

WYLER

Compendium

THE SECRETS OF INCLINATION MEASUREMENT



Edition 2018/1

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.

WYLER AG, Heinz Hinnen

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1. GENERAL INTRODUCTION TO INCLINATION MEASUREMENT

1.1 HISTORY OF INCLINATION MEASUREMENT

Inclination measurement was used already in ancient times

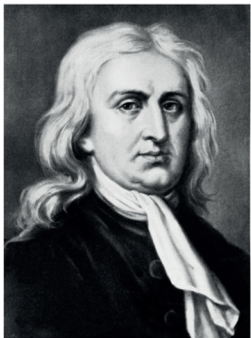
- for the construction of buildings
- for the creation of simple city maps
- for navigation at sea

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



Sextant



*Sir Isaac NEWTON
1642 - 1727*

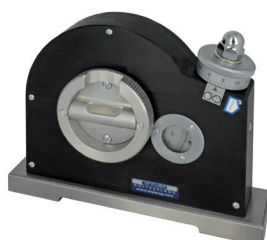
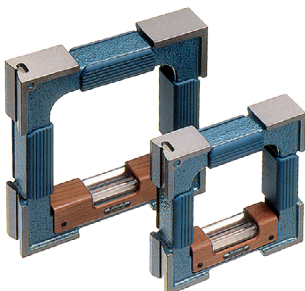
Especially in the field of quality assurance, inclination measurement is applied in various different forms

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
and Clinometers*

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



*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 .

INCLINATION is a specific, position-dependent angle whereas we distinguish 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:

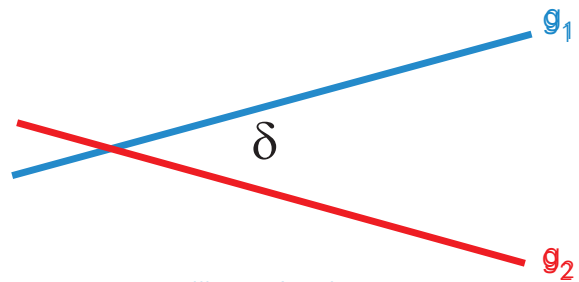
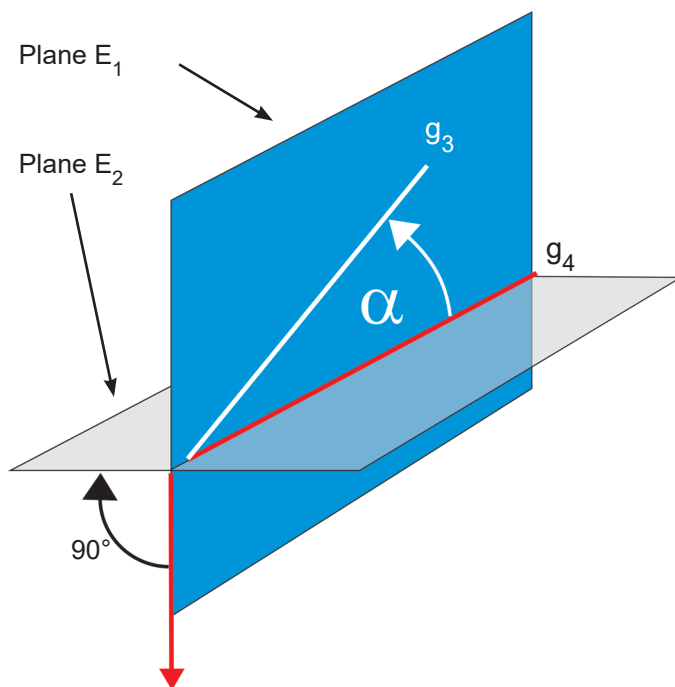


Illustration 1

Illustration 2



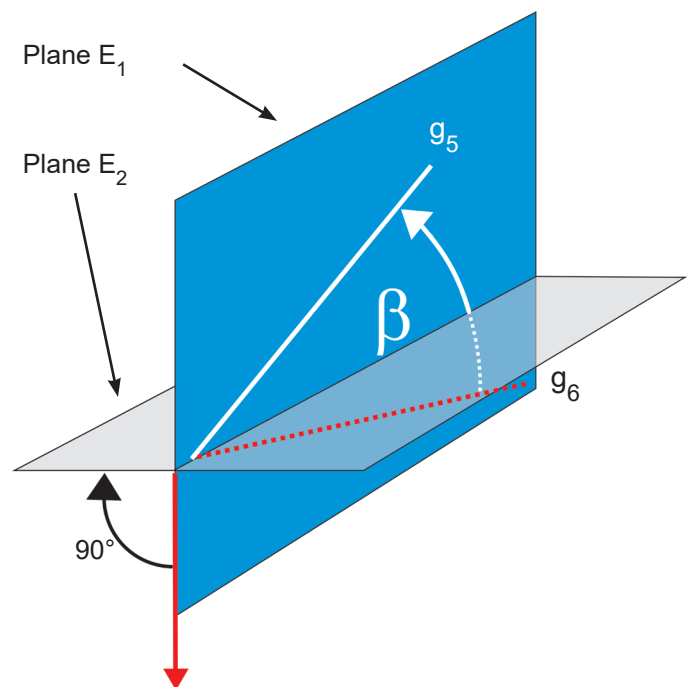
ABSOLUTE INCLINATION

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], [μ Rad],
- [mm/m], [μ m/m]

Illustration 3



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], [μ Rad],
- [mm/m], [μ m/m]

1.3 UNITS IN INCLINATION MEASUREMENT

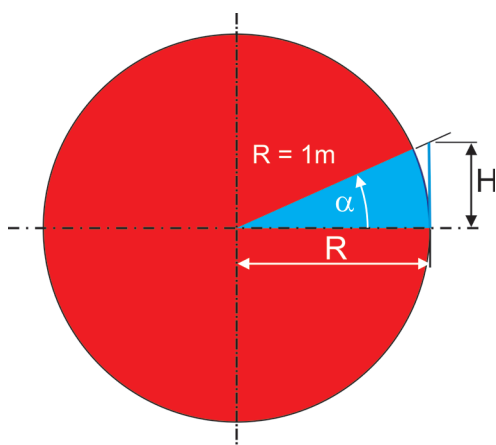
FOR LARGE INCLINATIONS FROM 5...10 DEGREES THE FOLLOWING UNITS ARE NORMALLY USED:

- 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

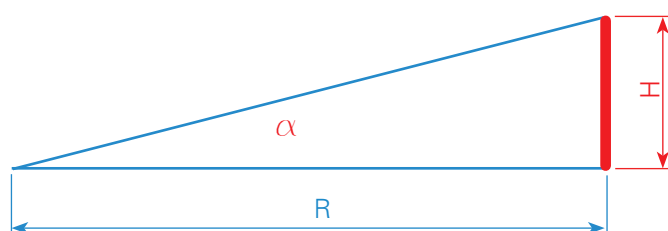
FOR SMALLER INCLINATIONS UP TO 5...10 DEGREES THE FOLLOWING UNITS ARE NORMALLY USED:

- xxx.xxx mm/m mm per m ($\mu\text{m}/\text{m}$)
- 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 $\mu\text{m}/\text{m}$



INCLINATION α defined as a height "H" related to base line "R", for instance in [mm/m] or [$\mu\text{m}/\text{m}$]



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.

Trigonometric function:

*Height "H" = base line "R" * $\tan \alpha$*

Assumption: inclination $\alpha = 1$ arcsec

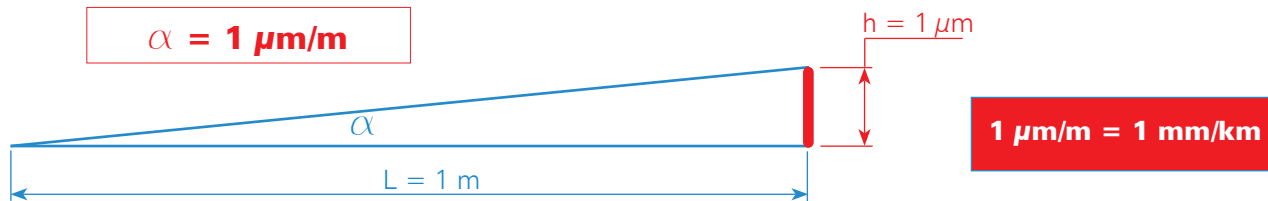
Height "H" = Height "R" * $\tan \alpha$

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 $\mu\text{m}/\text{m}$

1.5 WHAT IS A mm/m?



It is quite difficult to imagine an inclination of the size of $1 \mu\text{m/m}$. 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, $L=1\text{km}$ and $h=1 \text{ mm}$ (1 mm/km). This way, it is much easier to imagine an inclination of $1 \mu\text{m/m}$. 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.

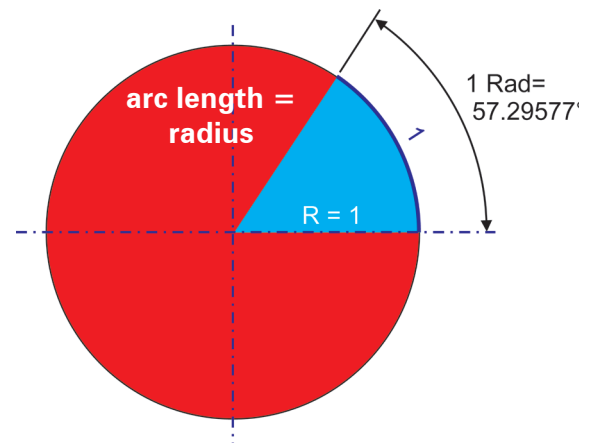
As stated, one radian is equal to $180^\circ/\pi$ degrees, therefore:

$$1 \text{ Rad} = 360^\circ / 2\pi = 180^\circ / \pi = 57.29577^\circ$$

$$1 \text{ mRad} = 0.05729^\circ = 3' 43.77''$$

$$1 \mu\text{Rad} = 0.206'' = \text{ca. } 1 \mu\text{m/m}$$

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: $1 \mu\text{Rad} = 1 \mu\text{m/m}$ is only valid in the range of very small inclinations (angles)!

1.7 CORRELATION BETWEEN THE MOST COMMON UNITS (SI)

	$\mu\text{m/m}$	mm/m	arcsec	arcmin	degree	mRad	Rad
$1 \mu\text{m/m}$	1	0.001	0.20627	0.00344	$5.730 \cdot 10^{-5}$	0.001	$1 \cdot 10^{-6}$
1 mm/m	1,000	1	206.265	3.43775	0.0573	1	$9.99 \cdot 10^{-4}$
1 arcsec	4.848	0.00485	1	0.01667	$2.778 \cdot 10^{-4}$	0.00485	$4.848 \cdot 10^{-6}$
1 arcmin	290.89	0.29089	60	1	0.01667	0.29089	$2.909 \cdot 10^{-4}$
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	$1.557 \cdot 10^6$	1,557	206,264.8	3,437.75	57.3	1,000	1

Important: $1 \mu\text{Rad} = 1 \mu\text{m/m}$ is only valid in the range of very small inclinations (angles)!

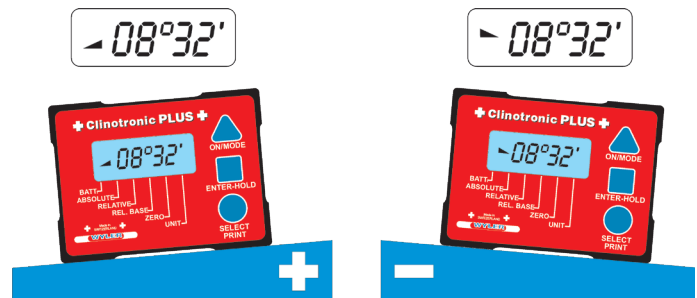
1.8 CORRELATION BETWEEN THE MOST COMMON UNITS IN INCLINATION MEASUREMENT

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:

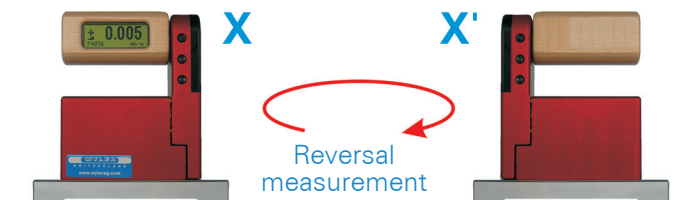
An inclination is positive when the instrument, on that side on which an electrical connector is installed, is lifted. When the instrument under the same precondition is declined, we define this as a negative inclination.



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

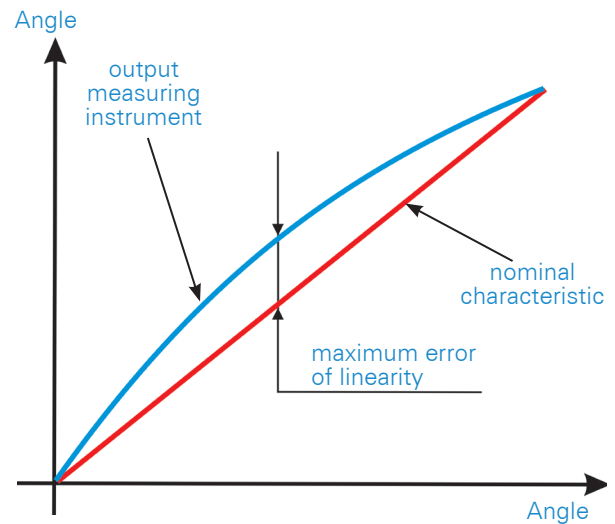
$$= \frac{(X - X')}{2}$$

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 $f_{\max} = 0,01 \cdot |M_v|$, at least 0.05% (BlueLEVEL at least 1 digit $\hat{=}$ 0.005% M_f) of the measuring range M_f

For measured values above half the measuring range:

Maximum error $f_{\max} = 0.01 (2 \cdot |M_v| - 0,5 \cdot M_f)$

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.

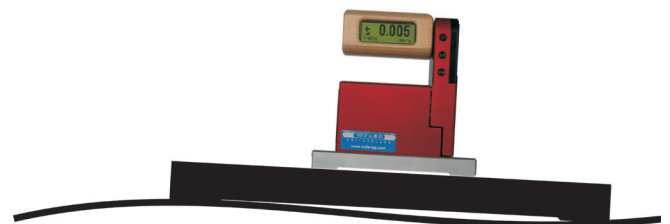


LOW INFORMATION DENSITY

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 wylerSPEC**. 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 SIGMA 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 SIGMA 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 wylerSPEC, 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.

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 pro-

cedures 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'ÉTALONNAGE
S SERVIZIO DI TARATURA IN SVIZZERA
S SWISS CALIBRATION SERVICE



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 **ME-TAS / 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%



Measuring categories Measuring object	Measuring range	Measuring conditions	Measuring uncertainty ±	Remarks
Flatness (Length) Surface plates	up to 12.5 m2		$(0.5 + 0.5 \times L) \mu\text{m}$ $L = \text{length in [m]}$	---
Angles / Inclination • Electronic inclinometers • Spirit levels with glass vial • Mechanical inclinometer	± 20 mm/m		$(1 + 0.002 \times E) \mu\text{m/m}$ $E = \text{measured value in } [\mu\text{m/m}]$	---
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 $\mu\text{m/m}$ 5 $\mu\text{m/m}$ 10 $\mu\text{m/m}$	5 $\mu\text{m/m}$ 7 $\mu\text{m/m}$ 8 $\mu\text{m/m}$	Prismatic and flat measuring bases
Rectangularity of flatness like angular standards and machine geometry	50 mm < width < 2500 mm 200 mm < length < 2500 mm		$(1.7 + 0.5 \times SL) \mu\text{m}$ 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

2.1 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 $\pm 180^\circ$

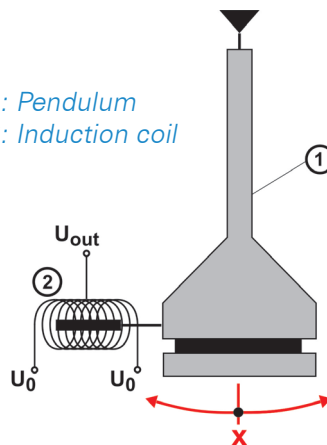


2.2 ELECTRONIC MEASURING INSTRUMENT WITH INDUCTIVE MEASURING SYSTEM

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

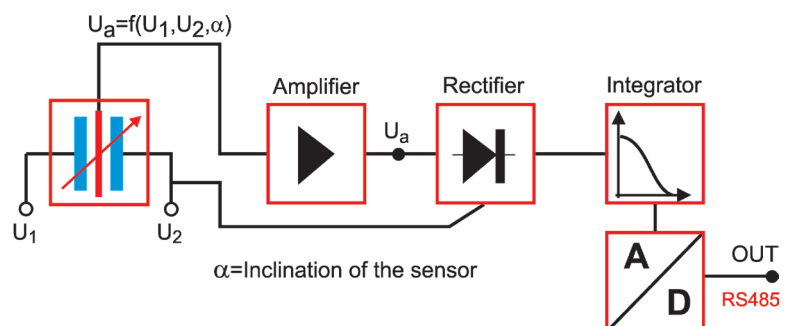


nivelSWISS

2.3 ELECTRONIC MEASURING INSTRUMENT WITH CAPACITIVE 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

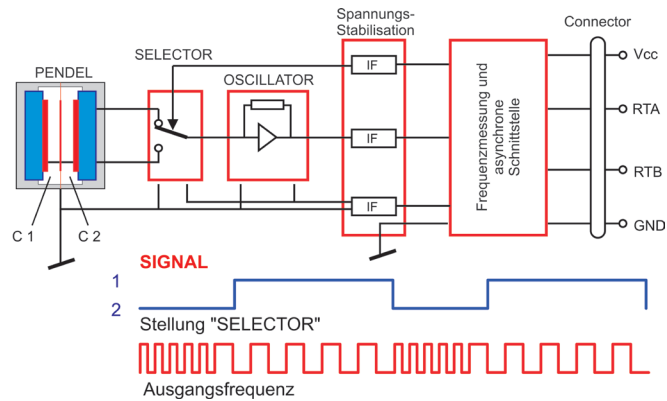


2.4 ELECTRONIC MEASURING INSTRUMENT WITH CAPACITIVE MEASURING SYSTEM AND DIGITAL SIGNAL OUTPUT

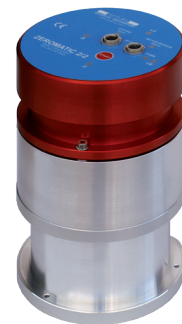
Measuring principle:

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



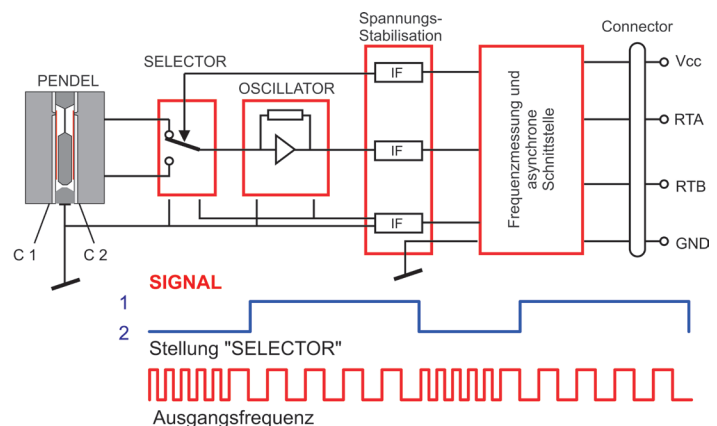
ZEROMATIC

2.5 ELECTRONIC MEASURING INSTRUMENT WITH CAPACITIVE 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 $\pm 10^\circ$.

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



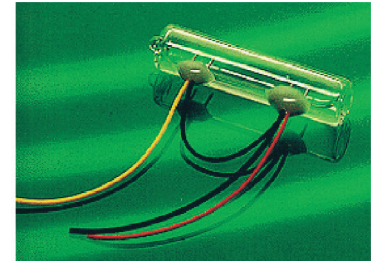
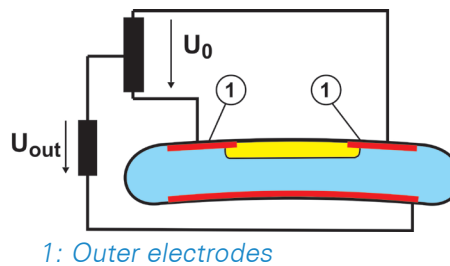
Clinotronic S



BlueCLINO

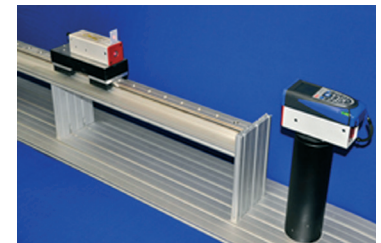
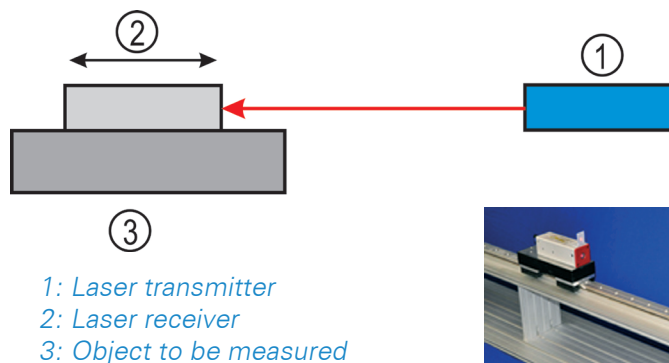
2.5 ELECTROLYTE VIALS

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.



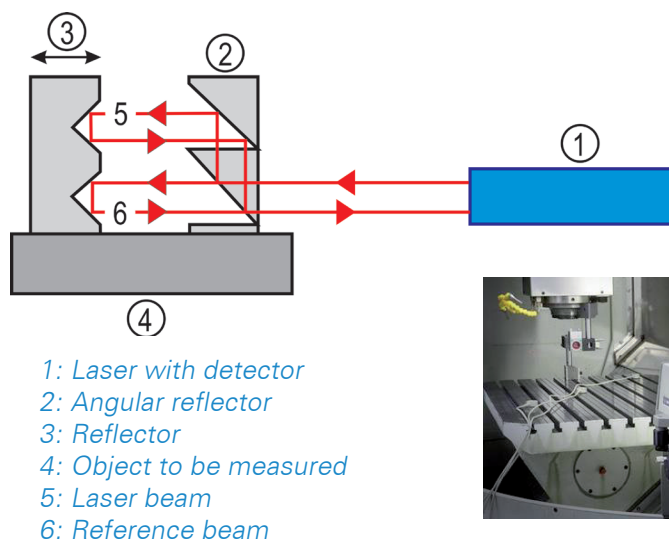
2.6 TARGET LASER

The system consists of a laser sender and a laser receiver unit. The sender unit is a high stability 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).



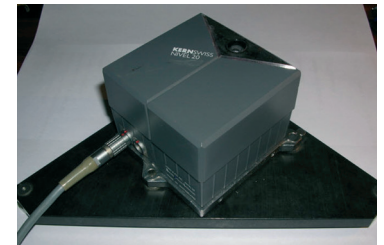
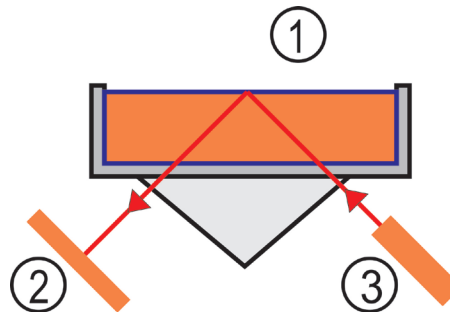
2.7 LASER INTERFEROMETER

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.



2.8 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

2.9 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.



2.10 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.



2.11 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.

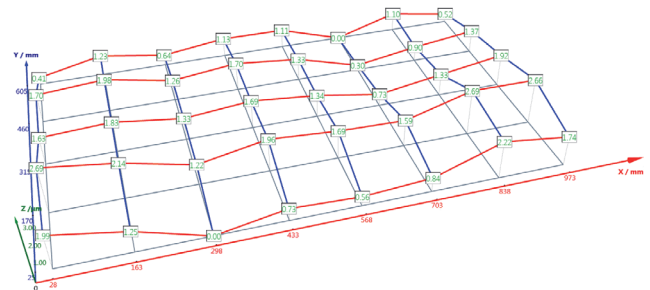


2.12 SOFTWARE WYLERELEMENTS

WYLERELEMENTS



The base package wylerELEMENTS contains the measurement and documentation of geometrical figures, which are measured with our BlueSYSTEM SIGMA.

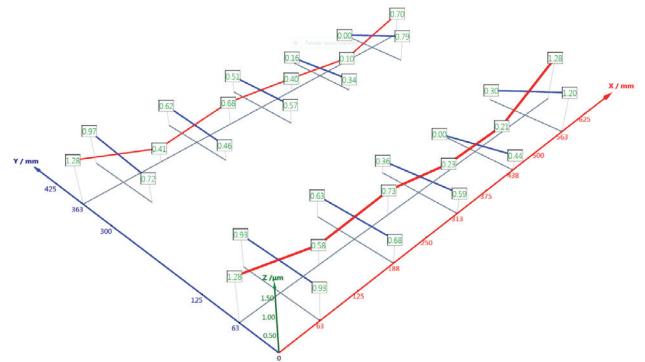


2.13 SOFTWARE WYLERPROFESSIONAL

WYLERPROFESSIONAL



The package wylerPROFESSIONAL includes wylerELEMENTS and contains the measurement and documentation of geometrical figures and rotations, which are measured with our BlueSYSTEM SIGMA. Measurements with a Laserinterferometer and Autocollimator are supported.

