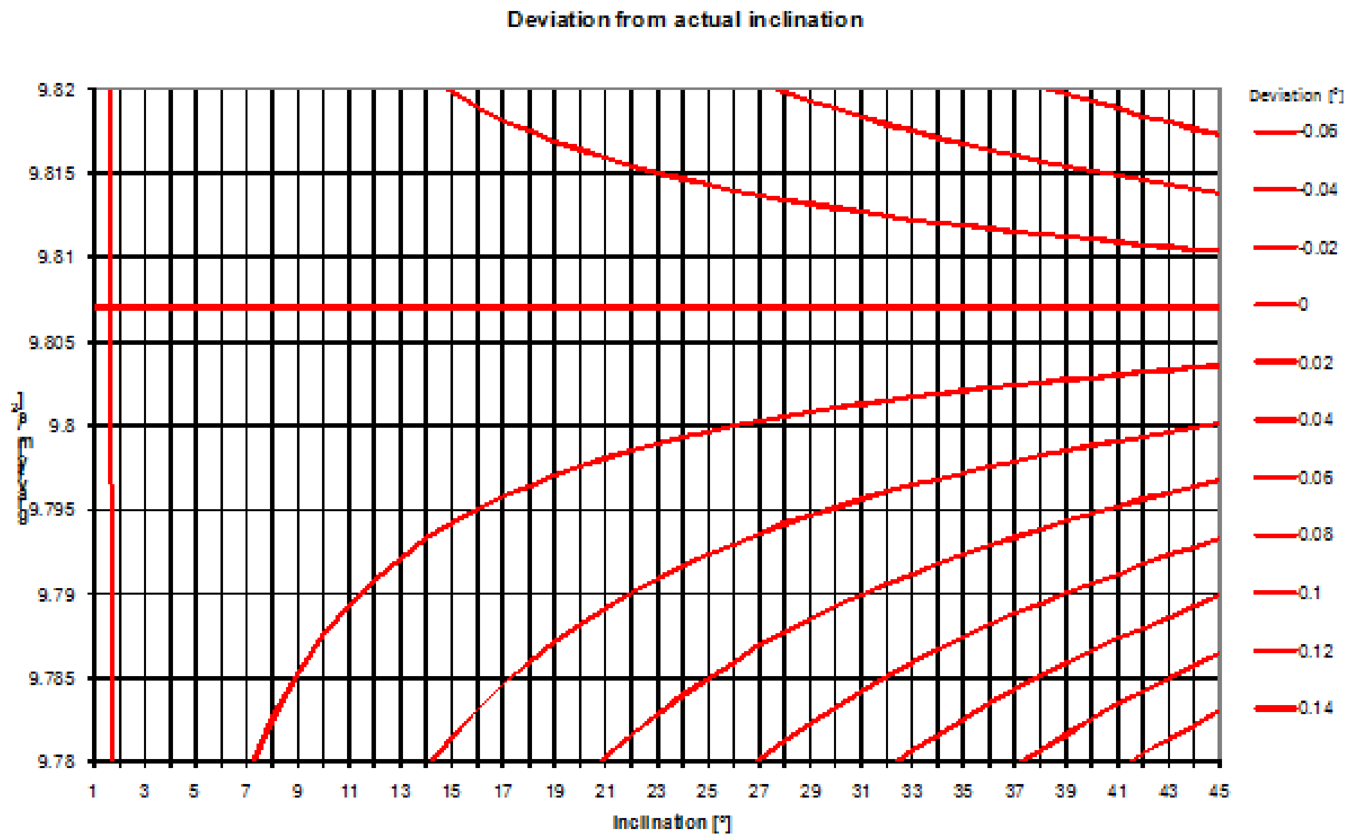


Fig. 2 Deviation of the measured angle from the effective one as a function of the gravitational force and of the effective angle

The angle is always measured against the local gravity vector. Anywhere on Earth away from the equator or poles, effective gravity points not exactly toward the centre of the Earth, but rather perpendicular to the surface of the geoid. This difference is called vertical deflection. Due to the flattened shape of the Earth, it is directed somewhat toward the opposite pole. About half of the deflection is due to centrifugal force, and half because the extra mass around the equator causes a change in the direction of the true gravitational force relative to what it would be on a spherical Earth. Further influences are caused by mountains and by geological irregularities of the subsurface and amount up to 10" in flat areas or 20-50" in alpine terrain.

At the place of measurement, the displayed angle can be corrected when the local gravity is taken into account. Since it is not known in advance where the sensors will be used, it is not possible to calibrate them to compensate for a different gravitational force. At the moment it is up to the customer to apply the correction formulae to obtain the most accurate results. However, WYLER AG has developed a tool that will allow adjustment of the calibration data to the local gravitational force.

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