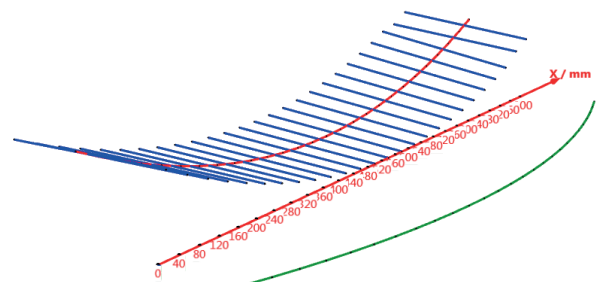


2.14 SOFTWARE WYLERSPEC

WYLERSPEC



The package wylerSPEC includes all modules of wylerELEMENTS, wylerPROFESSIONAL and completes the functionality with customer specific measurements and trend analysis.



2.15 SOFTWARE WYLERCHART

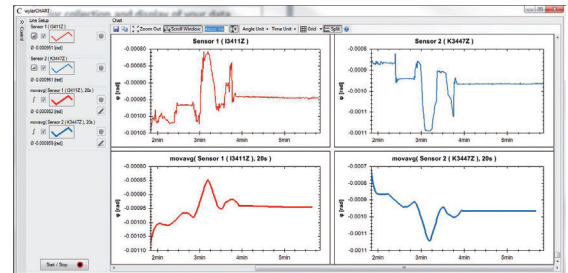


Software-Pakete, welche zusammen mit [WYLER-Neigungssensoren](#) verwendet werden:



WYLERCHART

wylerCHART is a preconfigured smaller version of wylerDYNAM. It is designed for simple **monitoring tasks** using mostly our **ZEROTRONIC** and **ZEROMATIC** sensors.

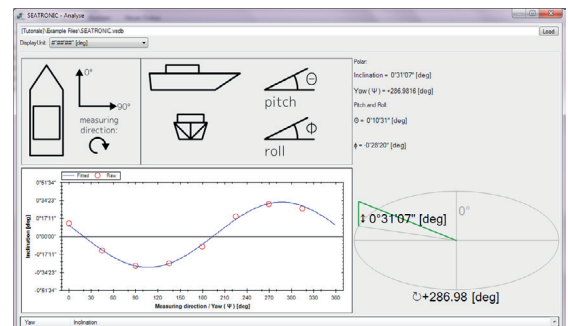


2.16 SOFTWARE WYLERDYNAM



WYLERDYNAM

wylerDYNAM is the free configurable Version of wylerCHART. It includes wylerCHART and special application setups as **"Seatronic"**. It is designed for all kinds of **monitoring tasks** using mostly our **ZEROTRONIC** and **ZEROMATIC** sensors.

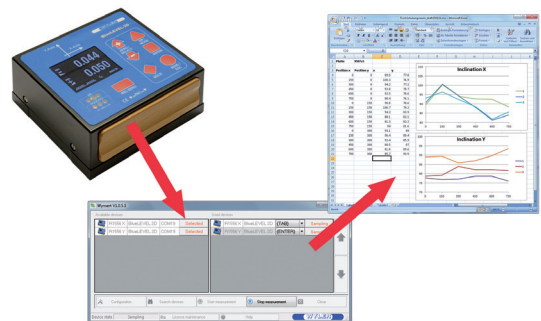


2.17 SOFTWARE WYLERINSERT



WYLERINSERT

wylerINSERT is an easy to use yet powerful tool to read inclination values from WYLER BlueSystem devices and insert them into any program at the current position of the cursor just like the values were typed in.



2.18 SOFTWARE SDK



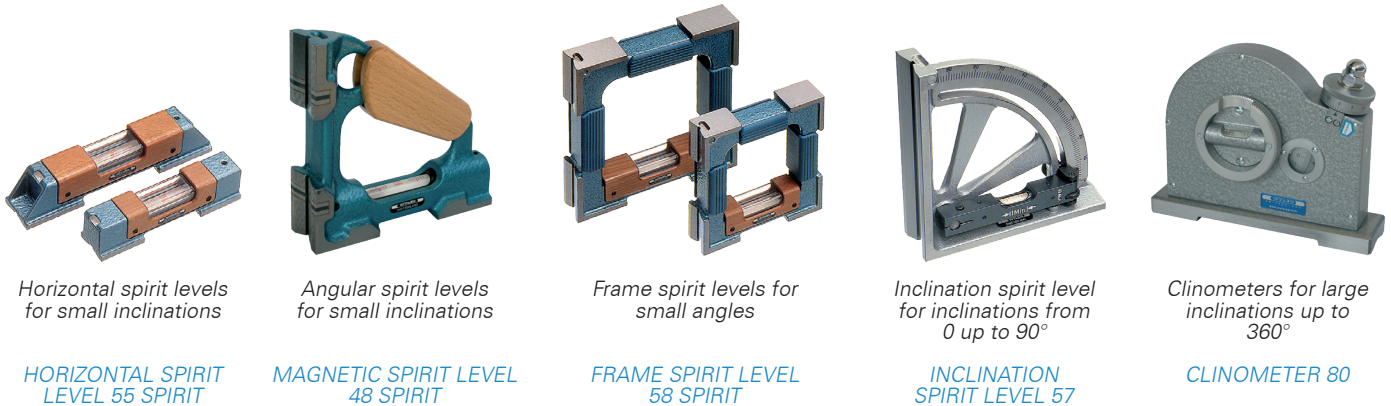
SDK

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 WYLER sensors either direct or via a software interface developed by WYLER. These examples should allow an experienced programmer to successfully develop their own application software.

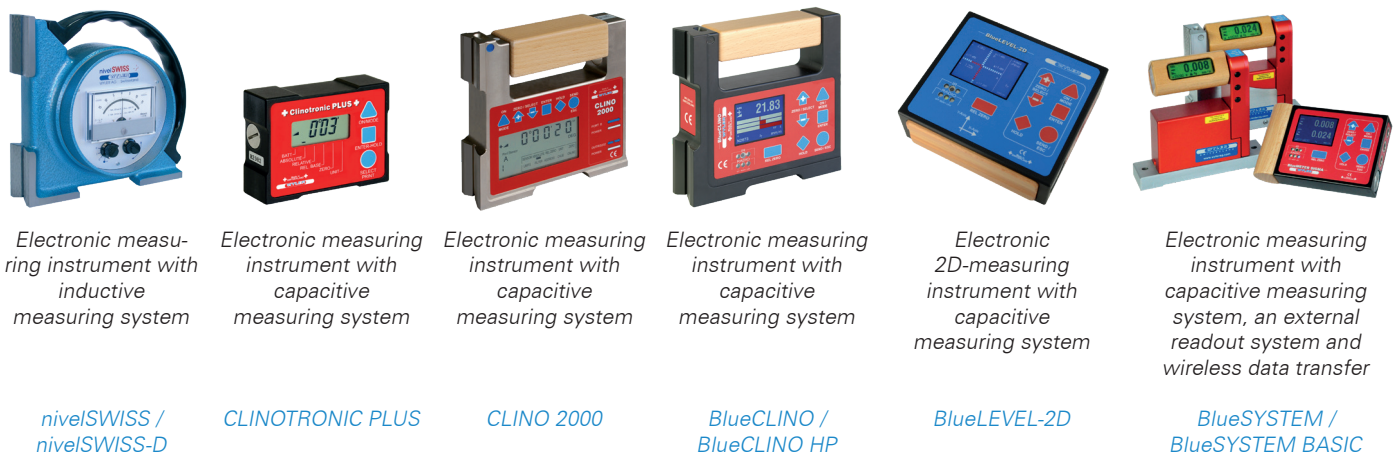
3 PRODUCT GROUPS IN THE AREA OF INCLINATION MEASURING INSTRUMENTS

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

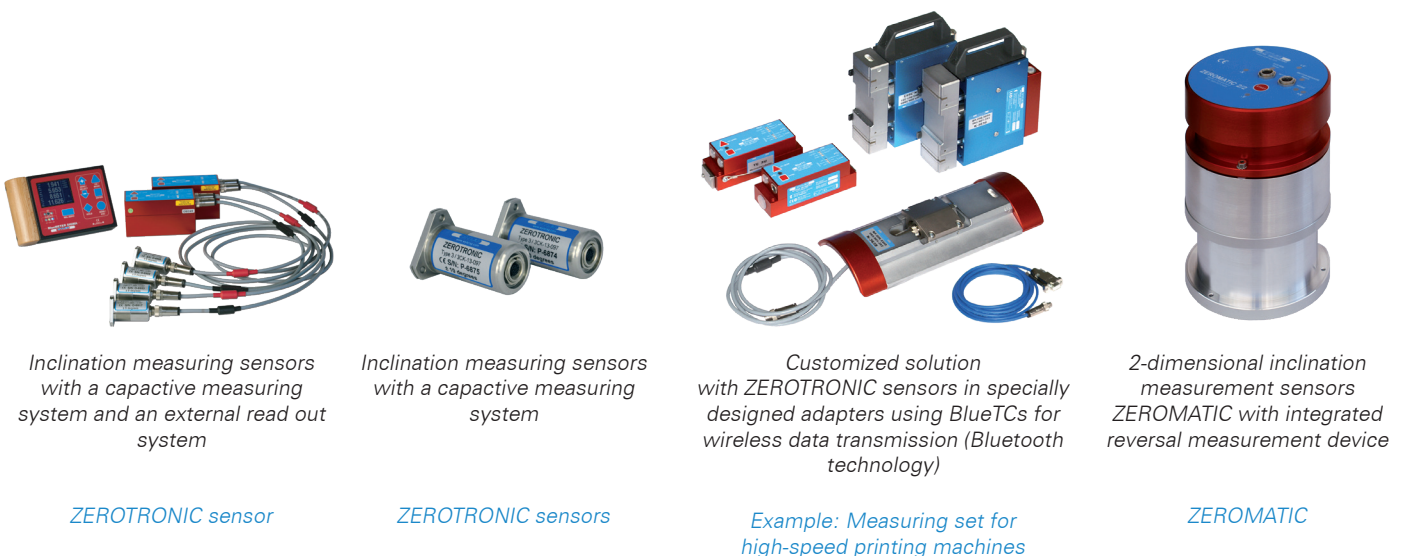
3.1 PRECISION SPIRIT LEVELS AND CLINOMETERS



3.2 ELECTRONIC MEASURING INSTRUMENTS



3.3 INCLINATION MEASURING SENSORS WITH A DIGITAL MEASURING SYSTEM



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



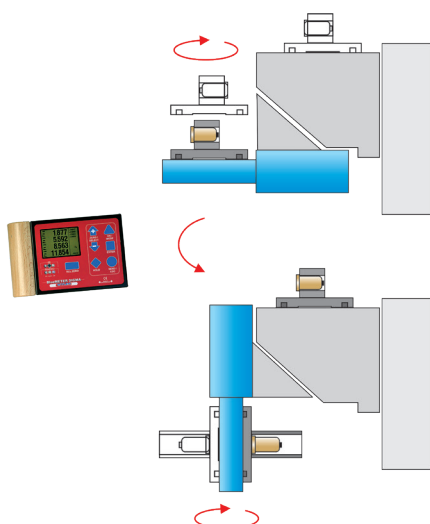
Subject:

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.

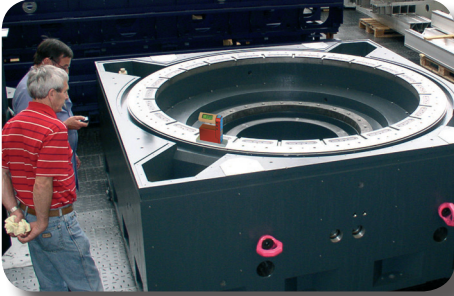
Measuring task:

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.

LONG TERM MONITORING OF DAMS



Subject:

The requirements regarding long term monitoring of dams are continuously increasing: where it was sufficient earlier to carry out periodic measurements, today more and more permanent monitoring is required.

Measuring task / Goal:

The changes in inclination of a dam shall be monitored continuously.

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 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.

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 wharf, the inclination, or heeling, should be measured during a loading test.

LARGE GRINDING MACHINE WITH FLAT GUIDEWAYS



Subject:

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 1.3 m 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.

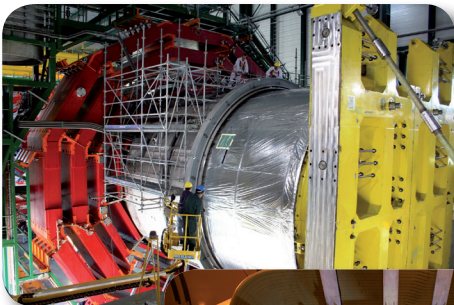
MONITORING OF A TRIPOD DURING THE ANCHORING PROCESS

Subject:

An offshore wind turbine requires a stable and exactly horizontal base. To achieve this, the Tripod, on which afterwards the wind turbine will be mounted, has to be monitored during the anchoring process.

Measuring task / Goal:

The position of the Tripod has to be monitored during the anchoring process with inclination sensors mounted at the upper end of the Tripod. The sensors have to withstand the high accelerations occurring during the ramming process. The measured data have to be transmitted wireless to the boat controlling the whole process.

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 SOLAR PANELS

Subject:

Solar panels have to be perfectly adjusted to the sun in order to ensure best possible performance.

Measuring task / Goal:

The inclination of each single solar panel has to be verified periodically. A measuring range of up to 60° is required.

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.

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

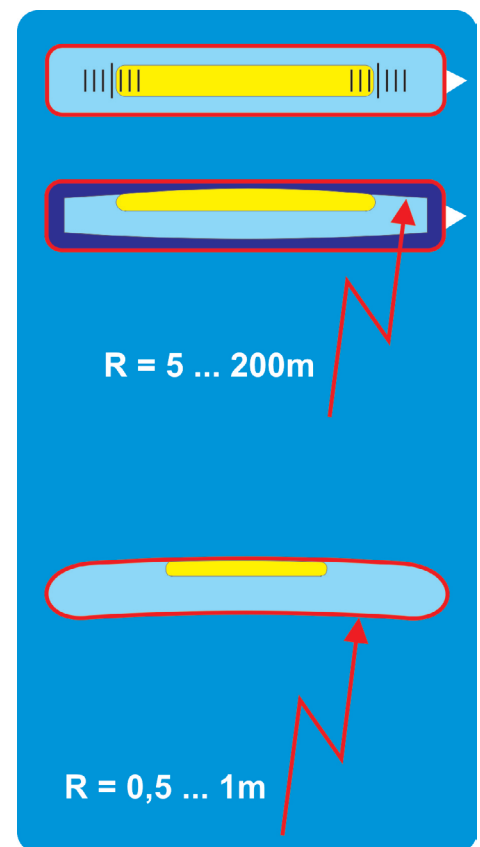
for measurements on shafts and spindles. In addition, the bases can be equipped with magnetic inserts.

Of greatest importance is the fact that the axis of the vial must be adjusted parallel to the base's contact surfaces. This is 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



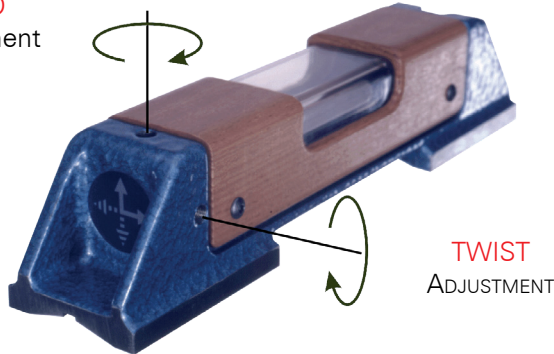
*Ground vial for
precision spirit levels,
radius = 5 ... 200 Meter
Height arc based on
80 mm = 160 ... 4 μm*



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).

ZERO
Adjustment



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

TWIST
ADJUSTMENT

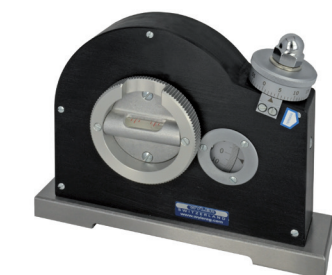
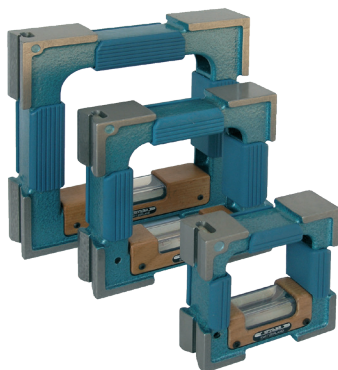
*Transversal vial
for twist control*

*Magnetic
inserts*

Vial

*Prismatic
measuring bases*

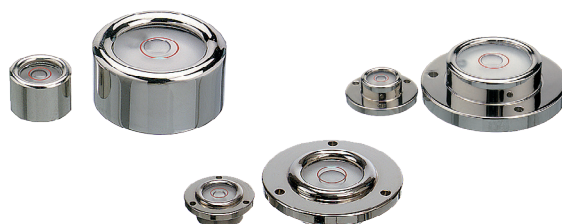
*Frame spirit levels for
small inclinations*



*Clinometers for large angles
up to $\pm 180^\circ$ inclinations*



*Horizontal spirit levels
for small inclinations*



*Circular spirit levels
in various sizes*

5.2 PRECISION SPIRIT LEVELS AND CIRCULAR SPIRIT LEVELS

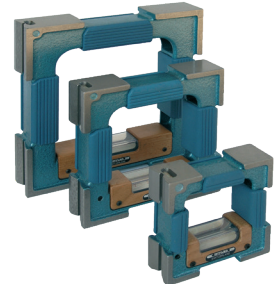
Magnetic Spirit Level No. 48 SPIRIT



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 grooves 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

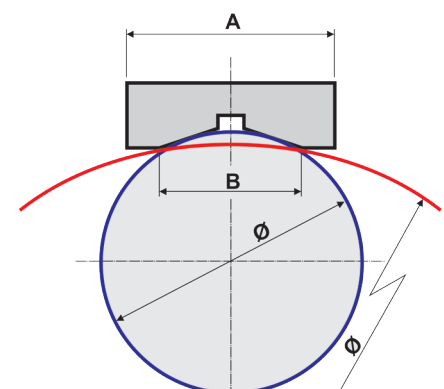


Used for measuring the flatness of surfaces, inclinations, taper or conicity, with prismatic measuring base of steel, hardened and ground, vial sensitivity 0,02 mm/m, with insulating handles.

Sensitivity:
0.02 mm/m

Standard dimensions of prismatic bases for shafts measurement

Length of base			Measurable shaft diameter
L	A	B	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

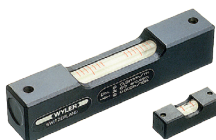
Tabular Spirit Level No. 59



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

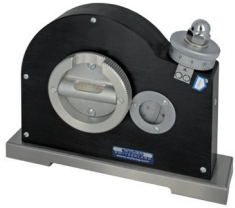


For fitting on to machines, apparatus, etc.

Sensitivities: various

5.3 CLINOMETER

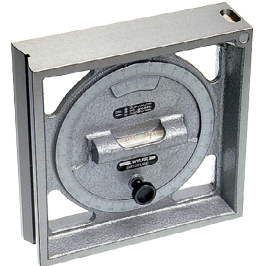
Clinometer Nr. 80



Instrument for measuring angular deviation accurately, with circular scale 2×180 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 2×180 deg., vernier for reading at 3 Arcmin.

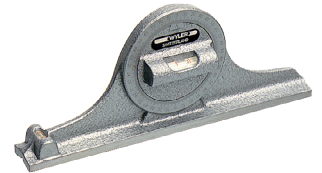
Vial sensitivity: 0.3 mm/m

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 2×180 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 family and for ZEROTRONIC sensors)

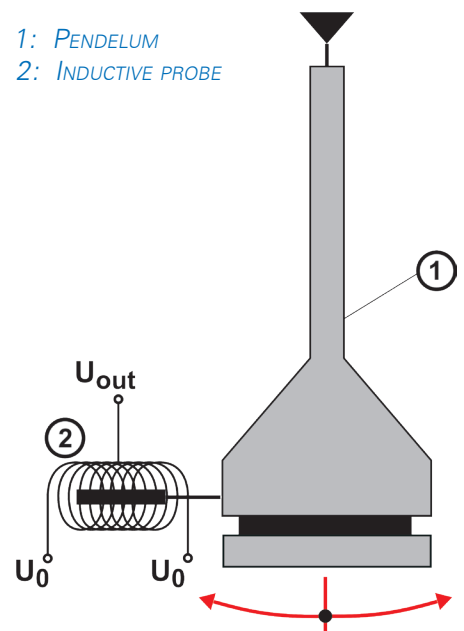
6.1 MEASURING INSTRUMENT WITH INDUCTIVE MEASURING SYSTEM NIVELSWISS AND NIVELSWISS-D

6.1.1 INDUCTIVE MEASURING SYSTEMS

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



6.1.2 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:

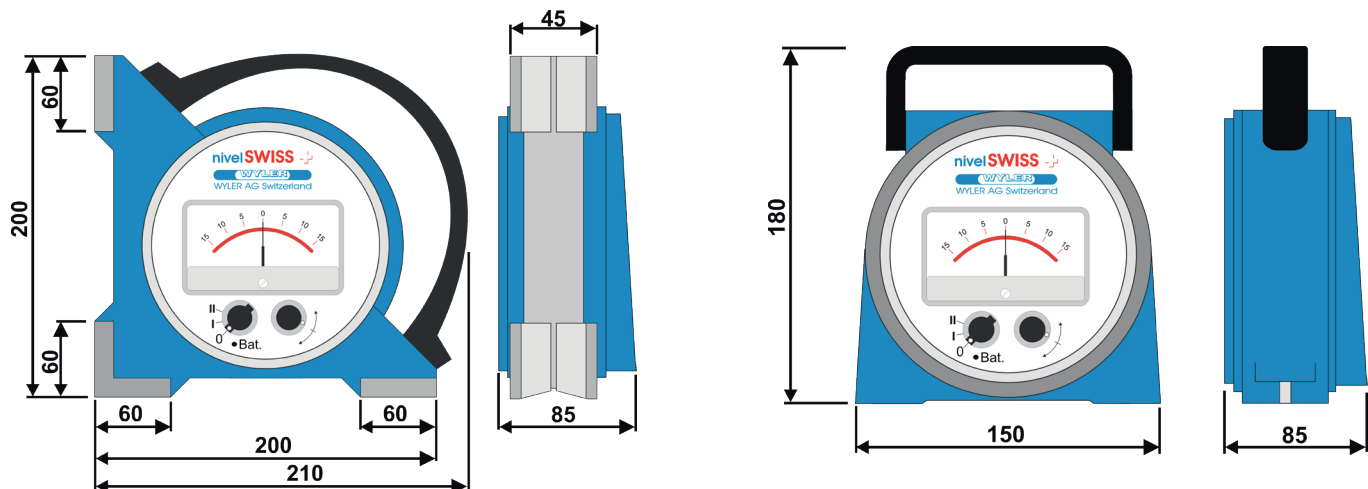
nivelSWISS 50-H HORIZONTAL VERSION

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 $\varnothing$ 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.



*Dimensions nivelSWISS
with horizontal and angular base*

TECHNICAL SPECIFICATIONS nivelSWISS classic		
	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 Sec	
Repeatability	1 µm/m	
up to ½ F.S. (DIN 2276)	max. 1% des MW / min. 0.001 mm/m	
from ½ F.S. to F.S. (DIN 2276)	max. 1% von (2*MW - 0.5*F.S.)	
Limits of error (DIN 2276/2)	M _W ≤ 0.5 M _E / max. 1 % M _W	
M _E = full-scale	M _W > 0.5 M _E / max. 0.01 (2 M _W - 0.5 M _E)	
M _W = measured value		

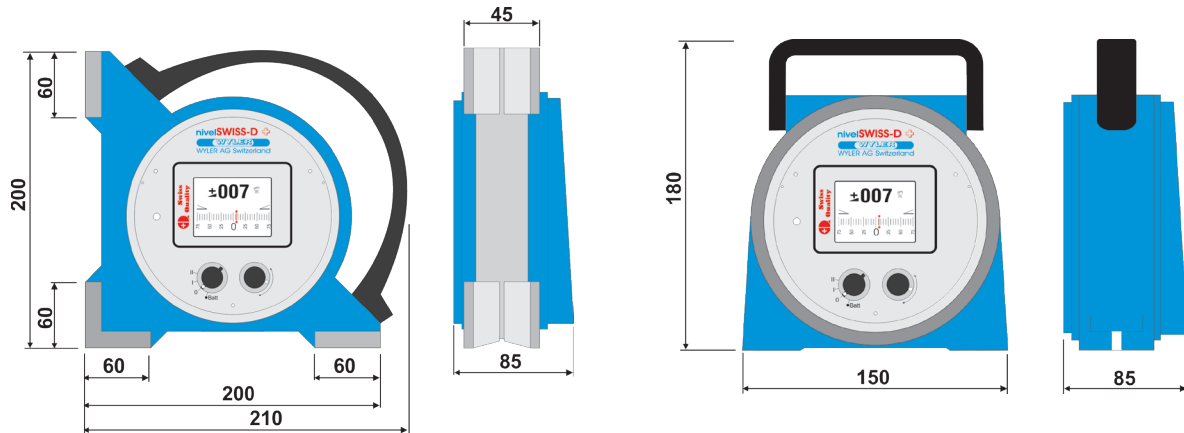
6.1.3 NIVELSWISS-D (DIGITAL SYSTEM)

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 evaluation 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.



*Dimensions nivelSWISS-D
with horizontal and angular base*

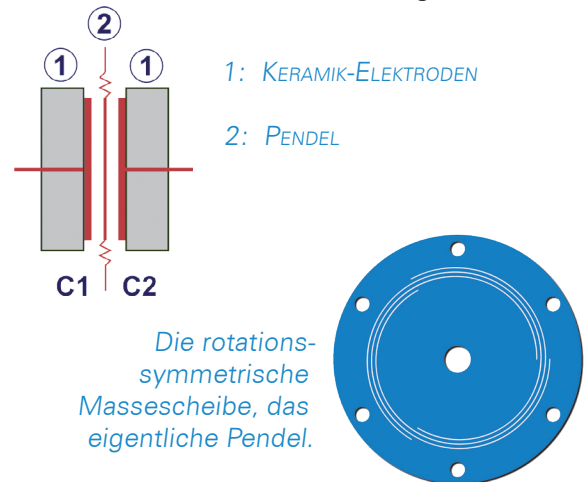
nivelSWISS-D TECHNICAL SPECIFICATIONS

	Bereich I	Bereich II
Range to choose	$\pm 0.750 \text{ mm/m}$ $\pm 150 \text{ arcsec}$	$\pm 0.150 \text{ mm/m}$ $\pm 30 \text{ arcsec}$
Sensitivity	0.005 mm/m 1 arcsec	0.001 mm/m 0.2 arcsec
Response time (DIN 2276/2)	<5 Sek (DIN 2256)	
Repeatability	$5 \mu\text{m/m}$	$1 \mu\text{m/m}$
Limits of error (DIN 2276/2)	$M_W \leq 0.5 M_E / \text{max. } 1 \% M_W$	
M_E = full-scale M_W = measured value	$M_W > 0.5 M_E / \text{max. } 0.01 (2 M_W - 0.5 M_E)$	

6.2 MEASURING INSTRUMENTS WITH CAPACITIVE MEASURING SYSTEM

6.2.1 MEASURING PRINCIPLE:

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**.

6.2.1.1 THE ANALOG MEASURING PRINCIPLE

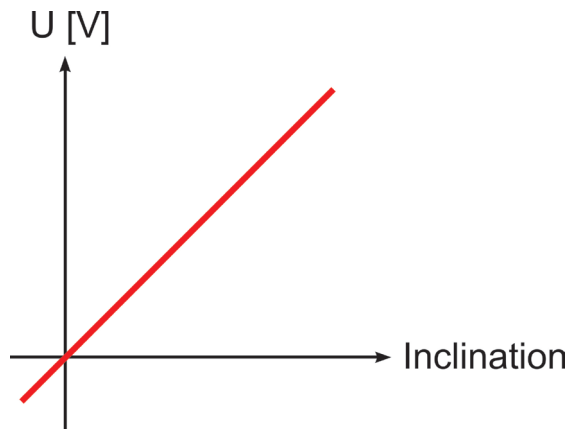
The measuring principle is used in handheld instruments such as the BlueLEVEL.

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]

6.2.1.2 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.

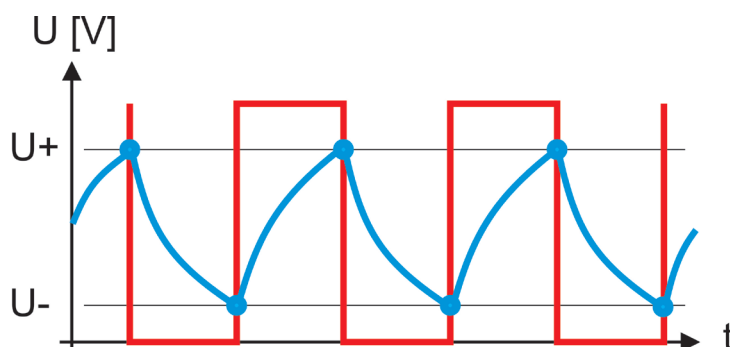
Advantages of the **digital measuring principle**:

- 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

Digital measuring principle



Measuring value of the system:

Quotient of frequencies f_1 and f_2

Output of the instrument:

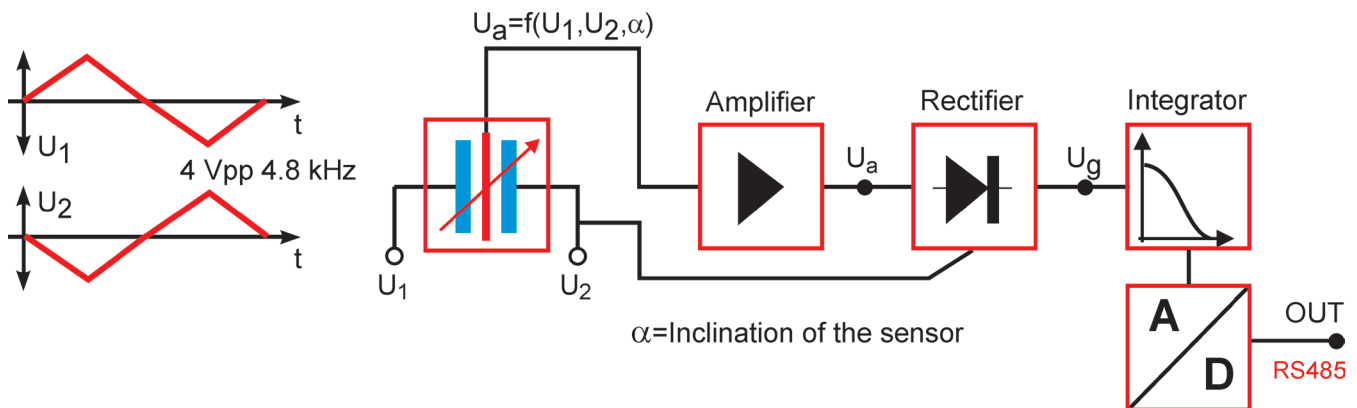
digital

Unit: Radian [Rad]

6.2.2 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.

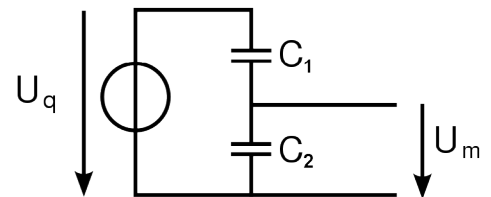
Simultaneously or alternatively, the analog signal is fed to an A / D converter and is available as a digital value in the WyBUS format at the RS 485-, or RS 232 output. The unit is Radian.



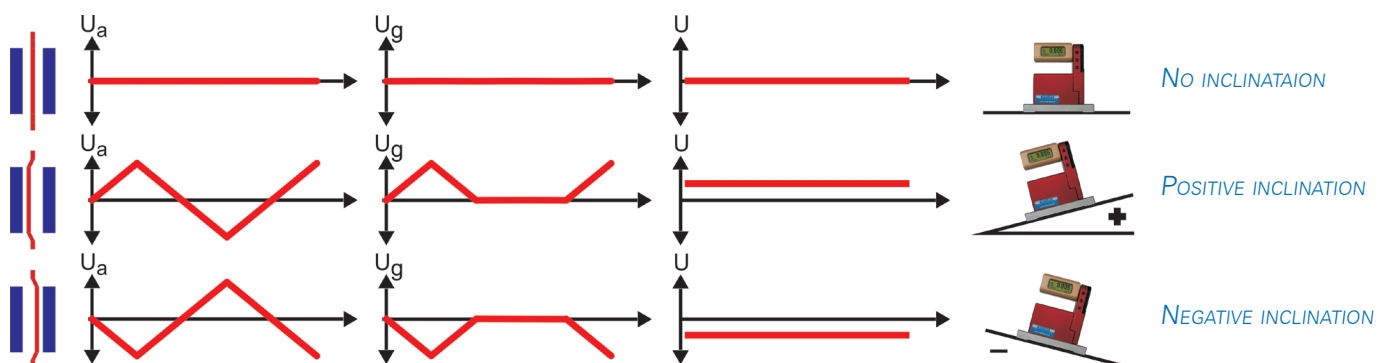
Schematic of an inclination measuring instrument with capacitive measuring system (BlueLEVEL + BlueLEVEL BASIC)

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

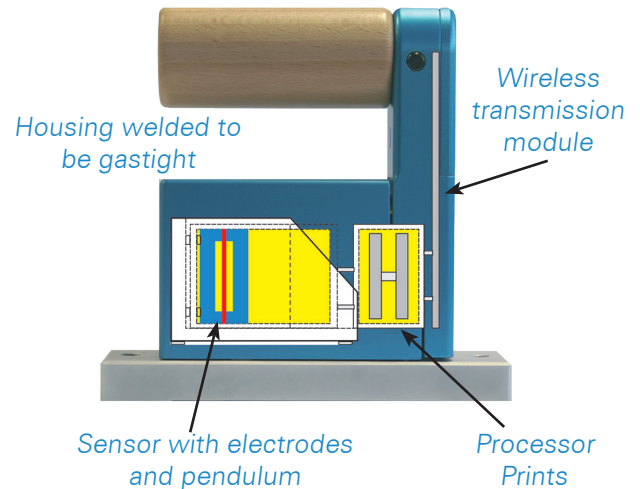


The figure below shows the function of the analog measuring system and the relationship between the deflection of the pendulum (mass disc) and the analog output signal.



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.

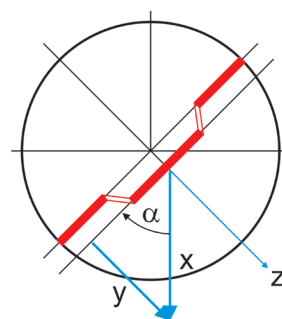
Thanks to this engineering advancement, the BlueLEVEL and BlueLEVEL BASIC can be used in very difficult climatic conditions.



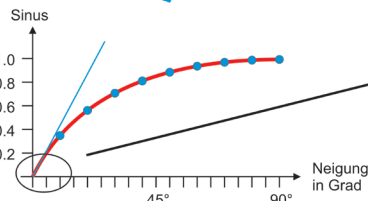
The picture shows a blue level with view of the sensor and the prints with wireless module

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.

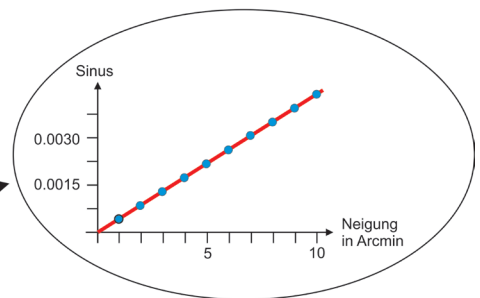
For larger inclinations the curve corresponds to the sine function and is no longer linear. Accordingly, devices with greater measuring range have to be calibrated with so-called calibration points.



X = Gravitation of pendulum
 $Y = f(\sin \alpha, X)$
 Z = Deflection of pendulum



Sine of angle in a range
up to 90 degrees



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

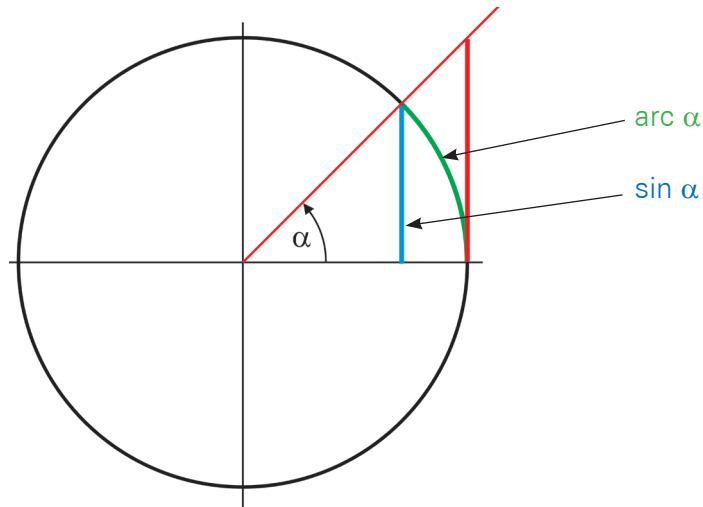
In measuring instruments with a smaller range, for example ± 1 degree, the pendulum has to be more sensitive to the slightest inclination in order to achieve optimal resolution. This sensitivity is achieved in this case by a thin membrane with a long spiral spring. For larger ranges, a thicker pendulum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

Variable as a function of the measuring range:

- Thickness of the pendulum from 50 μm 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 $\mu\text{m}/\text{m}$: approx. **10 nm**



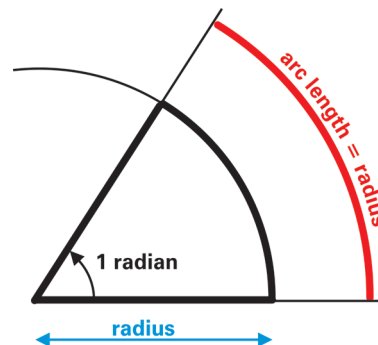
	$\sin \alpha$	$\tan \alpha$	$\text{arc } \alpha$
$\alpha = 0.5^\circ$	0.0087266	0.0087269	0.0087266
$\alpha = 45^\circ$	0.70711	1	0.78540

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

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

Important:

$1 \mu\text{Rad} = 1 \mu\text{m/m}$
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

6.2.2.1 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 MINILEVELNT and LEVELTRONICNT. 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 $\mu\text{m}/\text{m}$** : Range $\pm 20 \text{ mm}/\text{m}$
 - BlueLEVEL **5 $\mu\text{m}/\text{m}$** : Range $\pm 100 \text{ mm}/\text{m}$
 - BlueLEVEL **10 $\mu\text{m}/\text{m}$** : Range $\pm 200 \text{ mm}/\text{m}$

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

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?

Justification for the use of an interface:

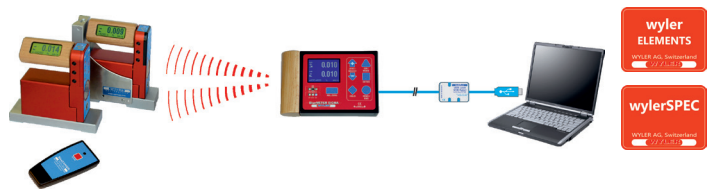
- There are different classes of Bluetooth systems, which directly affect the transmission distance. The Bluetooth components used in WYLER instruments guarantee a transfer of up to 100 meters
- With Bluetooth modules from a PC/laptop, only one device can be controlled. We need a module with multi-point 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

6.2.2.2 THE BLUESYSTEM BASIC / BLUELEVEL BASIC WITH BLUEMETER BASIC

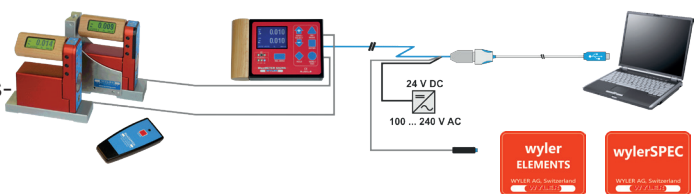
The BlueSYSTEM BASIC forms part of the BlueSYSTEM family, the latest generation of electronic inclination measuring instruments and systems. The main difference between the BlueLEVEL BASIC and the BlueLEVEL are as follows:

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.

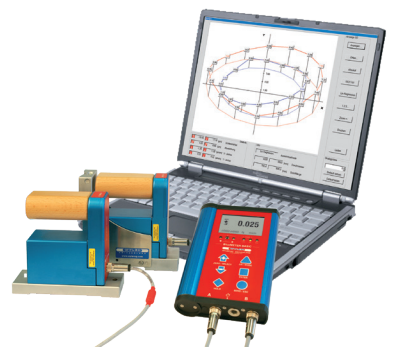
The instruments of the BlueSYSTEM BASIC family can be equipped with wireless data transmission as well.



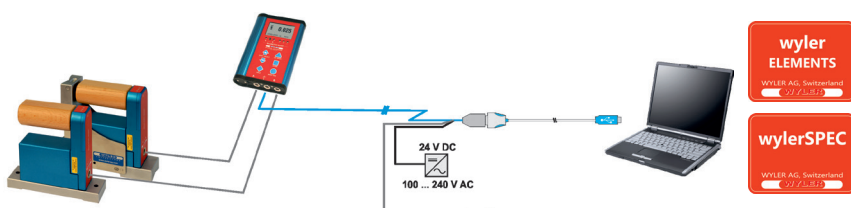
Set with BlueLEVEL and BlueMETER SIGMA with wireless data transmission



Set with BlueLEVEL and BlueMETER SIGMA connected by cables



BlueSYSTEM BASIC ENGINEERS SET in combination with a Laptop



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

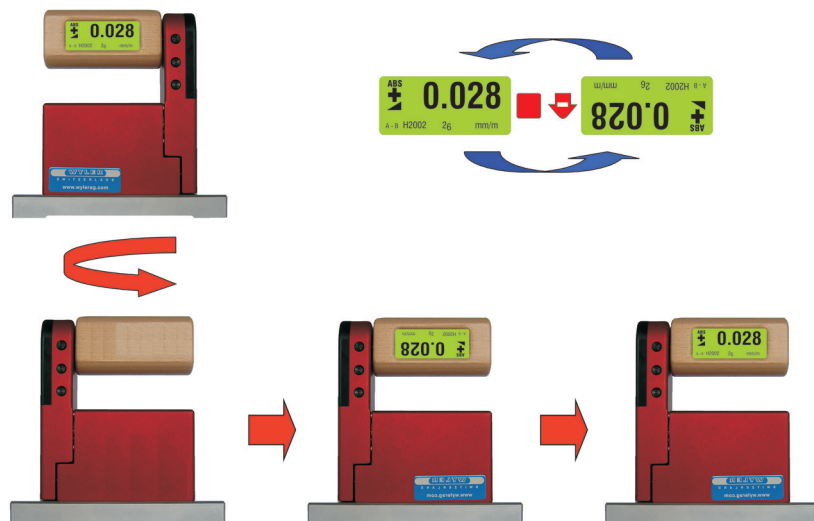


BlueLEVEL with flat and prismatic angular base and a nivelSWISS handle

BlueMETER SIGMA

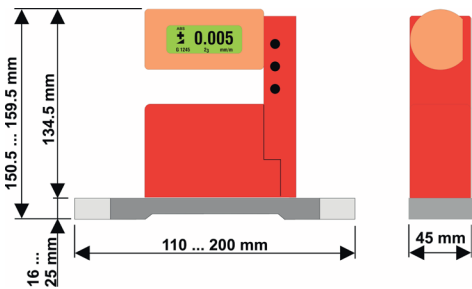


A special feature of the BlueLEVEL is **mirroring the display**. With this function in combination with the rotary handle bar, the values displayed can be perfectly seen from all possible angles. This function can be executed at all times, even when the instrument is remotely controlled by a BlueMETER.

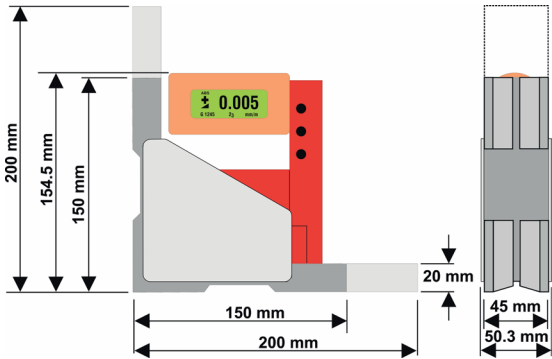


The measurement can be triggered by an infrared remote. The same applies in the case of the BlueSYSTEM BASIC.

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.

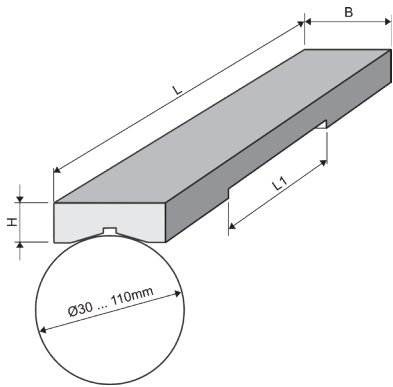


BlueLEVEL with horizontal base



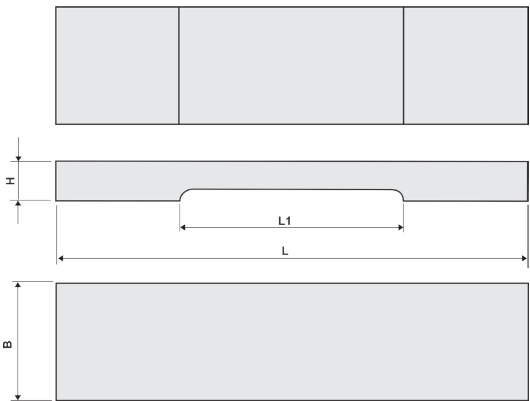
BlueLEVEL with angular base (cast iron only)

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



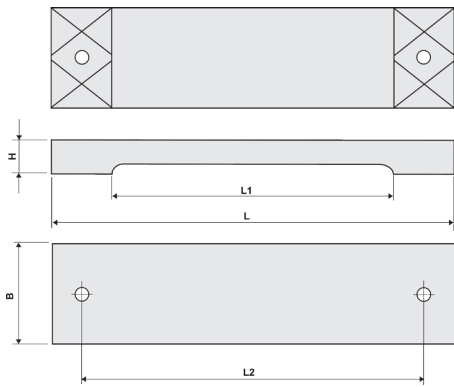
in [mm]

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



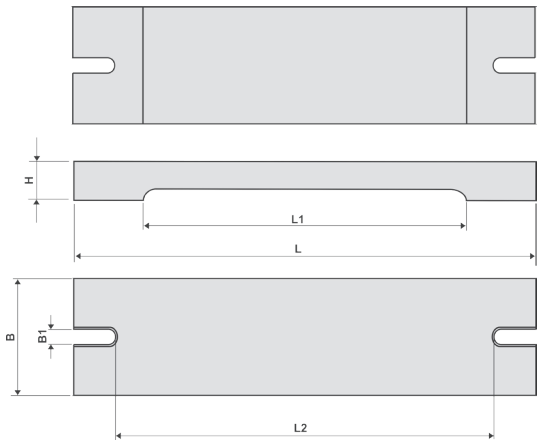
in [mm]

L	L1	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



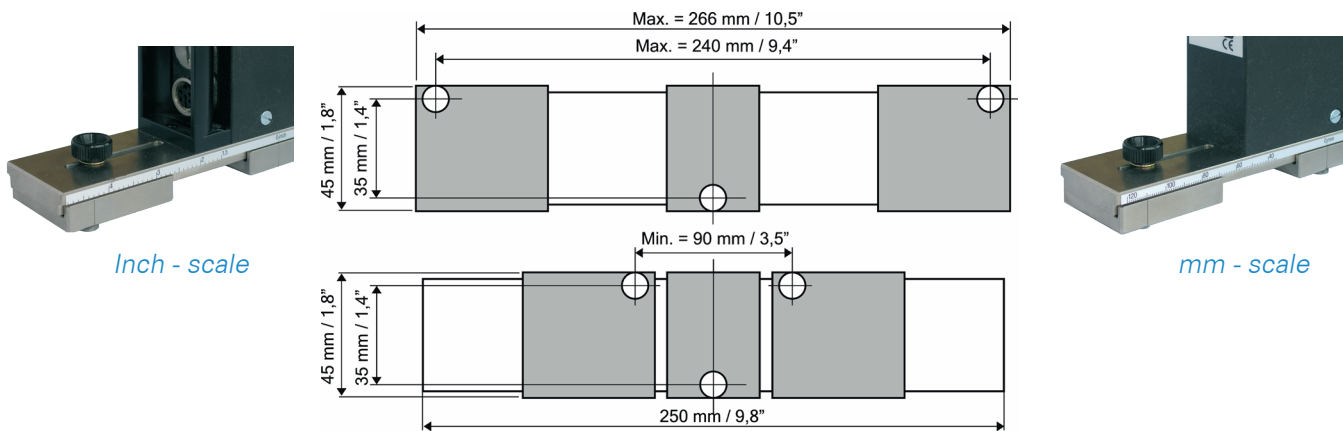
in [mm]

L	L1	L2	B	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	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


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	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 $\mu\text{m/m}$ 0.2 Arcsec	5 $\mu\text{m/m}$ 1 Arcsec	10 $\mu\text{m/m}$ 2 Arcsec
Display range	$\pm 20 \text{ mm/m}$	$\pm 100 \text{ mm/m}$	$\pm 200 \text{ mm/m}$
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 $\mu\text{m/m}$: max. 2 $\mu\text{m/m}$ up to 20000 $\mu\text{m/m}$: max. 20 $\mu\text{m/m}$	up to 10000 $\mu\text{m/m}$: max. 10 $\mu\text{m/m}$ up to 100000 $\mu\text{m/m}$: max. 100 $\mu\text{m/m}$	up to 20000 $\mu\text{m/m}$: max. 20 $\mu\text{m/m}$ up to 200000 $\mu\text{m/m}$: max. 200 $\mu\text{m/m}$
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 $\mu\text{m/m}$ 0.2 Arcsec	5 $\mu\text{m/m}$ 1 Arcsec	10 $\mu\text{m/m}$ 2 Arcsec
Display range	$\pm 10 \text{ mm/m}$	$\pm 50 \text{ mm/m}$	$\pm 100 \text{ mm/m}$
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 $\mu\text{m/m}$: max. 2 $\mu\text{m/m}$ up to 10000 $\mu\text{m/m}$: max. 15 $\mu\text{m/m}$	up to 10000 $\mu\text{m/m}$: max. 10 $\mu\text{m/m}$ up to 50000 $\mu\text{m/m}$: max. 75 $\mu\text{m/m}$	up to 20000 $\mu\text{m/m}$: max. 20 $\mu\text{m/m}$ up to 100000 $\mu\text{m/m}$: max. 150 $\mu\text{m/m}$

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 $\mu\text{m}/\text{m}$** : Range $\pm 20 \text{ mm}/\text{m}$
 - BlueLEVEL **5 $\mu\text{m}/\text{m}$** : Range $\pm 100 \text{ mm}/\text{m}$
 - BlueLEVEL **10 $\mu\text{m}/\text{m}$** : Range $\pm 200 \text{ mm}/\text{m}$
- 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*



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

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 $\mu\text{m}/\text{m}$** : range $\pm 10 \text{ mm}/\text{m}$
 - BlueLEVEL **5 $\mu\text{m}/\text{m}$** : range $\pm 50 \text{ mm}/\text{m}$
 - BlueLEVEL **10 $\mu\text{m}/\text{m}$** : range $\pm 100 \text{ mm}/\text{m}$

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 $\mu\text{m}/\text{m}$
- 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 $\mu\text{m}/\text{m}$ (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

6.2.2.3 Two-axis inclination measuring instrument BlueLEVEL-2D WITH DIGITAL MEASURING SYSTEM

The BlueLEVEL-2D is a high-precision and compact inclination measuring instrument for two axes. In spite of its small outer dimensions, the instrument contains two inclination sensors: one for the X axis, and one for the Y axis, together with a fully 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.



BlueLEVEL-2D has the following features:

- Rugged, rust-protected housing made of aluminium
- High precision bases with three inserts made of hardened steel Ø 20 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
- Wireless communication, based on Bluetooth technology
- The instrument is compatible with the full range of WYLER digital sensors
- Powered by standard 1.5 V batteries, rechargeable batteries or with main adapters
- The internal software allows a simple zero setting, using a reversal measurement
- Fulfills the strict CE- / FCC requirements (immunity / emission electromagnetic smog)
- Options:
 - External power supply 24 V
 - Cable to connect the instrument to a PC
 - Software to collect measuring data
 - Various attachable measuring bases on special request, like e.g. prismatic, varioBase-2D



Graphical 2D-display

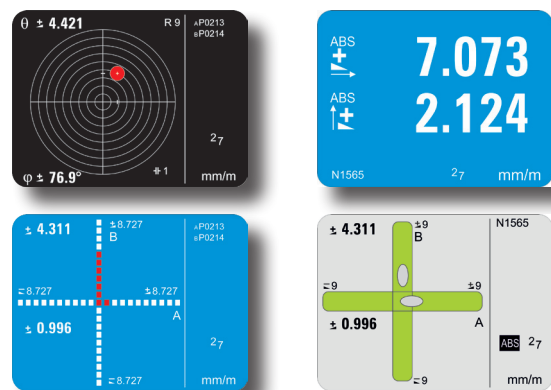
The 2D-display shows graphically the position of an object in space, respectively the change of its position and makes the information easily understandable.

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:

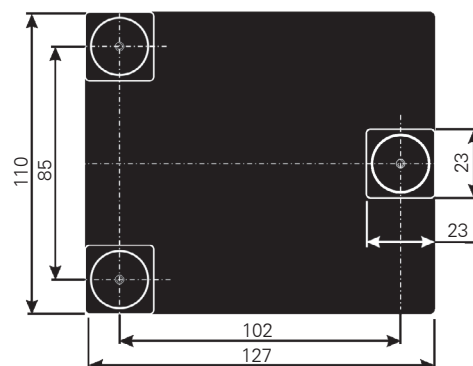
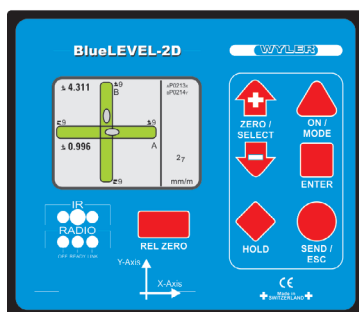
- Units
- Display of measuring range
- Type of display
- Filter settings



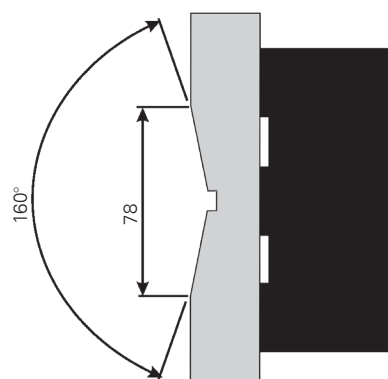
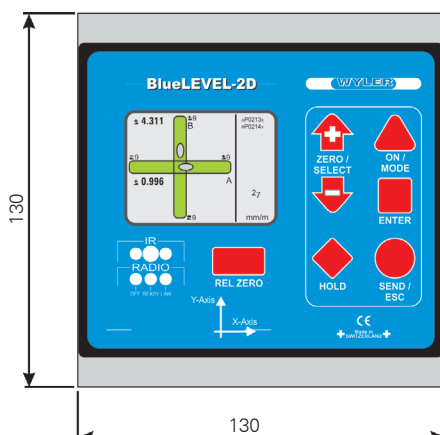
It is possible to send the measured data via an RS232 port to a PC/laptop and therewith to the WYLER software wylerSPEC, wylerELEMENTS, wylerPROFESSIONAL, wylerCHART, wylerINSERT and wylerDYNAM.

TECHNICAL SPECIFICATIONS BOTH AXIS		BLUELEVEL-2D
Sensitivity	0.001 mm/m 0.2 arcsec	0.005 mm/m 1 arcsec
Measuring range	±20 mm/m	±100 mm/m
Limits of error (DIN 2276/2)	$M_W < 0.5 M_E$ max. 1% M_W / min. 1 digit	
M_E = full-scale M_W = measured value	$M_W > 0.5 M_E$ max. 0.01 (2 M_W - 0.5 M_E)	
Temperature error / °C (Ø 10 °C) (DIN 2276/2)	$M_W \leq 0.1 M_E$ max. 0.002 mm/m max. 0.01 mm/m	
M_E = full-scale	$M_W > 0.1 M_E$ max. 0.02 mm/m max. 0.1 mm/m	
Twist error of Sensor X <-> Y	max. 0.010 mm/m	max. 0.050 mm/m
Response time (DIN 2276/2)	< 5 sec	
Digital output	RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps	
Batteries - size C Optional (rechargeable)	2 x 1.5 V Alkaline, 2 x 1.2 V NiMH	
External power supply	+ 5 V DC (USB) 24 V DC	
Operating temperature	0 ... + 40 °C	
Radio transmission (Bluetooth®) frequency	ISM Band / 2,4000 ... 2,4835 GHz	
CE conformity: Meets emission and immunity requirements		

DIMENSIONS OF THE BLUELEVEL-2D



3 inserts made of hardened steel Ø 20 mm with one M4 thread each



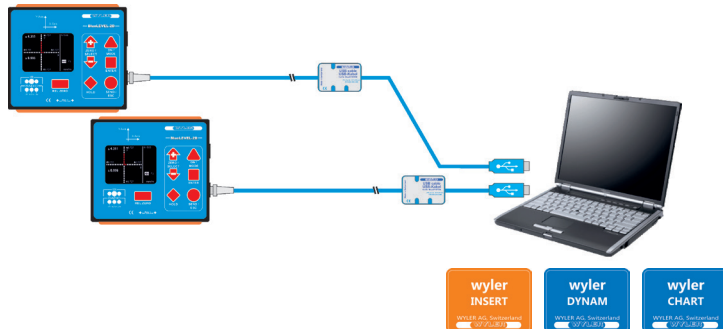
Primatic base made of **cast iron** for shaft Ø80 ... 370 mm

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

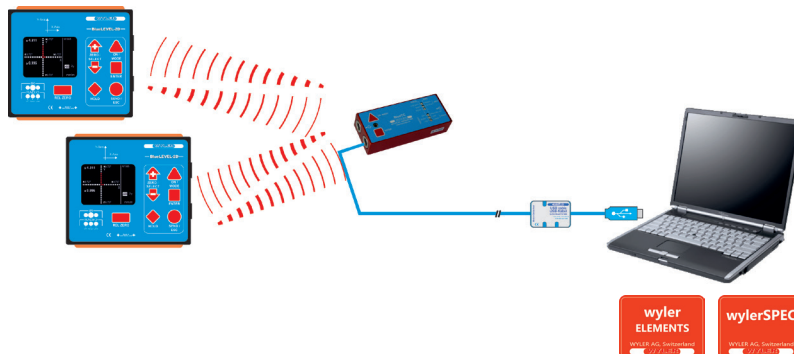
POSSIBLE CONFIGURATIONS WITH BLUELEVEL-2D (EXAMPLES)



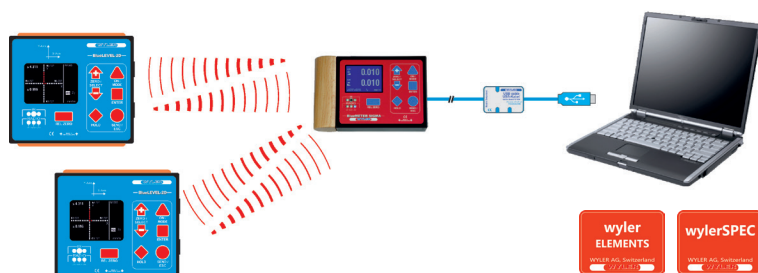
The data from the BlueLEVEL-2D can be transmitted to a BlueMETER SIGMA.



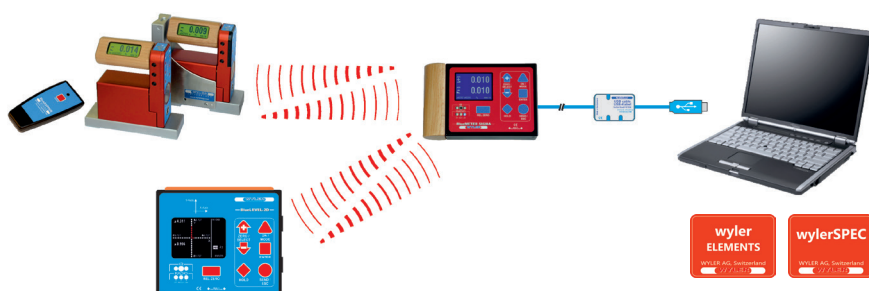
Two BlueLEVEL-2D connected to a laptop with USB cables allowing simultaneous differential measurement in 2 directions. The instruments are powered from the USB ports.



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. The BlueMETER SIGMA is powered from the USB port.



One BlueLEVEL-2D and two BlueLEVELS connected via Bluetooth to a BlueMETER SIGMA and to a laptop. The BlueMETER SIGMA is powered from the USB port.

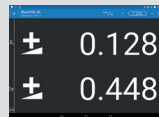


The app reads the data from **ONE** BlueLEVEL-2D, when you need to read your values from a distance or without a direct line of sight to the display, e.g.

- alignment of bigger machine parts, machines and objects
- Analyse of pitch and roll movements

Link: <https://play.google.com/store/apps/details?id=com.wylerag.application.blueLevel2D>

Display types



- Numbers for X- and Y-axis



- Vials or needles (zoomable scale) for X- and Y-axis



- Circular Spirit Level (zoomable scale) displaying polar coordinates
- LED Cross (zoomable scale) for X- and Y-axis

mm/m
° ' ''
"/10"
"/12"

Units

Functions

- REL zero setting of the axis-values
- Reactivate the ABS offset correction value stored in the instrument

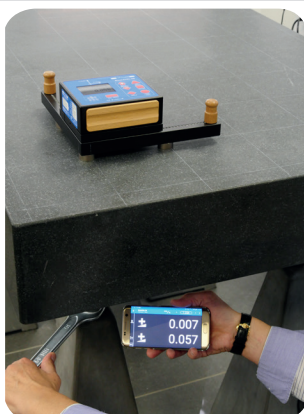
Requirements

- Android device with Android 3.0 or above
- BlueLEVEL-2D with integrated Bluetooth
- The BlueLEVEL-2D app is free of charge



Outdoor smartphone

- with preinstalled BlueLEVEL-2D APP
- P/N 016-006-001



6.3 APPLICATION SOFTWARE

6.3.1 SOFTWARE WYLERSPEC

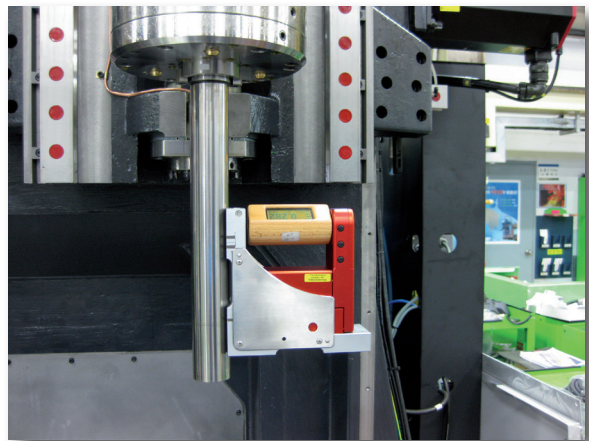
The software **wylerSPEC** software stands out through:

- User friendliness
- Straightforward interpretation of results
- Adaptability to your measuring tasks
- Modular design
- Efficient – time can be saved thanks to simultaneous measurements of multiple variances
- Integration of laser interferometers and autocollimators

Efficient measurement of machine tools:

- for increasing quality requirements
- for high-precision machines

For more than 30 years, WYLER AG has been supplying software to execute this very task easily, quickly, and precisely.



The **wylerSPEC software** replaces our LEVELSOFT PRO and MT-SOFT software packages. Thanks to its user-friendliness and informative display of readings, it is even easier to set up, calibrate, and measure machines.

The integration of laser interferometers and autocollimators makes it possible to record all the desired parameters of a machine with a single software solution.

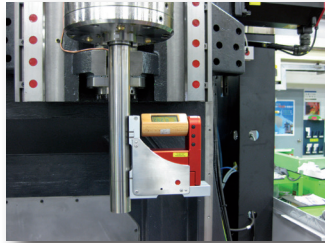


wylerSPEC – the ideal software for assessing your machines

Machine beds
Guide ways



Shafts
Rotating machine elements



Roll, pitch
and yaw

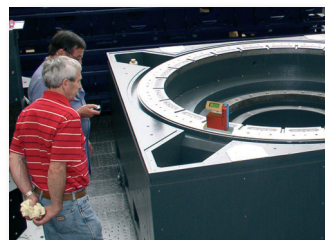


wylerSPEC

Straightness
Parallelism
Flatness



Circular horizontal paths

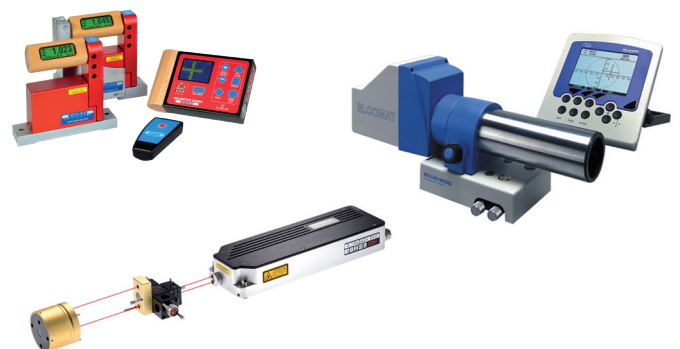


Coplanarity
Flatness of
surfaces



Universal:

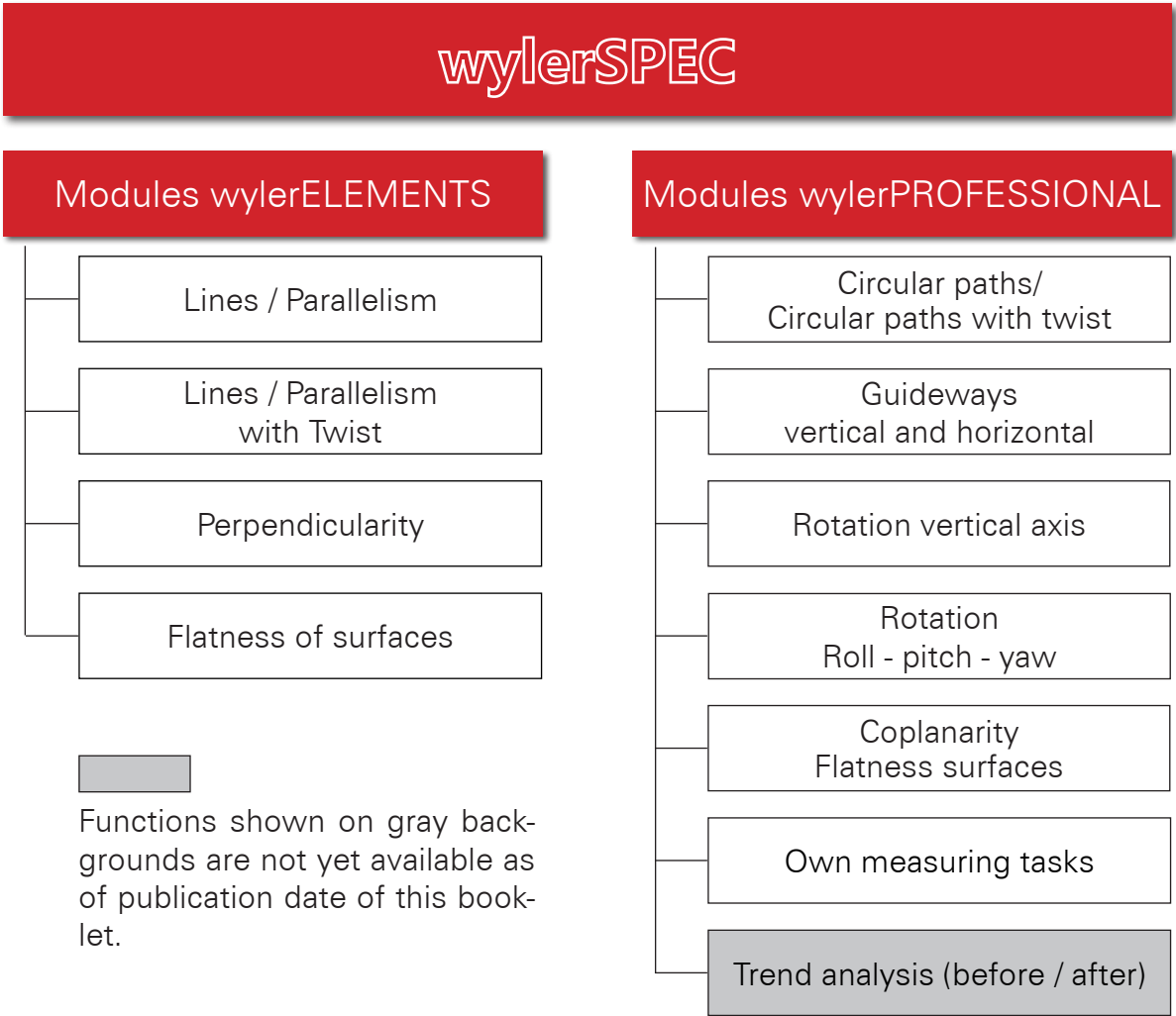
wylerSPEC makes it possible to input measurement readings not only from WYLER inclination measuring instruments tools, but also from laser interferometers and autocollimators.



Fingerprint:

wylerSPEC is superbly suited to creating a fingerprint of your machines. Any errors are detected and eliminated in a timely fashion.





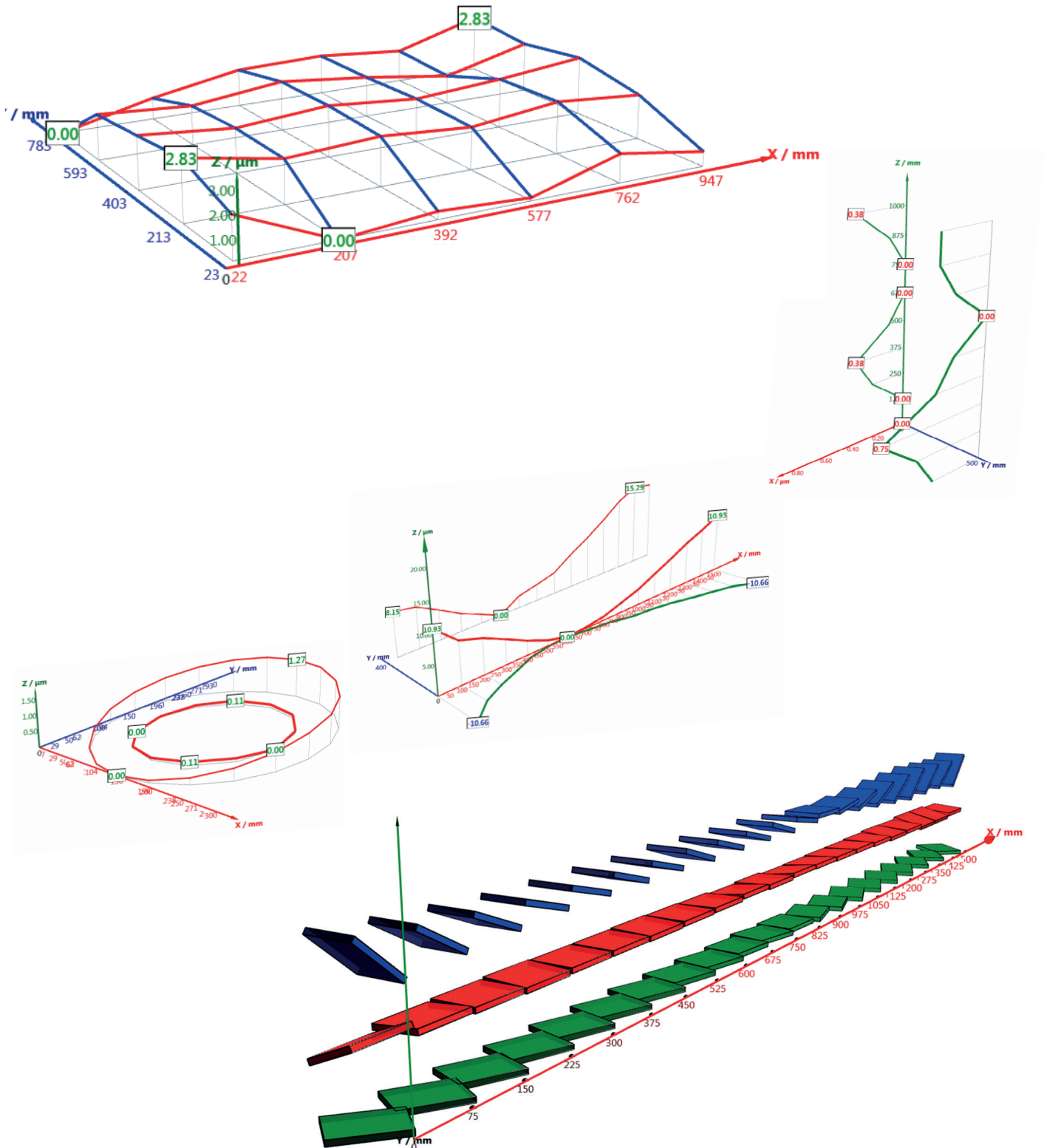
wylerSPEC adapts to your needs: You select the modules that you need in order to conduct your measuring tasks. The individual modules are centralized in **easy-to-use packages**.

Clear and self-explanatory measurement results

Measurement parameters can be modified according to the measurement in question:

- Choice of reference
- Choice of reporting method: absolute, endpoint, regression, and ISO 1101

Unrestricted rotation of representation in space

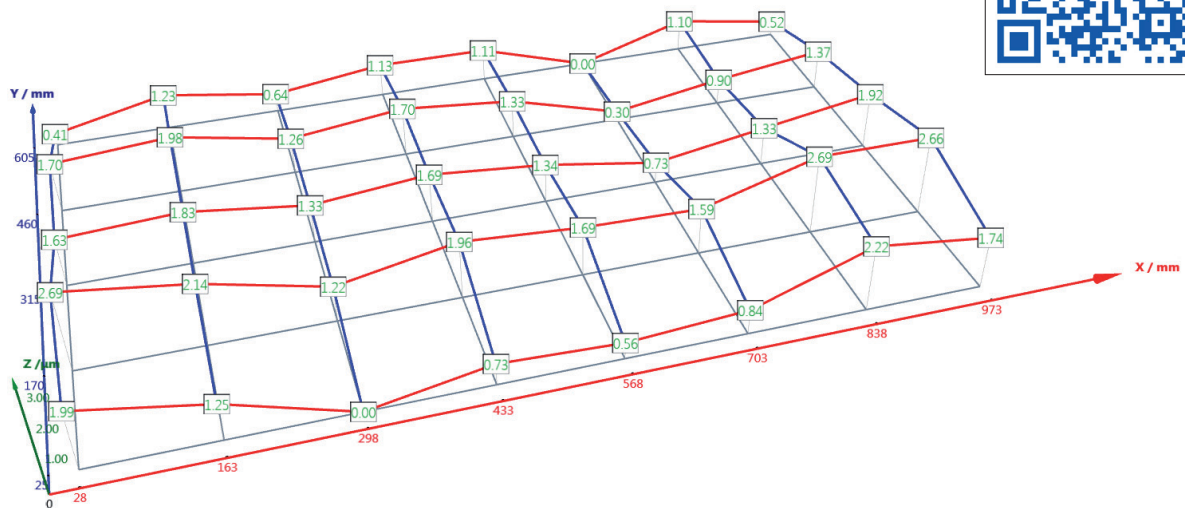


Measurement of flatness with BlueLEVEL-2D and wylerSPEC – save up to 50% of time



The wylerSPEC software makes it possible to utilize the full functionality of the BlueLEVEL-2D: The measurement values along the X and Y axes are read out simultaneously.

It is thus possible to reduce the time spent on the measurement of a setting and measuring plate by up to 50%.



The perfect pair for measuring flatness:

The bidirectional inclination measuring device BlueLEVEL-2D and the baseline vario-BASE-2D for simultaneous measurement of the longitudinal and lateral axis in a grid.

6.3.2 MODULES SOFTWARE WYLERSPEC

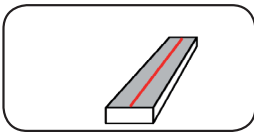
GEOMETRY

WYLERSPEC

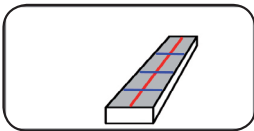
The package wylerSPEC includes all moduls of wylerELEMENTS, wylerPROFESSIONAL and completes the functionality with customer specific measurements and trend analysis.



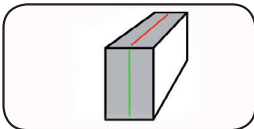
MODULE 1 - LINE



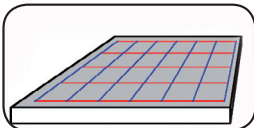
MODULE 2 - LINE WITH TWIST



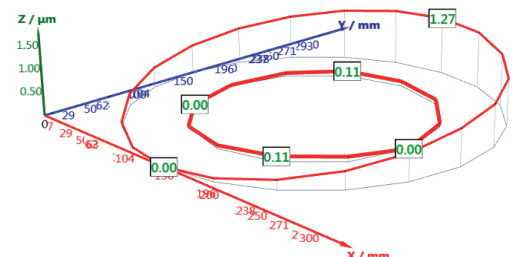
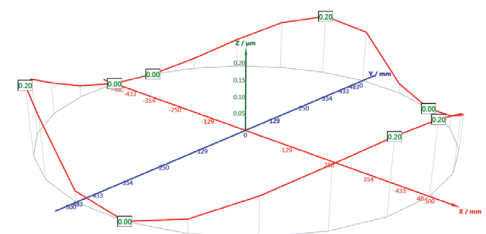
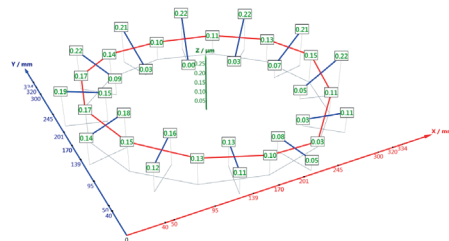
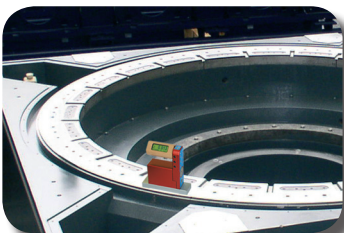
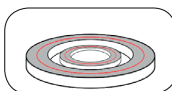
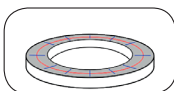
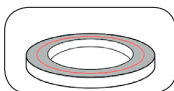
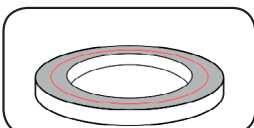
MODULE 3 - PERPENDICULARITY

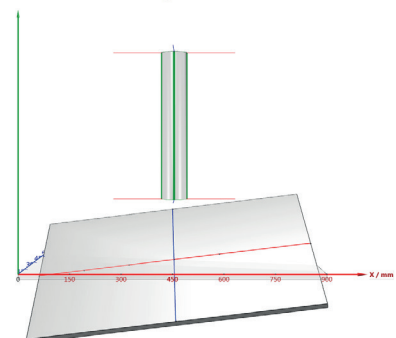
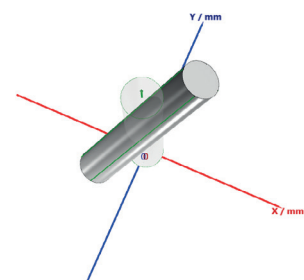
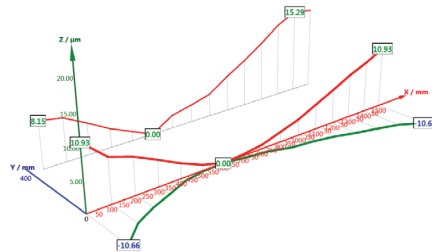
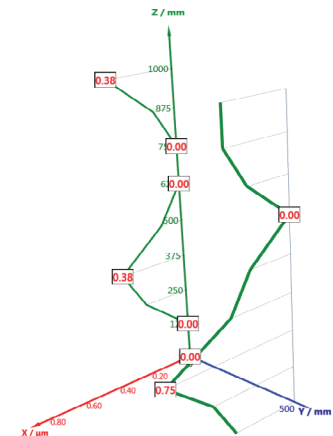
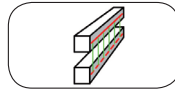


MODULE 4 - FLATNESS

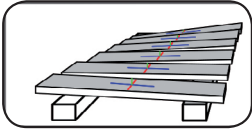


MODULE 5 - CIRCLES

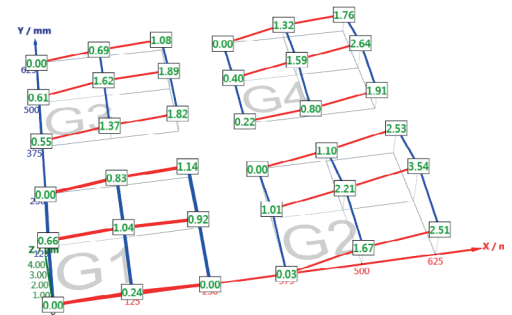
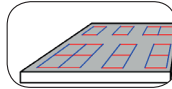
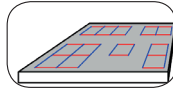
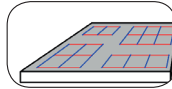
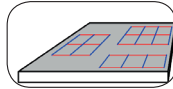
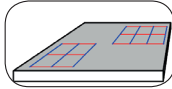
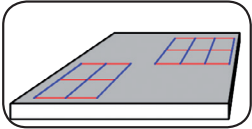




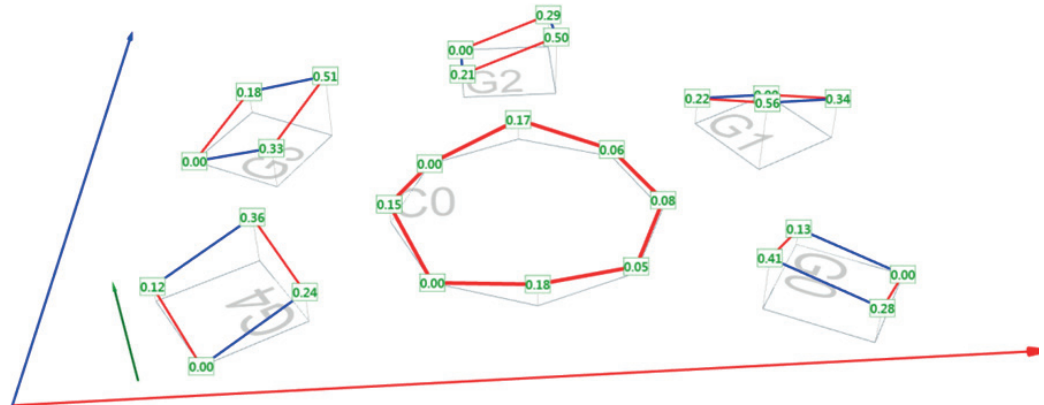
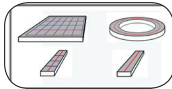
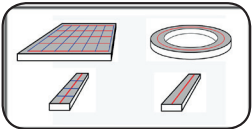
MODULE 8 - ROTATION



MODULE 9 - COPLANARITY OF AREAS



MODULE 10 – OWN MEASURING FIGURES



MODULE 11 – TREND ANALYSIS

Two measurements can be laid over top of each other for comparison.

Analysis of a series of measurements:

For the purpose of trend analysis as well, the curves from a series of measurements can be laid atop each other in order to assess how the shape of the machine has changed over time



wylerSPEC WYLER AG, Switzerland 024-SPEC	Licence	P/N Art. Nr.	Module Modul										
			1	2	3	4	5	6	7	8	9	10	11
wylerSPEC	First Licence	024-SPEC											
wylerSPEC L2	Second Licence	024-SPEC-L2											TREND
wylerSPEC Up (any MT-SOFT)	Software upgrade	024-SPEC-UP											
wylerSPEC Up-F (wylerPROFESSIONAL)	Function upgrade	024-SPEC-UP-F											TREND

Scope of delivery:
Software per download from our homepage www.wylerag.com
USB-Dongle as licence key (for new licences, where necessary)

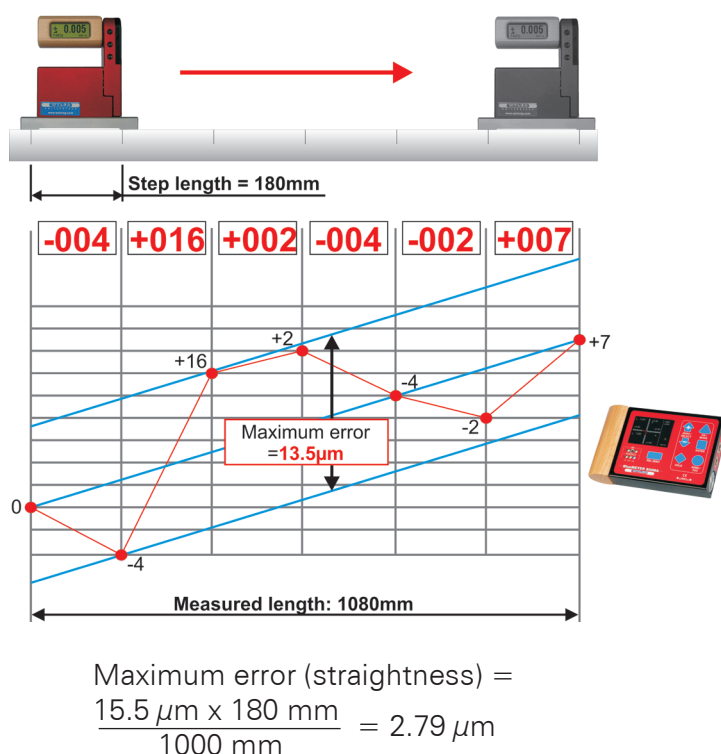
System requirements:
Microsoft Windows WIN 7 / WIN 8 / WIN 10
Optimized for resolution 1920 x 1080 pixel

6.4 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)		

6.4.1 THE TERMS ARE EXPLAINED IN MORE DETAIL WITH THE AID OF A LINE MEASUREMENT BY HAND



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.

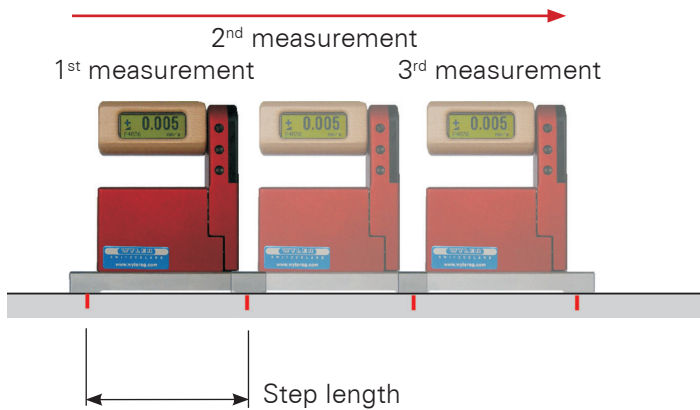
For the measurement it is now important that

- 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 $\mu\text{m}/\text{m}$. 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.

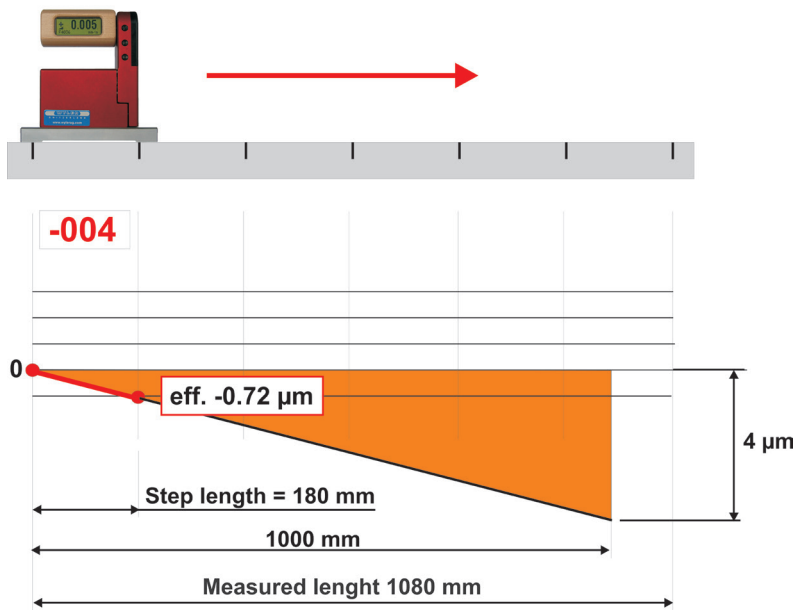
6.4.2 COMMENTS ON STEP LENGTH AND OVERLAP OF MEASUREMENTS



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 $-4 \mu\text{m/m}$. This corresponds to a height difference of $-4 \mu\text{m}$ relative to a base length of 1000 mm.

Relative to a base length of 180 mm, the height difference corresponds to $-0.72 \mu\text{m}$ 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)

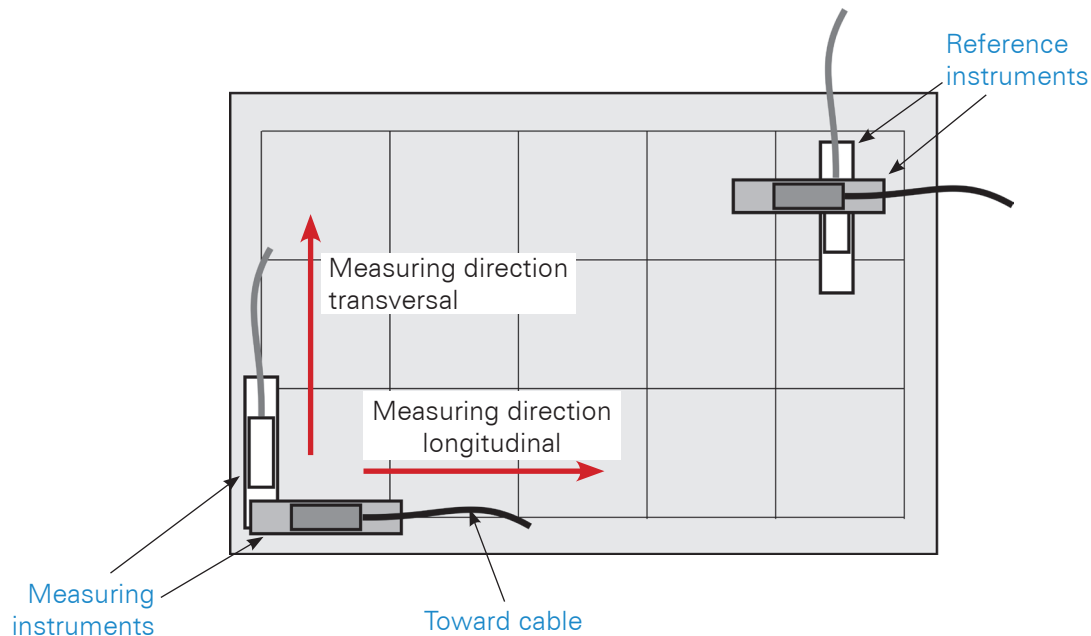
If these criteria, or conditions are not met, this affects the **measurement uncertainty**. **The more accurate the measurement should be, the more time must be given to preparation and measurement.**

6.4.3 FLATNESS MEASUREMENT / FURTHER PRINCIPLES FOR MEASURING INCLINATIONS

MEASURING DIRECTION

To ensure accurate measurements, it is important to:

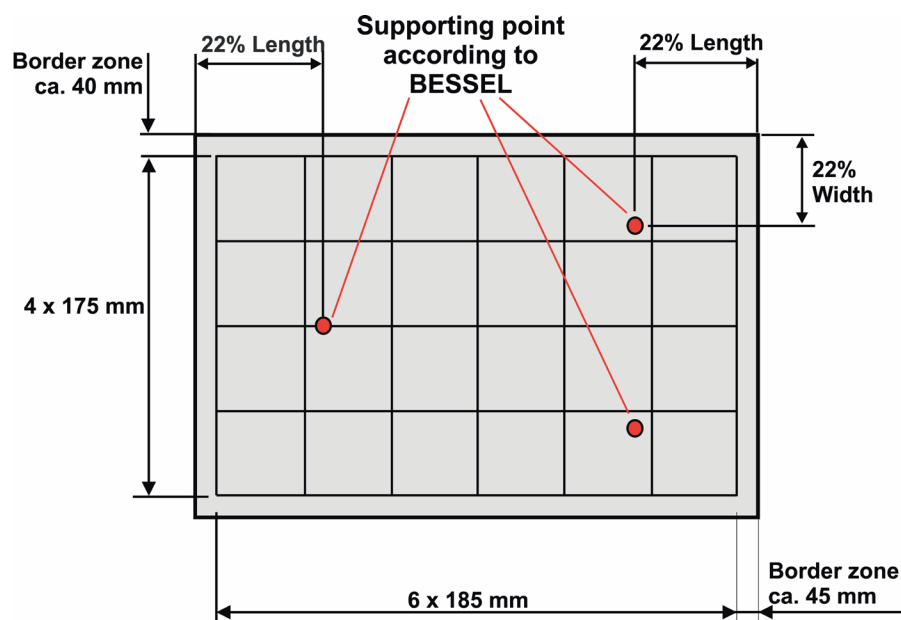
- Always move the instrument toward the cable from left to right or from front to back
- Touch the instruments only by using the handle (temperature)



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.



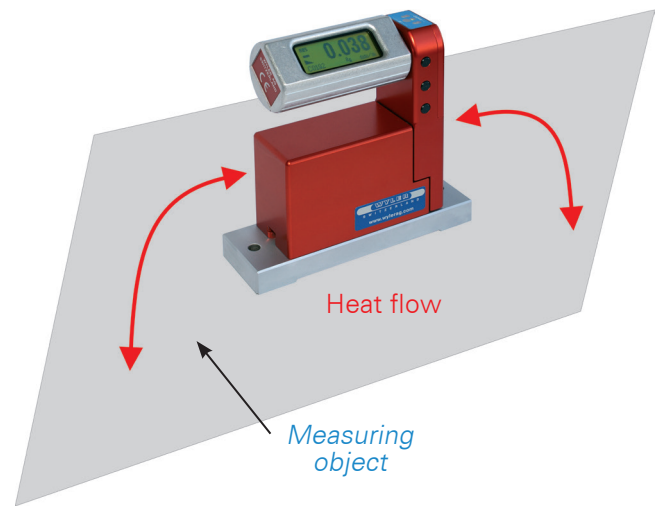
6.4.4 INFLUENCE DUE TO THE TEMPERATURE DIFFERENCES BETWEEN THE INSTRUMENT AND THE OBJECT TO BE MEASURED

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)

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

- 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 ($5.6 \cdot 10^{-6}$ [m/°K])
 L : Length of the plate (m)
 B : Thickness of the plate (m)

6.4.5 CLOSURE ERROR CORRECTION ACCORDING TO PHILIPS AND ALIGNMENT METHOD ACCORDING TO ISO 1101

Introduction to the closure error correction according to "PHILIPS"

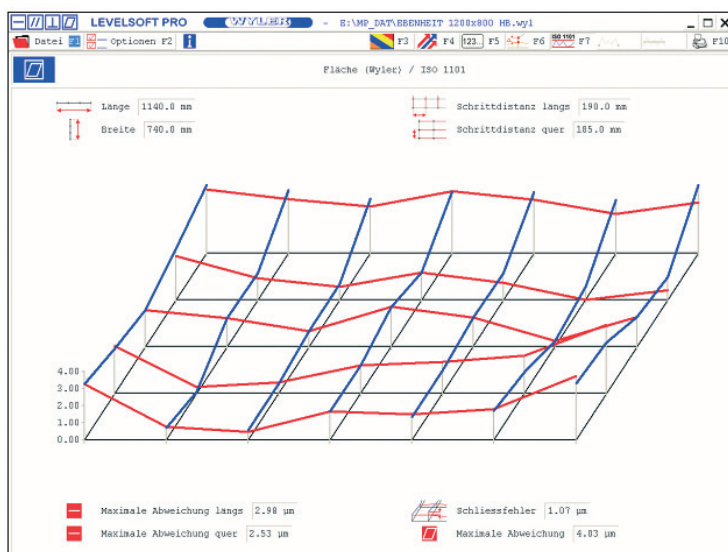
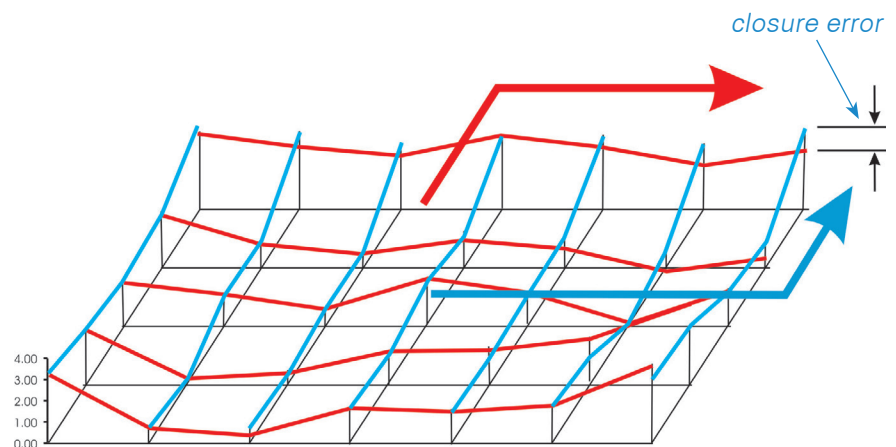
The closure error correction according to PHILIPS is used in the WYLER grid flatness measuring method. At the end of a measurement, the result (flatness of a surface) can be displayed in two versions:

- 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).

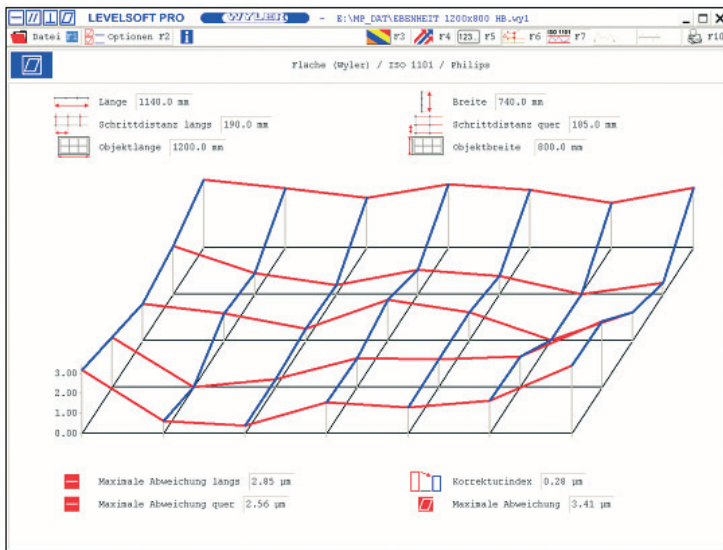


Display of a flatness measurement without correction of the closure error according to PHILIPS

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**



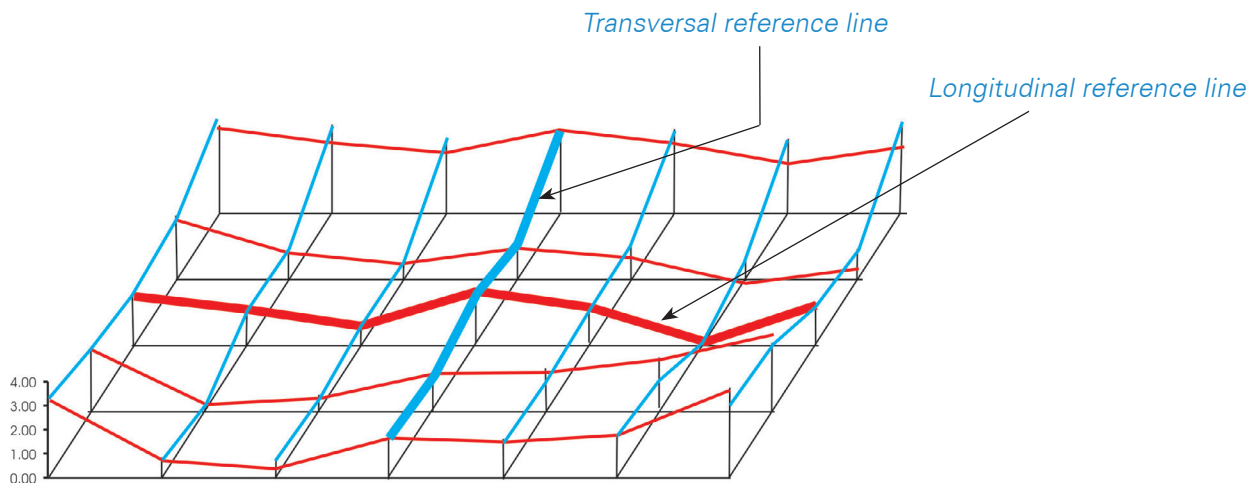
Display of a flatness measurement with correction of the closure error according to PHILIPS

Remarks regarding closure error correction:

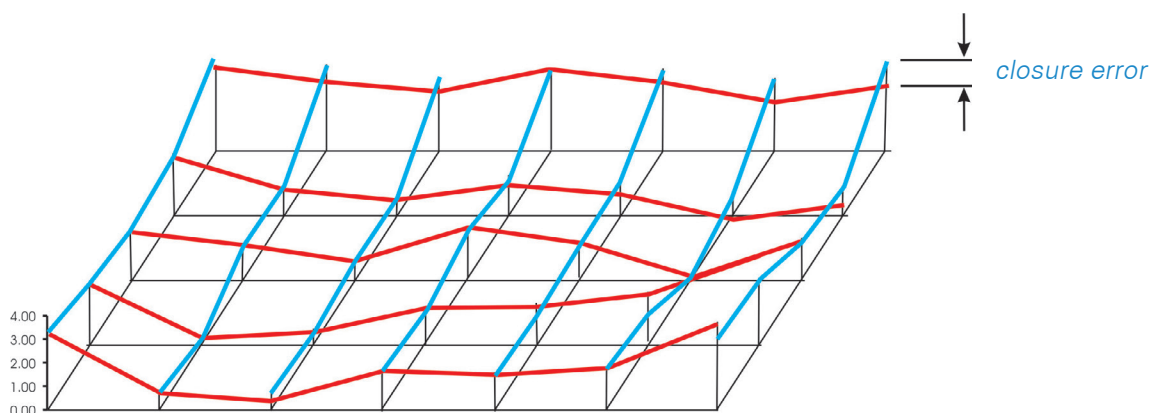
- After finishing a measurement, the display of the grid without correction of the closure error must be consulted. The closure error is an important indicator of the quality of the measurement and the measuring uncertainty.
- Normally the closure error should not exceed 20% to 25% of the maximum error.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

6.4.6 CLOSURE ERROR / ALIGNMENT METHOD ACCORDING TO ISO1101

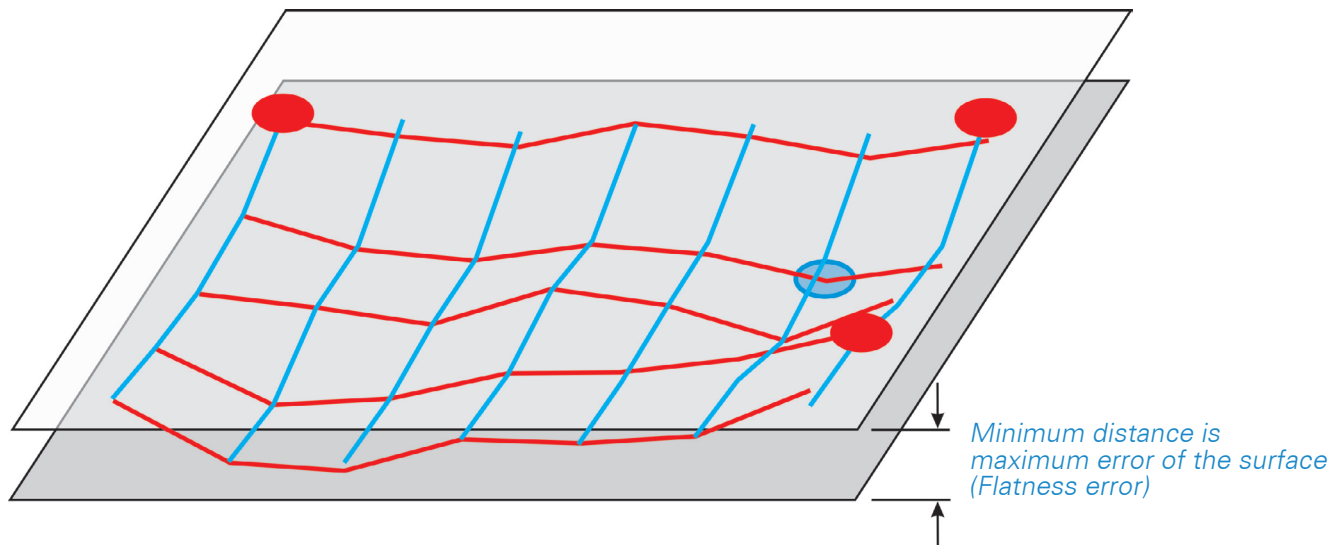
- The angular relationship of all measurements taken in the longitudinal and the transversal direction must remain unchanged.
- The lines in the centre of the longitudinal and the transversal directions are used as reference line. Should the number of lines in a direction be even, the line closer to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

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

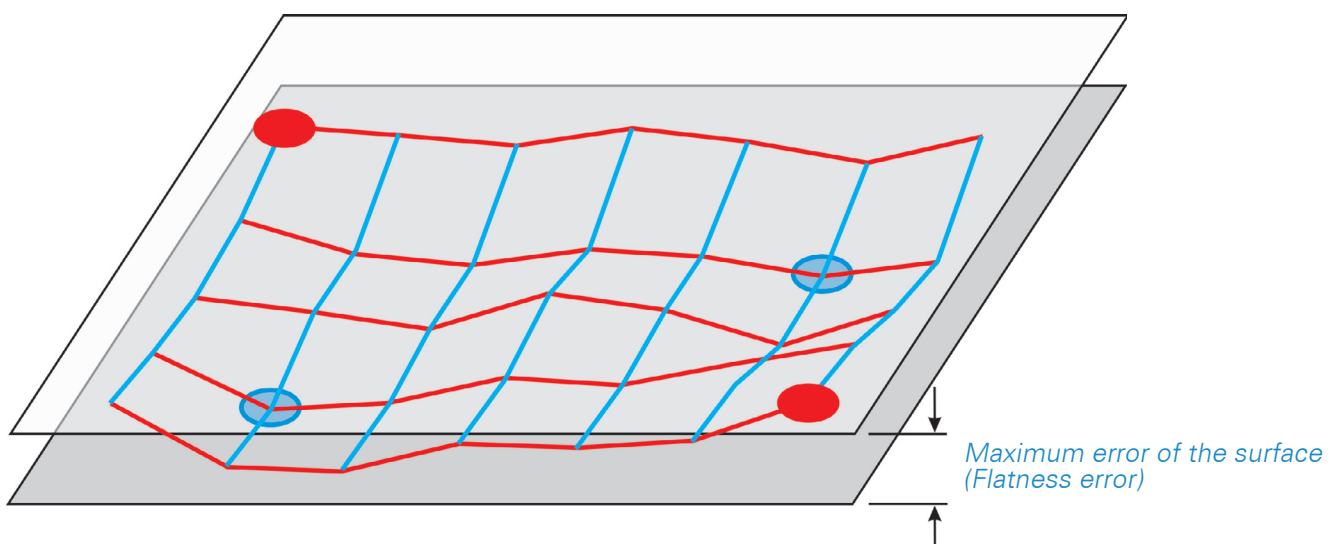
Remarks:

- 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.

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



Remarks:

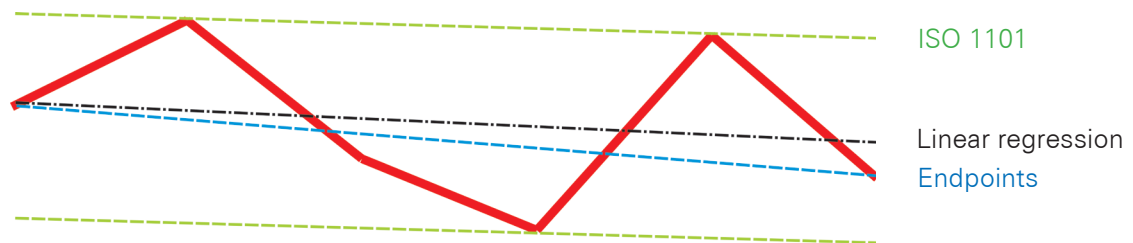
The maximum deviation from a completely flat surface (flatness error) is smaller now. It is also quite possible that due to the correction of the closure error a new distribution of the contact points with the virtual surfaces has taken place. In the example above there are now two points on top and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

6.4.7 METHODS OF ALIGNMENT

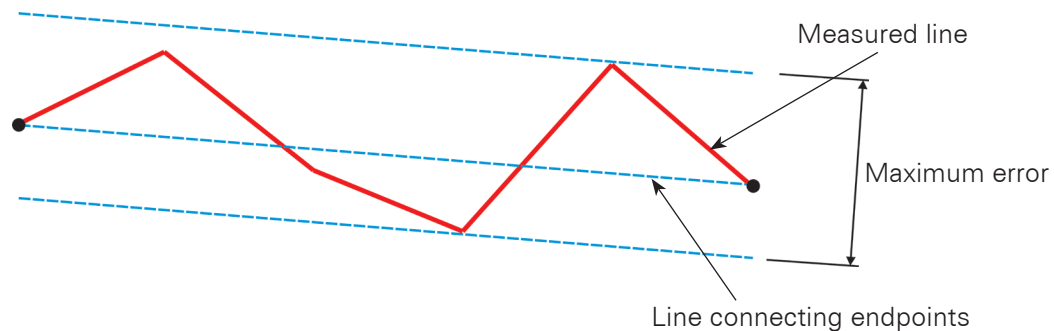
With WYLER LEVELSOFT PRO the following methods of aligning the measuring objects are possible:

- 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.

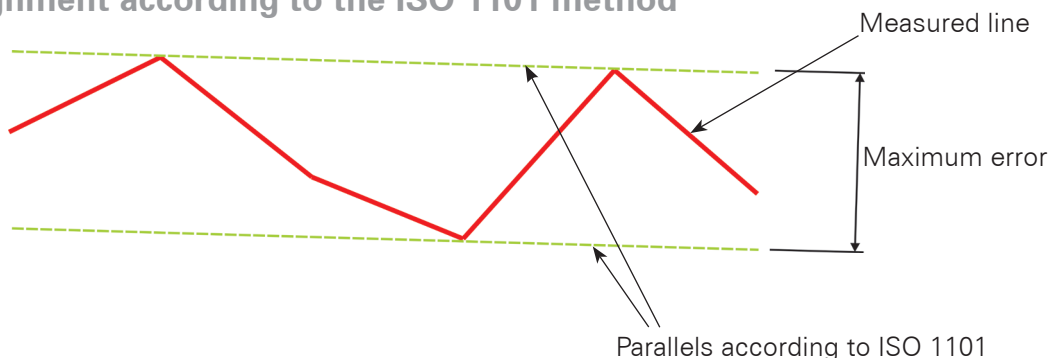


6.4.7.1 Alignment according to the endpoints method



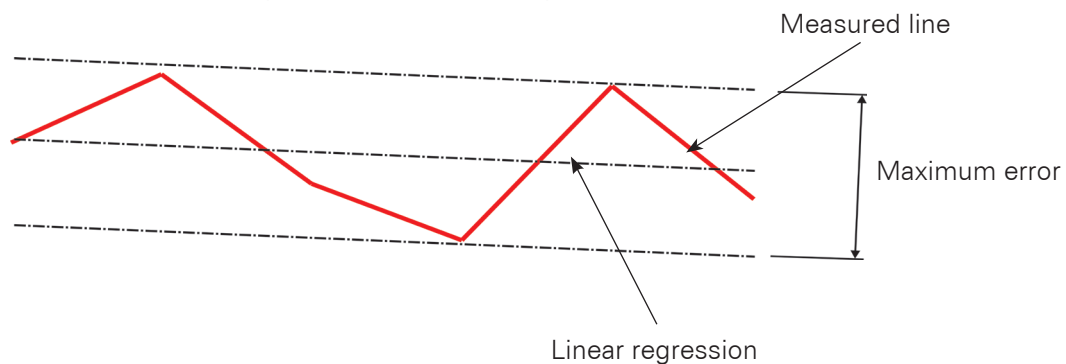
In this method the first and the last measured point are connected by a straight line. The connecting line is moved **parallel to the highest and the lowest point** of the object. The **distance** between the two lines is the maximum error calculated according the endpoints method.

6.4.7.2 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.

6.4.7.3 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.

6.4.8 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.



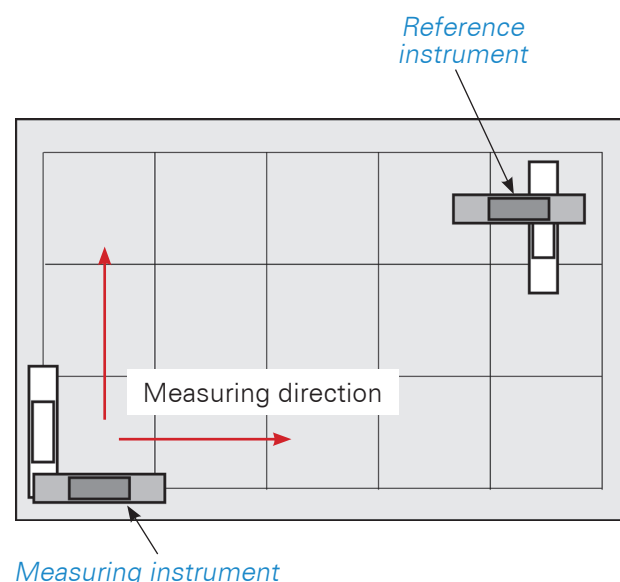
Flatness measurement with a measuring and reference instrument

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.

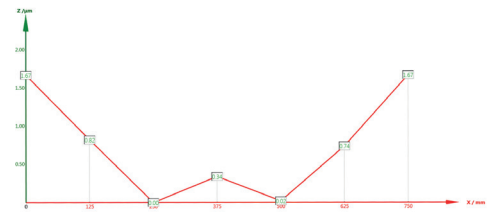
The measurement is always in the direction of the cable connection. If this rule is not met, the result may be mirror inverted. The whole measurement is wrong and could lead to erroneous conclusions and decisions.



MEASUREMENT OF STRAIGHTNESS (LINES) - SOFTWARE WYLERELEMENTS

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)

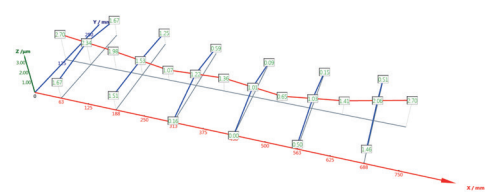


Alignment according to **endpoints**, to **ISO 1101** or **linear regression** is possible.

MEASUREMENT OF STRAIGHTNESS WITH TWIST (LINES WITH TWIST) - SOFTWARE WYLERPROFESSIONAL

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)

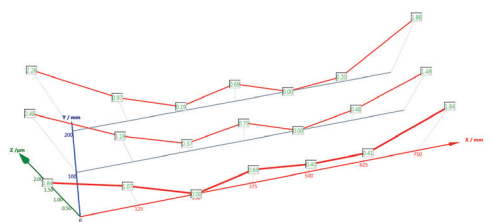


Alignment according to **endpoints**, to **ISO 1101** or **linear regression** are possible.

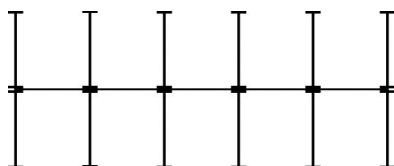
PARALLELS WITH TWO OR THREE PARALLELS - SOFTWARE WYLERPROFESSIONAL

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

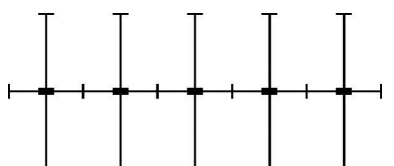
- Number of parallels
- Step length and number of measurements for all parallels



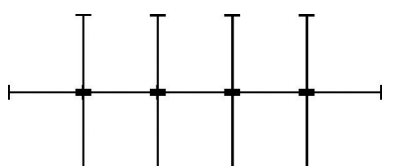
Alignment according to **endpoints** only.



TWIST LEFT OF STEP



TWIST CENTRE OF STEP



TWIST RIGHT OF STEP

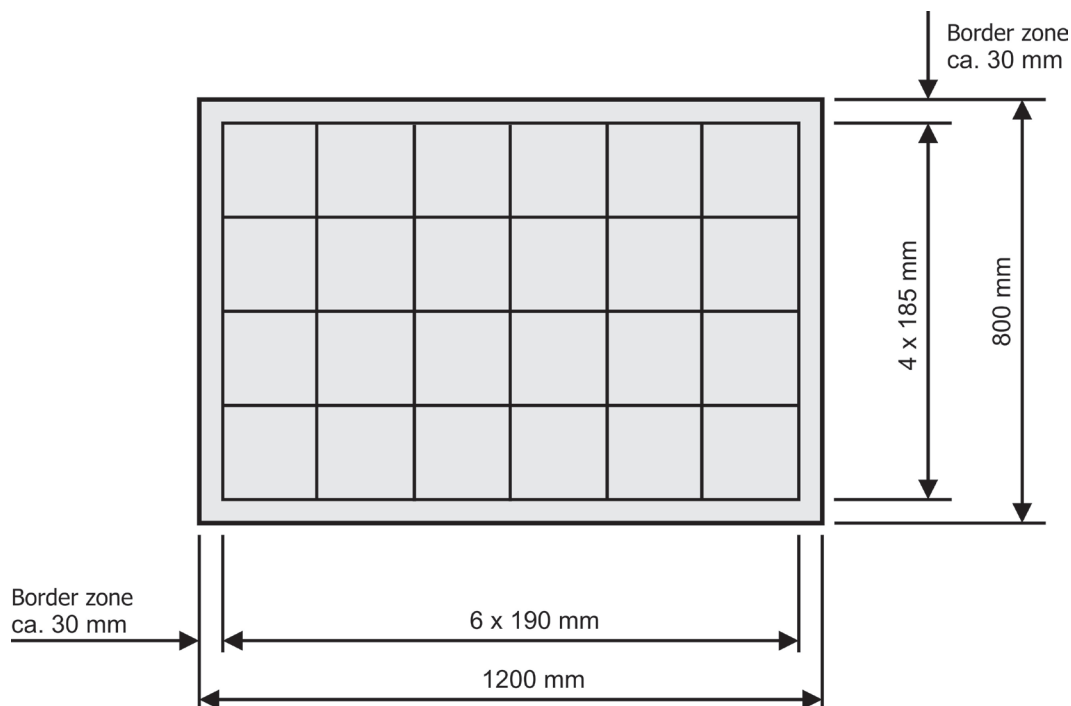
FOR THE MEASUREMENT OF FLATNESS, THE FOLLOWING OPTIONS ARE AVAILABLE:

- 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:

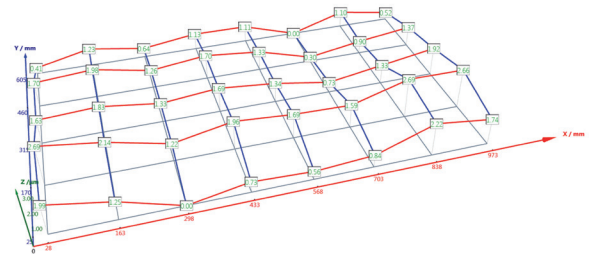
- The object to be measured must be adjusted horizontally in both directions (longitudinal and transversal) as well as possible (within approx. $50 \mu\text{m/m}$). If not done, measuring errors may occur if the measuring instrument is not placed exactly in line with the measuring direction
- The object 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 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:



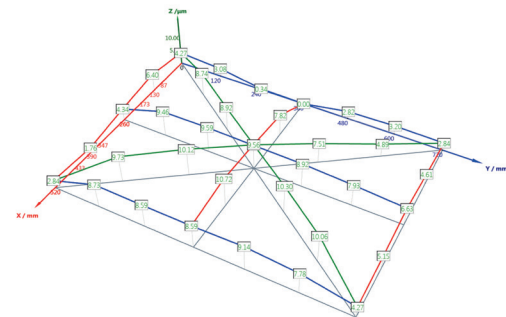
Required inputs:

- Step length longitudinal and transversal
- Number of longitudinal and transversal lines
- Measuring density 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:

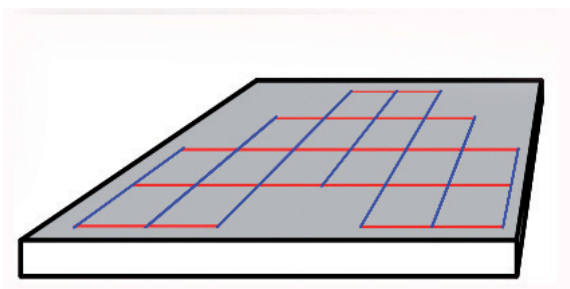
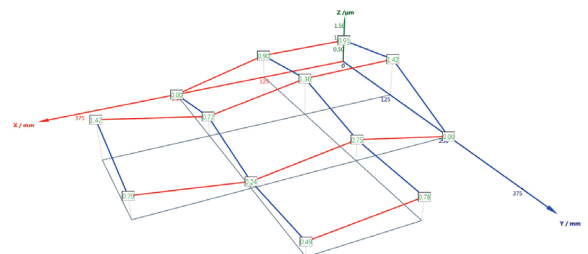
- Base length and width: 250 x 45 mm
- Adjustable step length standard 90 (100) mm to 240 mm
- Extended step length 70 mm to 270 mm
- Dimensions of three-point tungsten carbide base: Diam. = 3/8", Distance width = 1.4"

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.

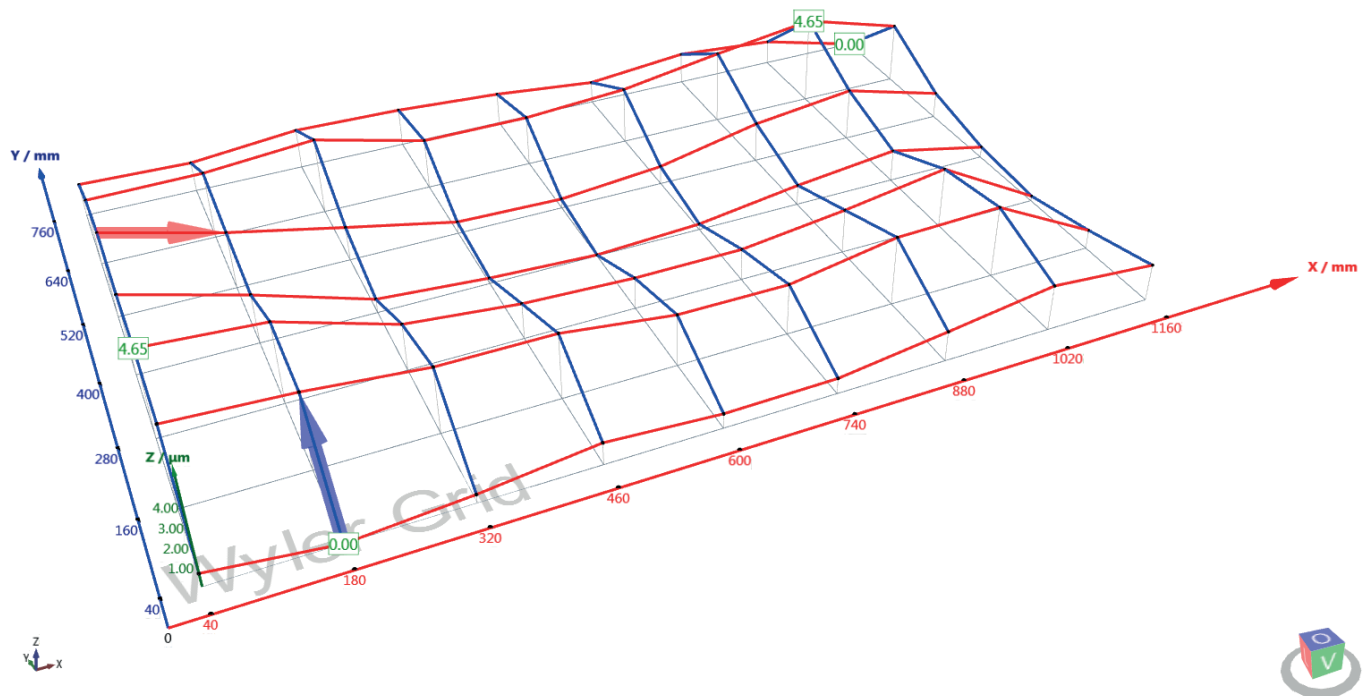


Required inputs:

- 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.

6.4.9 "STANDARDS" FOR THE FLATNESS OF SURFACE PLATES

QUALITY OF THE MEASURED OBJECT:



Formulas for the different standards are as follows:

- **DIN 876:**

- Grade 00 $< 2 \times (1 + L/1000) \mu\text{m}$ (L: Longer edge of plate in mm)
- Grade 0 $< 4 \times (1 + L/1000) \mu\text{m}$ (L: Longer edge of plate in mm)
- Grade 1 $< 10 \times (1 + L/1000) \mu\text{m}$ (L: Longer edge of plate in mm)
- Grade 2 $< 20 \times (1 + L/1000) \mu\text{m}$ (L: Longer edge of plate in mm)

- **JIS**

- Grade 00 $< L \times 0.0015 + 1.25 \mu\text{m}$ (L: Diagonal of the plate in mm)
- Grade 0 $< L \times 0.003 + 2.50 \mu\text{m}$ (L: Diagonal of the plate in mm)
- Grade 1 $< L \times 0.006 + 5 \mu\text{m}$ (L: Diagonal of the plate in mm)
- Grade 2 $< L \times 0.012 + 10 \mu\text{m}$ (L: Diagonal of the plate in mm)

- **GGG-P-463c**

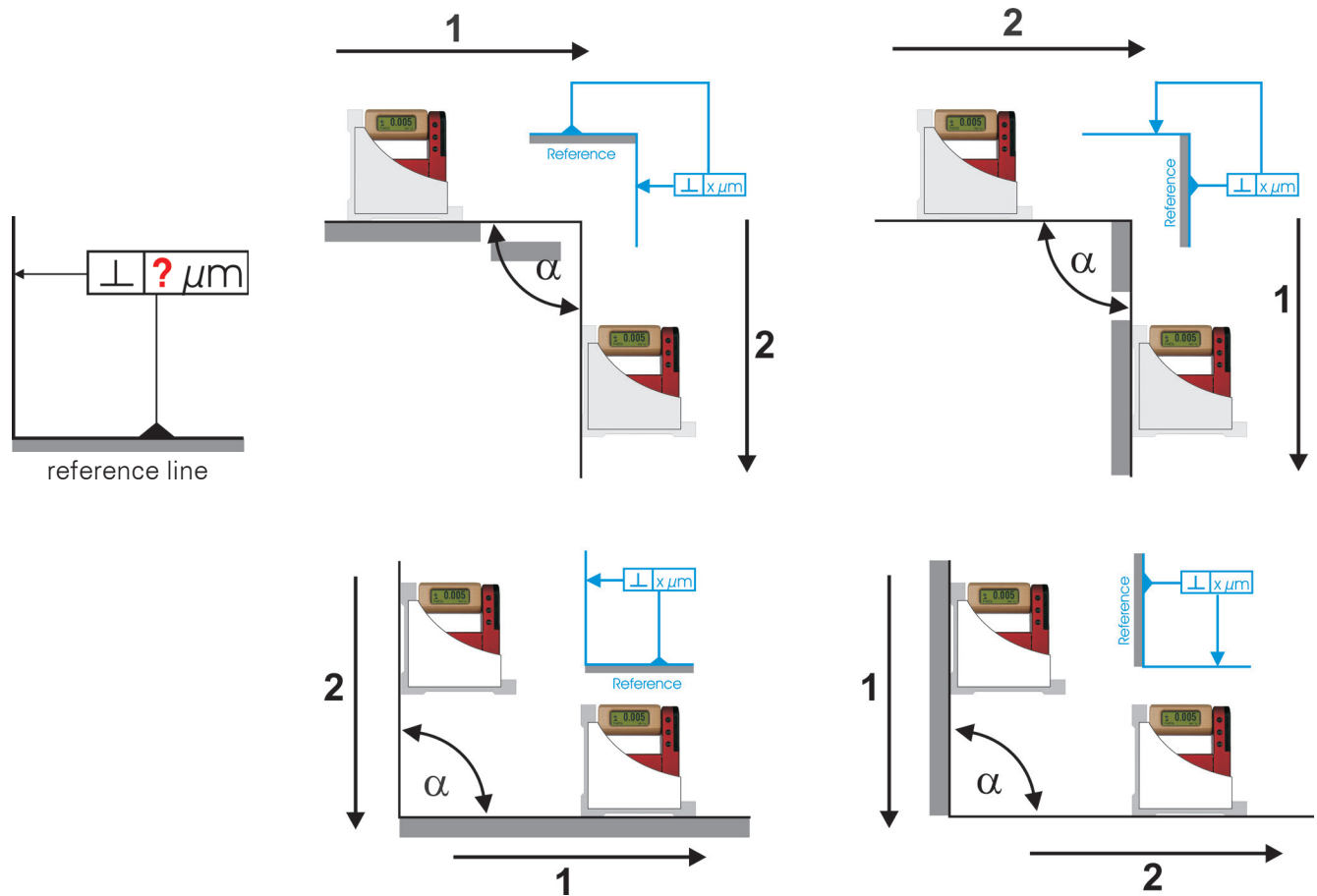
- Grade AA $< 40 + (D/25)$ D: Diagonal in inches
Result in x.xxx inches
- Grade A $< [40 + (D/25)] \times 2$ D: Diagonal in inches
Result in x.xxx inches
- Grade B $< [40 + (D/25)] \times 4$ D: Diagonal in inches
Result in x.xxx inches

- **BS 817**

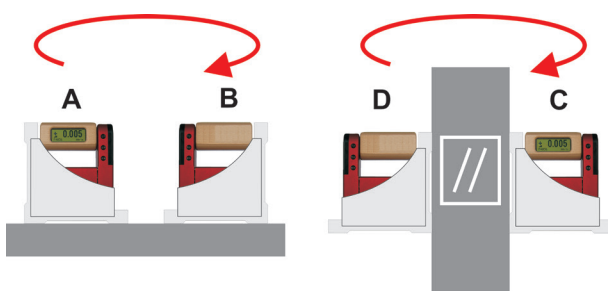
Length of plate in [mm]	Grade 0 in [μm]	Grade 1 in [μm]	Grade 2 in [μm]	Grade 3 in [μm]
180	3.0	Grade "0" x 2	Grade "0" x 4	Grade "0" x 8
250	3.5	ditto	ditto	ditto
400	4.0	ditto	ditto	ditto
630	4.5	ditto	ditto	ditto
1000	5.5	ditto	ditto	ditto
1600	7.5	ditto	ditto	ditto
2000	8.5	ditto	ditto	ditto
2500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

6.4.10 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.



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

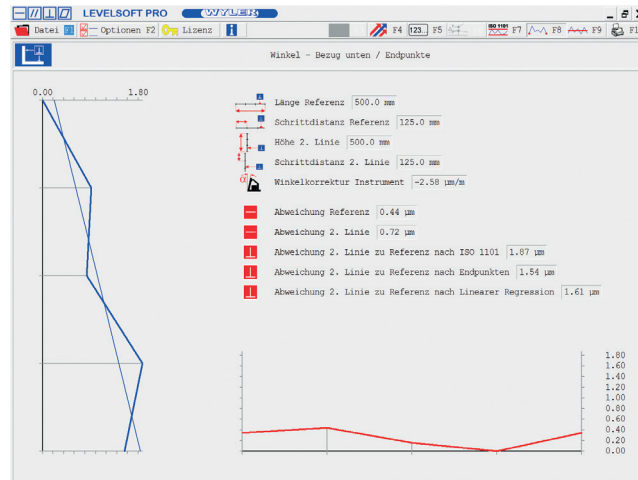
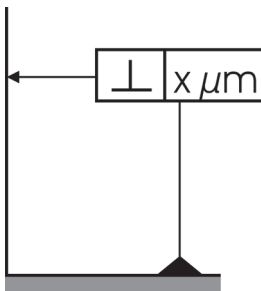
Remark:

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

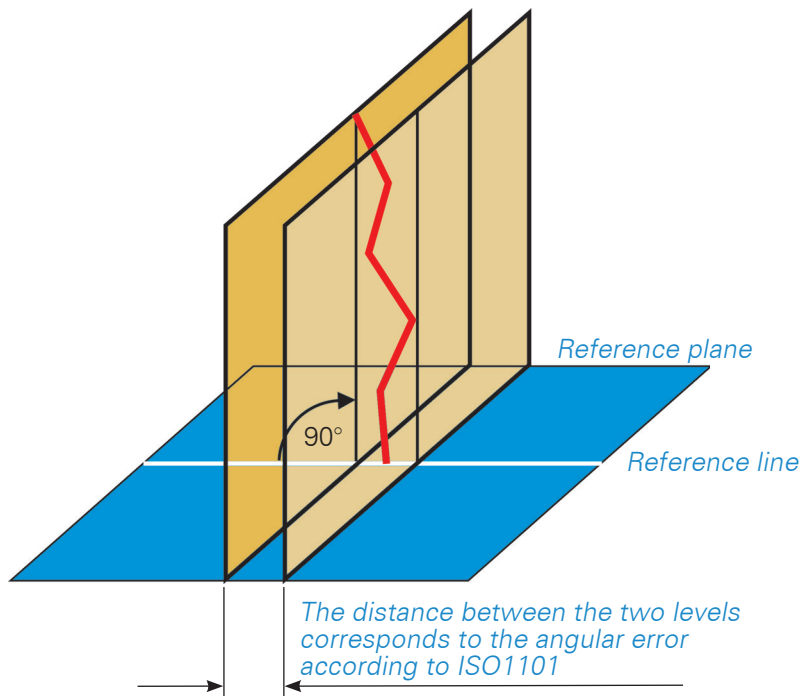
$$\text{Index of correction} = \frac{C + D}{2} - \frac{A + B}{2}$$

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 transferred 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.

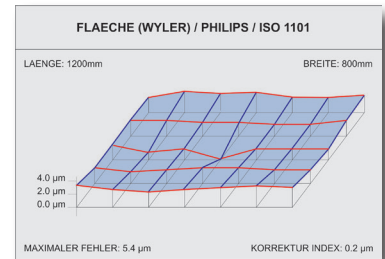
6.4.11 RELATIVE AND ABSOLUTE MEASUREMENTS / LONG-TERM MONITORING

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.



6.4.11.1 RELATIVE 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 wylerSPEC software is well suited for the evaluation of the results.



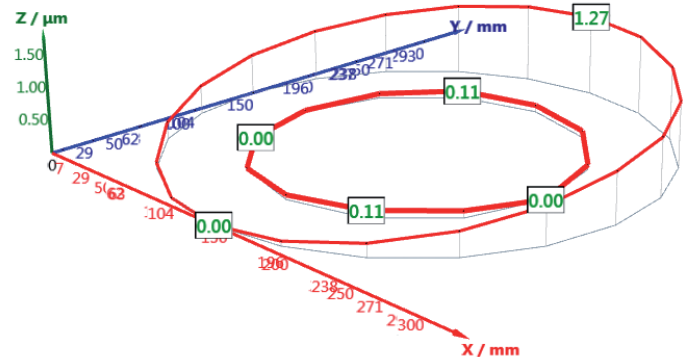
The readings are transmitted wirelessly from the measuring instruments to the BlueMETER. As a radio system for wireless transmission of measurement data, the Bluetooth® wireless technology is used.

6.4.11.2 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.

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

*Vermessung eines Rundtisches mit
zwei Führungsbahnen*



7. Inclination measuring sensors

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** and **LEVELMATIC C** analog sensors, which allows an easy integration into any measuring system, as it provides a standard analog voltage / current output.

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.

DIGITAL SENSOR FAMILY ZEROTRONIC

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.



Sensor ZEROTRONIC

Analoge Sensoren LEVELMATIC 31 und LEVELMATIC C

The LEVELMATIC 31 is an analog sensor with an analog 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.

LEVELMATIC 31



LEVELMATIC C

7.1 DIGITAL INCLINATION MEASURING SENSORS

7.1.1 ZEROTRONIC SENSOR

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

The ZEROTRONIC 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:

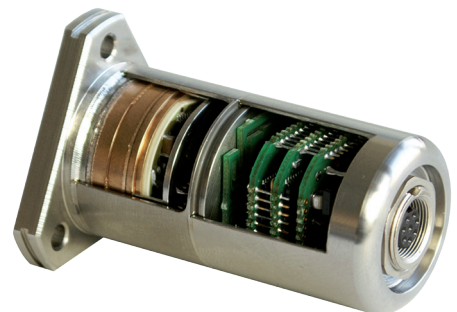
- **ZEROTRONIC Type 3**
- **ZEROTRONIC Type C**

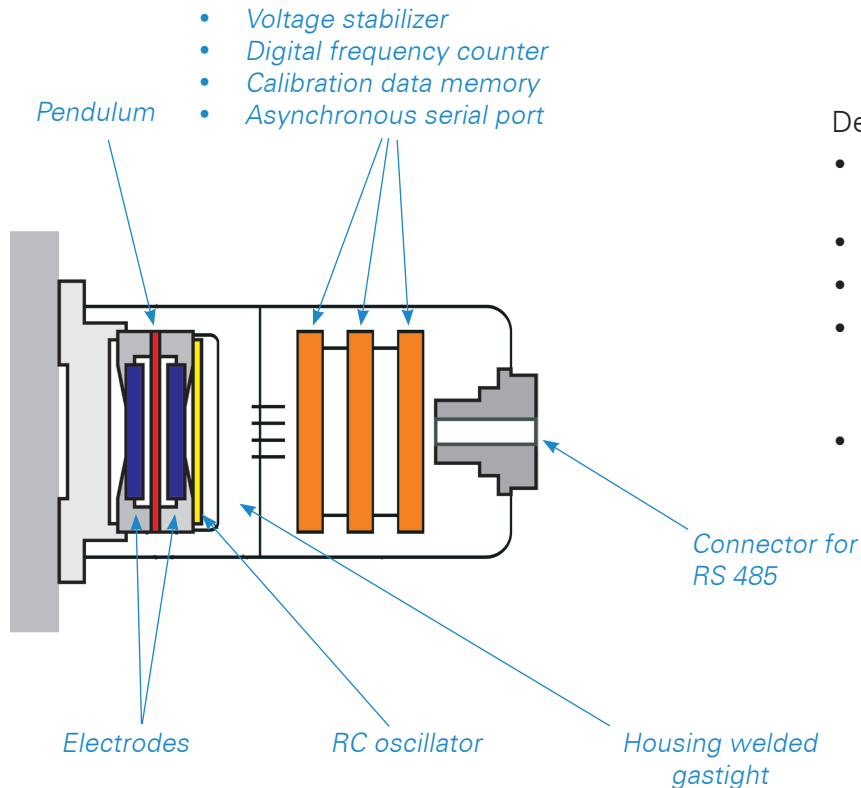
COMMON CHARACTERISTICS OF THE TWO SENSORS:

- 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:

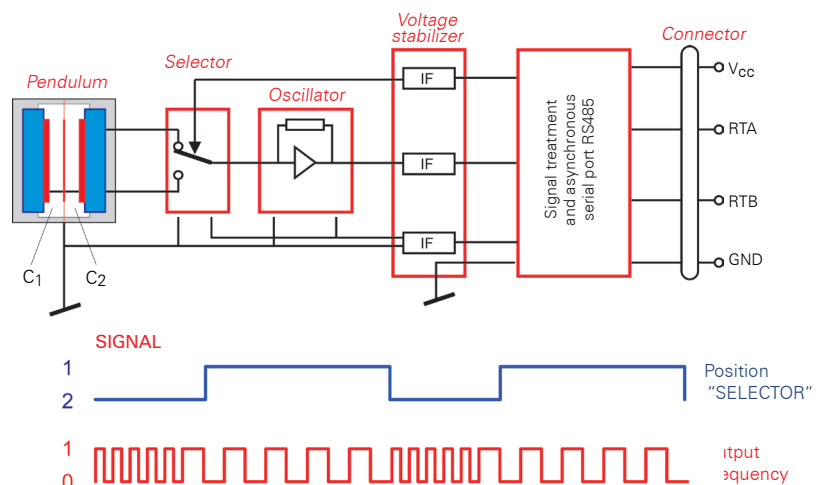
- Sensor including pendulum held by Archimedes helical springs
- RC oscillator
- Voltage stabilizer with level-shifter
- Digital frequency counter with calibration data memory and asynchronous serial port
- Housing and mounting bracket

7.1.1.1 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 $-40\text{ }^{\circ}\text{C}$ and $+70\text{ }^{\circ}\text{C}$ 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.



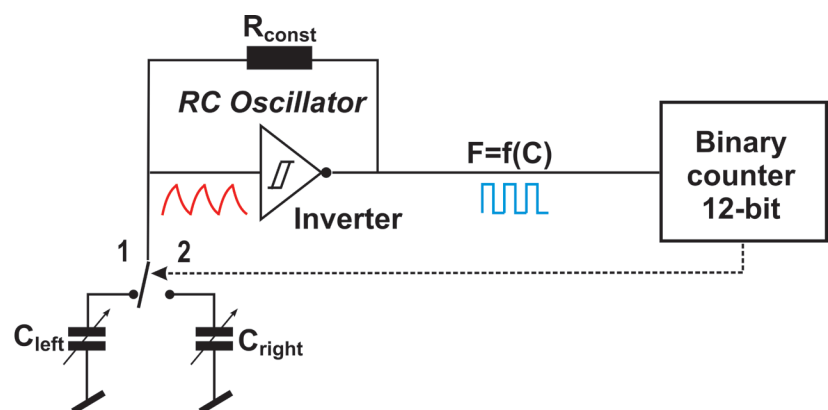
The frequency difference of approx. 100,000 Hz assures that, even when a high measuring rate is applied (numbers of measurements per second), an excellent resolution is available. Most of the existing measuring instruments have an output rate of ± 2 volts. This output rate is equal to a possible range of $\pm 2,000$ 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.

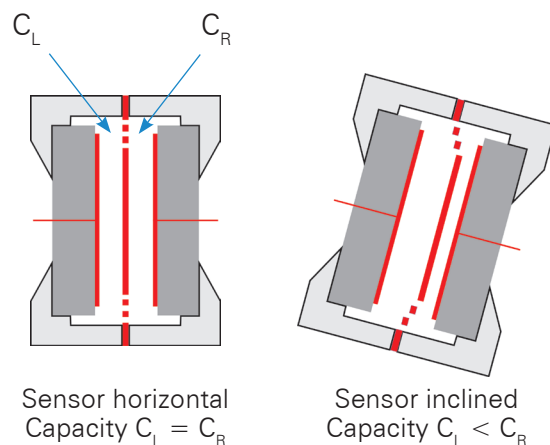
The frequency-differences between the two oscillating circuits are measured digitally and out of these values the inclination is calculated. Thanks to this concept, the signal-to-noise ratio can be optimized and the inclination can be determined very accurately.

7.1.1.2 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.



$$C = \frac{\epsilon_r \times \epsilon_0 \times A}{X}$$

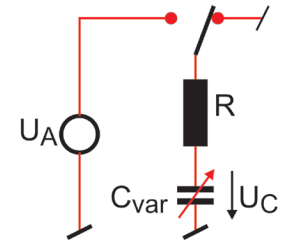
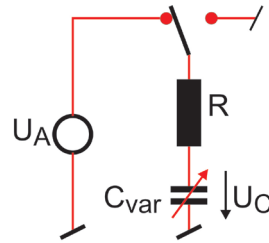
A: Face of the electrode

X: Distance between electrode and pendulum

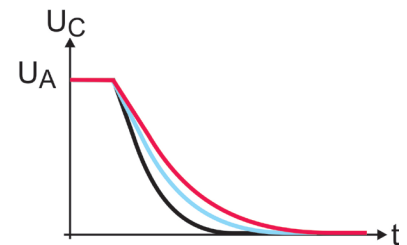
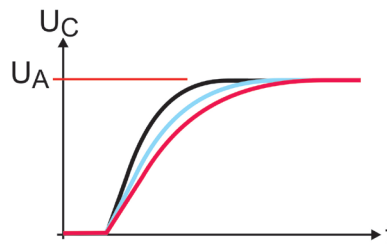
ϵ : Permittivity

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.



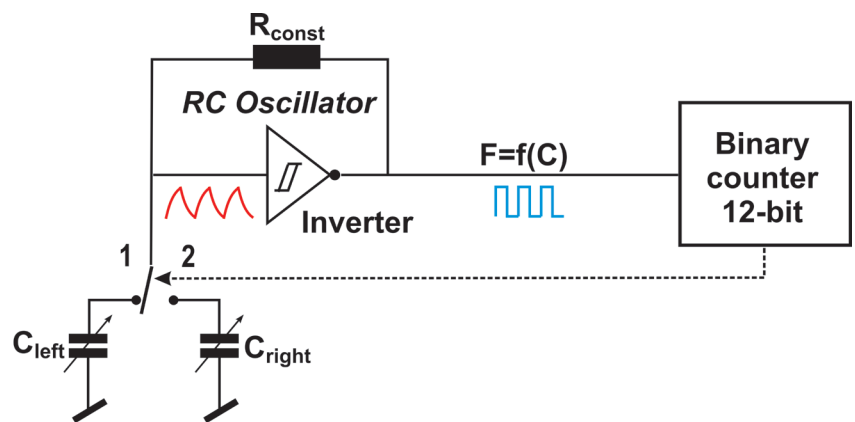
black curve: small capacity
red curve: large capacity



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

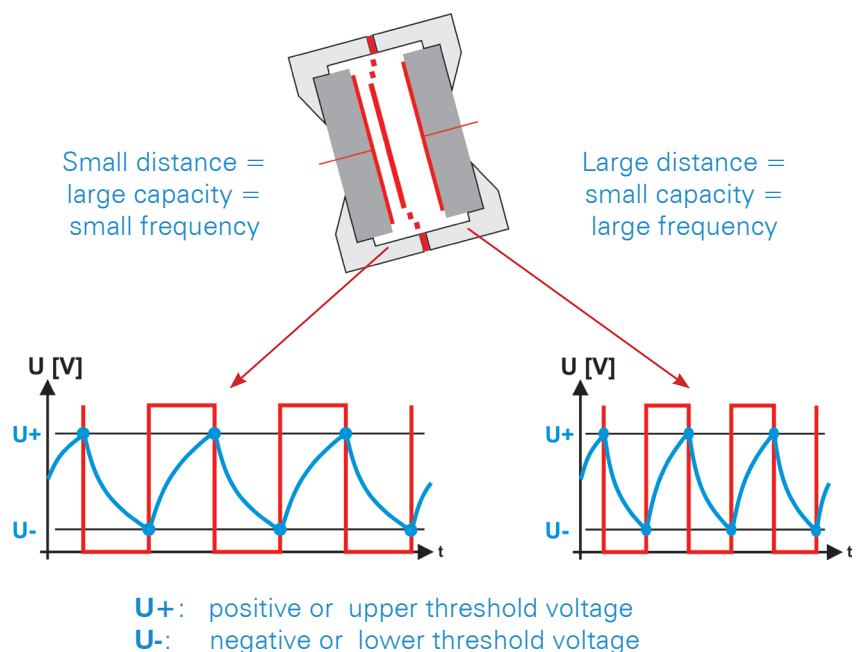
Through a 12-bit binary counter, the process switches from the left electrode to the right, and vice-versa.



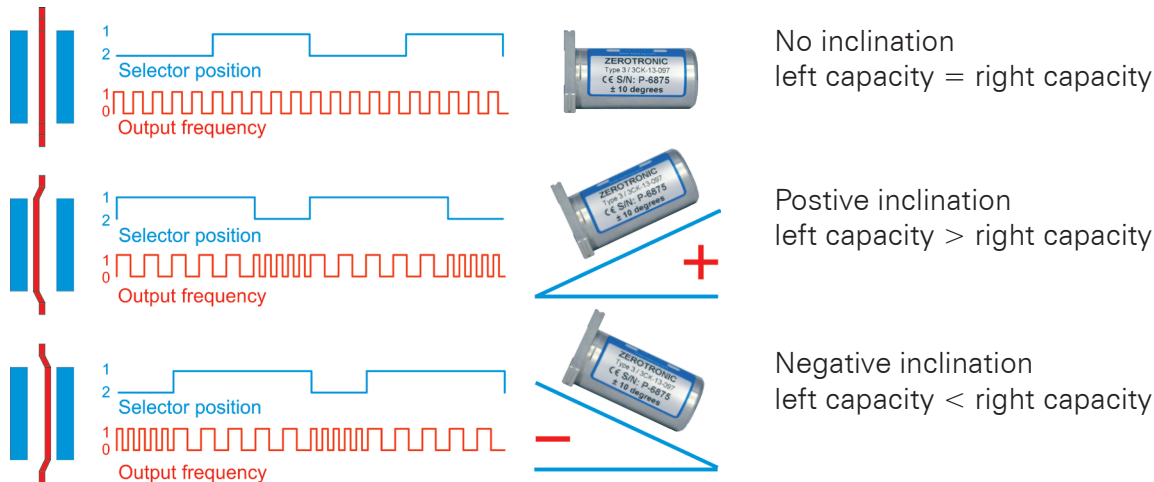
Small distance =
large capacity =
small frequency

Large distance =
small capacity =
large frequency

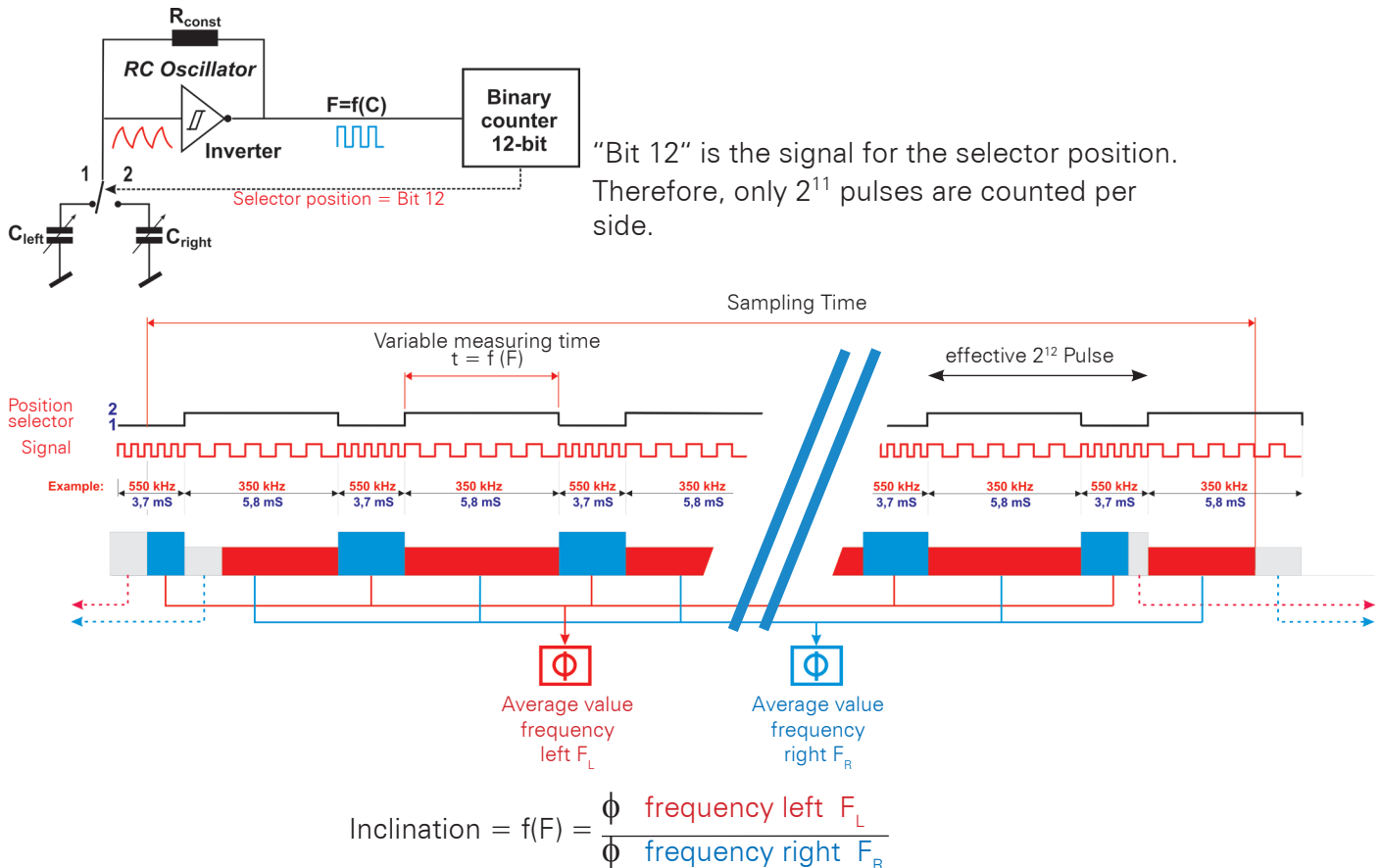
The illustration on the right shows the relationship between the inclination of the sensor, the distance between the electrodes and pendulum, and the resulting frequency.



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



RELATIONSHIP BETWEEN SAMPLING TIME (SAMPLING TIME) AND VARIABLE MEASURING TIME OF THE SENSOR



Example, according to the above illustration

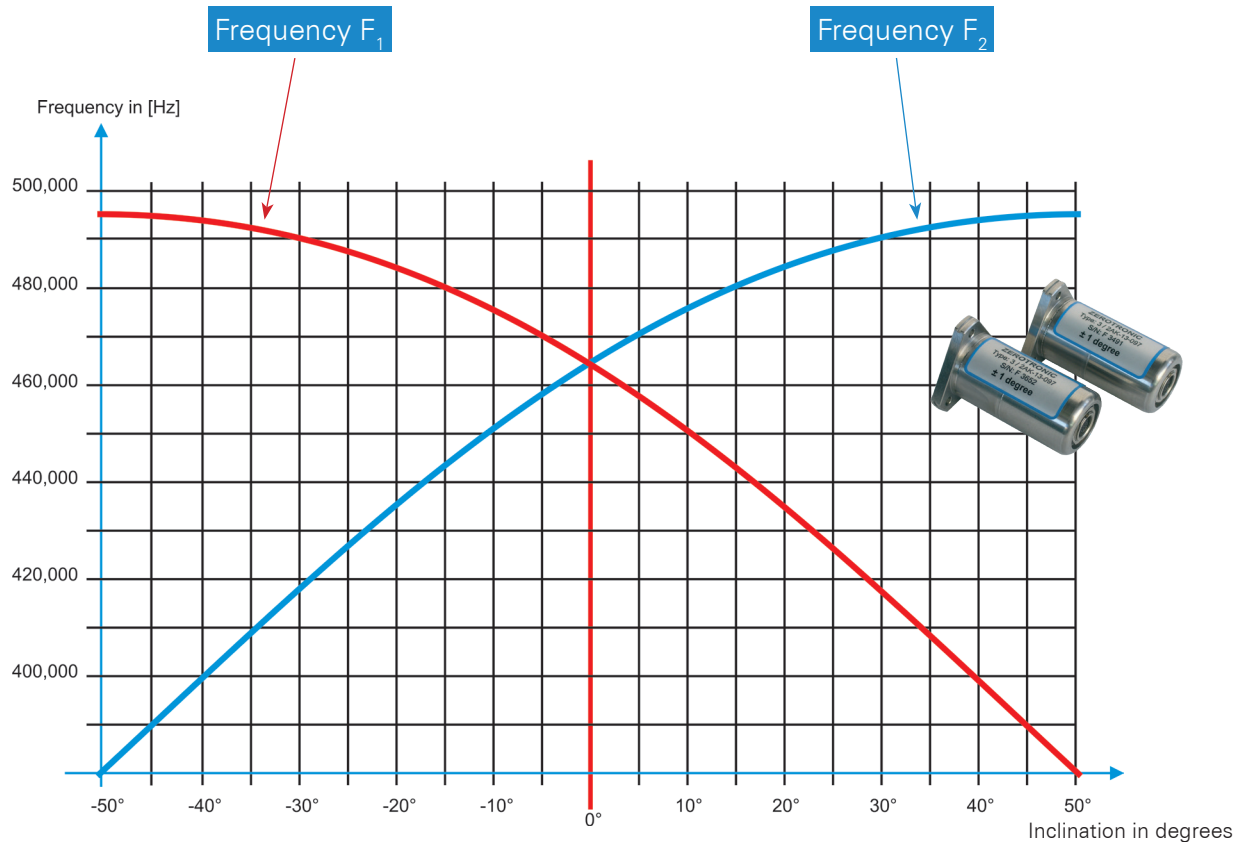
Left side S1:
 $F = 550,000 \text{ Hz}$
 $t_1 = \frac{1}{550,000 \text{ Hz}} \times \frac{4096}{2} = 3.7 \text{ ms}$

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

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

7.1.1.3 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.

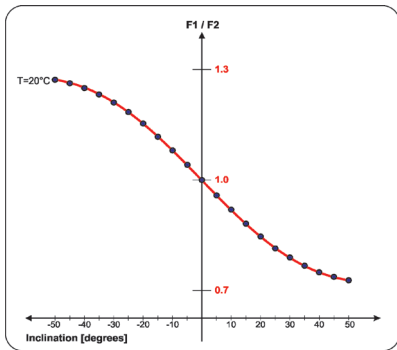
Two temperature calibrations are available:

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.

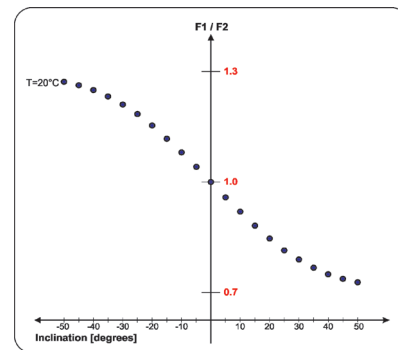
The **HTR (High Temperature Range) calibration** is suited for those sensors that are exposed to outdoor conditions. These sensors are calibrated at various temperatures, which ensures that they function well across the entire temperature range the sensor can be used in, which is from -40 °C to +85 °C. 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:

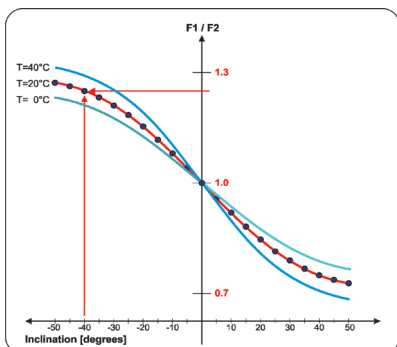
- 1st: Basic calibration at 20 °C with so-called reference points, which vary according to measuring range
- 2nd: In addition to the basic calibration, additional calibrations carried out at different temperatures
- 3rd: The calibration is checked for deviations of the reference points from the nominal value



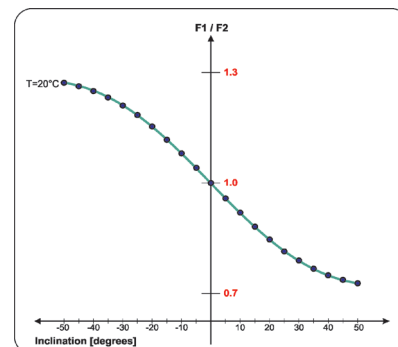
Number of reference points:
depending on the measuring range of the
sensor



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



Finally, the calibration followed by further
temperatures



The values between the reference points
are determined by interpolation

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)

7.1.1.4 SPECIFICATIONS SENSOR ZEROTRONIC

TECHNICAL SPECIFICATIONS	ZEROTRONIC 3			
Measuring range	$\pm 0.5^\circ$	$\pm 1^\circ$	$\pm 10^\circ$	$\pm 30^\circ$
Limits of error within 24 hours ($T_A = 20^\circ\text{C}$)				
• ZERO-POINT (Drift)	$0.070\% M_E$ $= 1.26 \text{ arcsec}$	$0.050\% M_E$ $= 1.8 \text{ arcsec}$	$0.015\% M_E$ $= 5.4 \text{ arcsec}$	$0.010\% M_E$ $= 10.8 \text{ arcsec}$
Limits of error within 6 months ($T_A = 20^\circ\text{C}$)				
• ZERO-POINT (Drift)	$0.170\% M_E$ $= 3.06 \text{ arcsec}$	$0.140\% M_E$ $= 5.04 \text{ arcsec}$	$0.055\% M_E$ $= 19.8 \text{ arcsec}$	$0.030\% M_E$ $= 32.4 \text{ arcsec}$
• GAIN	$0.250\% M_W$	$0.250\% M_W$	$0.060\% M_W$	$0.050\% M_W$
• Base value	$+ 1 \text{ arcsec}$	$+ 1.5 \text{ arcsec}$	$+ 3.6 \text{ arcsec}$	$+ 5.4 \text{ arcsec}$
Temperature error / $^\circ\text{C}$ ($\varnothing 10^\circ\text{C}$) ($-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$)				
• ZERO-POINT (Drift)	$0.060\% M_E$ $= 1.08 \text{ arcsec}$	$0.040\% M_E$ $= 1.44 \text{ arcsec}$	$0.008\% M_E$ $= 2.88 \text{ arcsec}$	$0.005\% M_E$ $= 5.40 \text{ arcsec}$
• GAIN	$0.200\% M_W$	$0.200\% M_W$	$0.030\% M_W$	$0.020\% M_W$
• Base value, if $T_A < 10^\circ\text{C}$ or $T_A > 30^\circ\text{C}$	$+ 2 \text{ arcsec}$	$+ 3 \text{ arcsec}$	$+ 6 \text{ arcsec}$	$+ 6.5 \text{ arcsec}$

M_E = full-scale (mainly drift related)

M_W = measured value (mainly gain related)

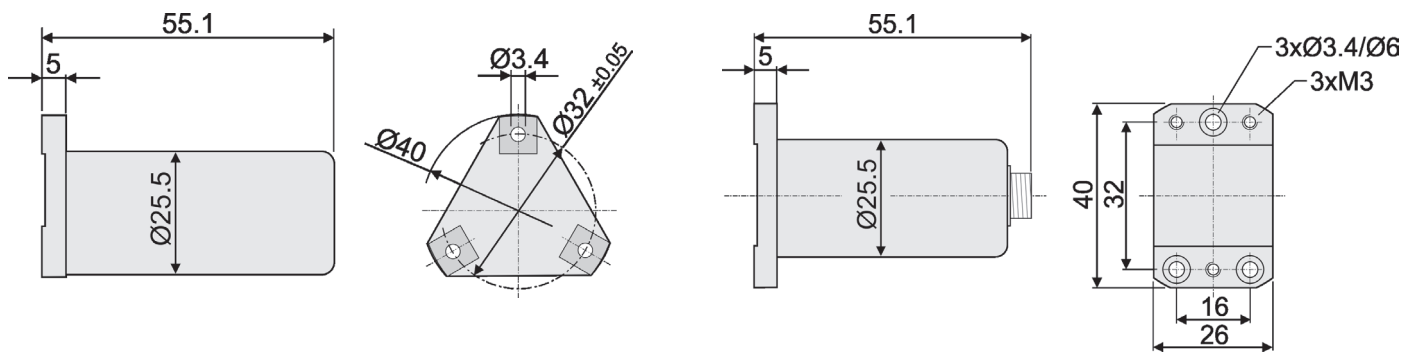
T_A = ambient temperature

TECHNICAL SPECIFICATIONS	ZEROTRONIC C			
Measuring range	$\pm 10^\circ$	$\pm 30^\circ$	$\pm 45^\circ$	$\pm 60^\circ$
Limits of error within 24 hours ($T_A = 20^\circ\text{C}$)				
• ZERO-POINT (Drift)	$0.015\% M_E$ $= 5.4 \text{ arcsec}$	$0.008\% M_E$ $= 8.64 \text{ arcsec}$	$0.005\% M_E$ $= 8.1 \text{ arcsec}$	$0.005\% M_E$ $= 10.8 \text{ arcsec}$
Limits of error within 6 months ($T_A = 20^\circ\text{C}$)				
• ZERO-POINT (Drift)	$0.085\% M_E$ $= 30.6 \text{ arcsec}$	$0.050\% M_E$ $= 54.0 \text{ arcsec}$	$0.040\% M_E$ $= 64.8 \text{ arcsec}$	$0.035\% M_E$ $= 75.6 \text{ arcsec}$
• GAIN	$0.080\% M_W$	$0.030\% M_W$	$0.030\% M_W$	$0.027\% M_W$
• Base value	$+ 4 \text{ arcsec}$	$+ 6 \text{ arcsec}$	$+ 10 \text{ arcsec}$	$+ 12 \text{ arcsec}$
Temperature error / $^\circ\text{C}$ ($\varnothing 10^\circ\text{C}$) ($-40^\circ\text{C} \leq T_A \leq 85^\circ\text{C}$)				
• ZERO-POINT (Drift)	$0.011\% M_E$ $= 3.96 \text{ arcsec}$	$0.005\% M_E$ $= 5.4 \text{ arcsec}$	$0.008\% M_E$ $= 8.1 \text{ arcsec}$	$0.005\% M_E$ $= 8.64 \text{ arcsec}$
• GAIN	$0.015\% M_W$	$0.020\% M_W$	$0.025\% M_W$	$0.030\% M_W$
• Base value, if $T_A < 10^\circ\text{C}$ or $T_A > 30^\circ\text{C}$	$+ 6.5 \text{ arcsec}$	$+ 7 \text{ arcsec}$	$+ 11 \text{ arcsec}$	$+ 14 \text{ arcsec}$

TECHNICAL SPECIFICATIONS ZEROTRONIC SENSOR

ZEROTRONIC sensor Typ 3 ZEROTRONIC sensor Typ C

Power consumption		ca. 70 mW	ca. 100 mW
Power supply	Sensor	5 V $\pm$ 10%	5V $\pm$ 10%
Digital Output	Baudrate (automatic adjustment)	RS 485 / asynchr. , 7 DataBits, 2 StopBits, no parity 2'400 ... 115'000	9'600 ... 57'600
Analog output PWM		0.5 V ... 2.5 V ... 4.5 V @ 5 V Supply	-----
Operating temperature		-40 °C bis +85 °C	
Storage temperature		-55 °C bis +95 °C	
Net weight		118 g	100 g
Shock resistance		40g (11ms) / 2000g (1ms) / IEC 60068-2-27	



Customized solution

with ZEROTRONIC-sensors in specially designed adapters using BlueTCs
for wireless data transmission.

7.1.1.5 CUSTOMIZED 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 right shows ZEROTRONIC-sensors, which are mounted in a 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.

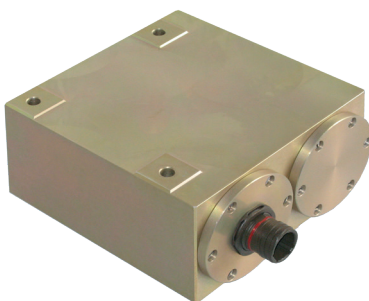
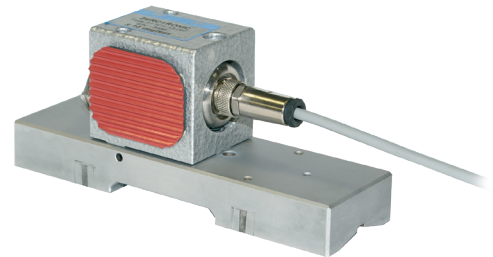
Both sensors have a common electrical interface to the RS485 bus.

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 the BlueMETER SIGMA or can be further treated with software

- **wylerSPEC**
- **wylerCHART**
- **wylerDYNAM**

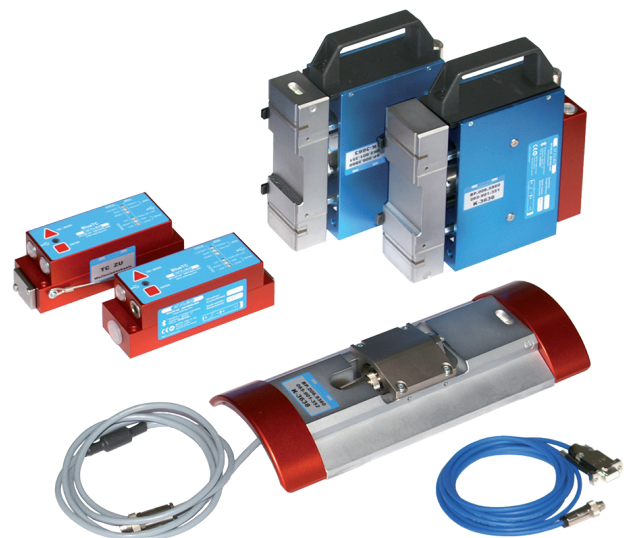
on a PC/laptop.



When it comes to heavy duty applications a special housing, like on the picture can be used to protect the 2D sensor completely. Fullfills special EMC requirements. Available with galvanic isolated excitation.

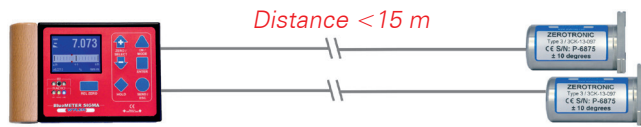
Customized solution

with ZEROTRONIC-sensors in specially designed adapters using BlueTCs for wireless data transmission.

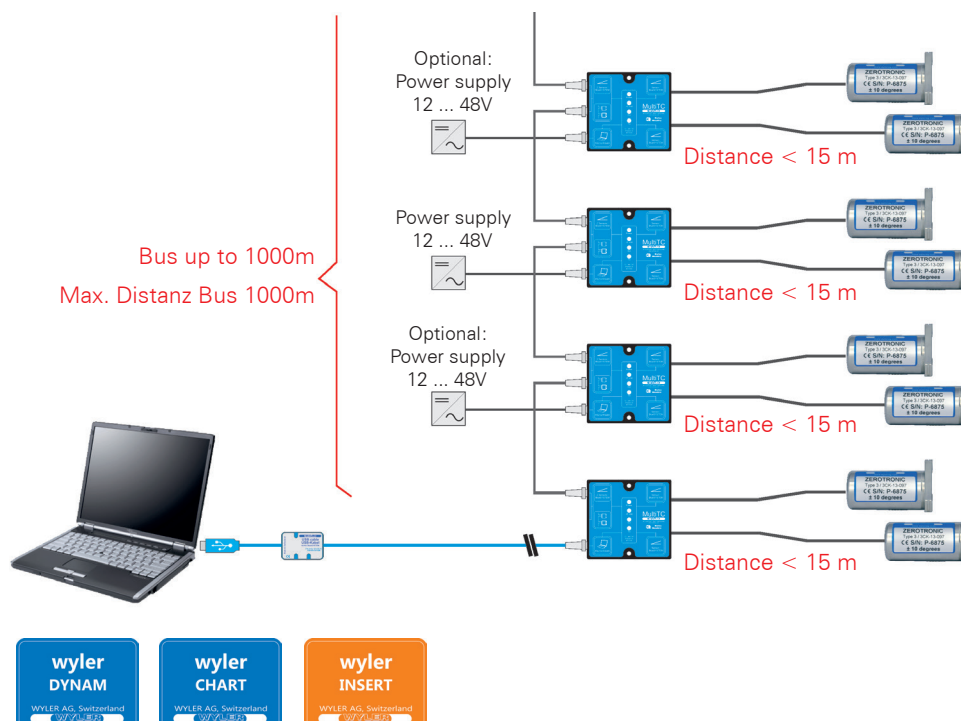
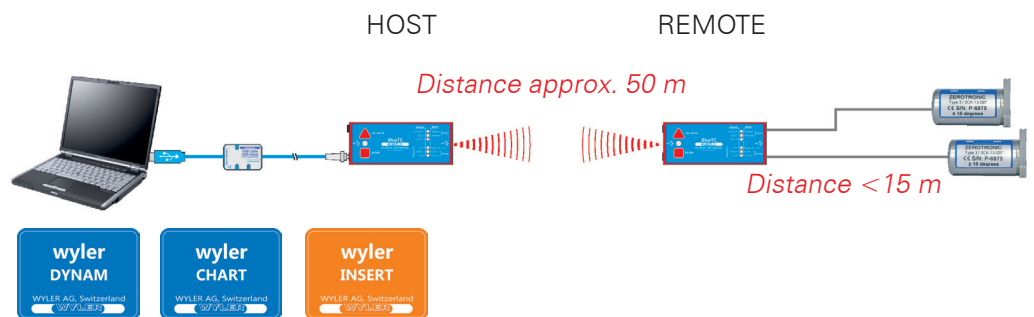
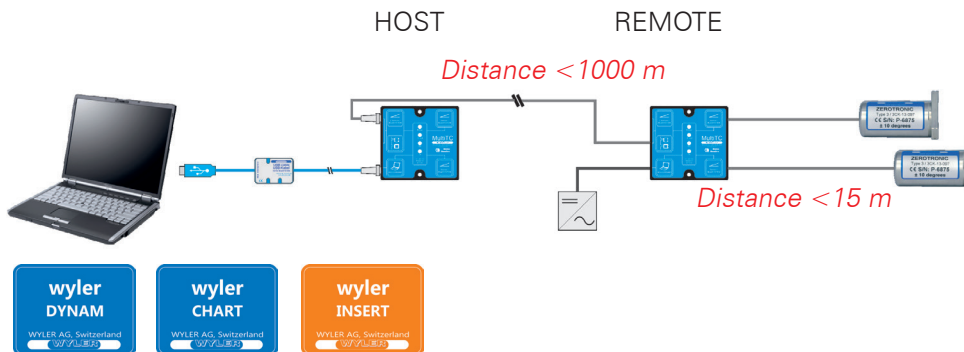


The above examples show that the application of **ZEROTRONIC-sensors** is **very flexible**. Our engineers are interested in discussing your special applications and defining customer specific solutions for you.

7.1.1.6 STANDARD-KONFIGURATIONEN FÜR ZEROTRONIC-SENSOREN



ZEROTRONIC sensors connected to a **BlueMETER SIGMA**



7.1.2 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 an USB port of the laptop, where the values can be evaluated with one of the WYLER measuring software like LEVELSOFT PRO, MT-SOFT or LabEXCEL.
- 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

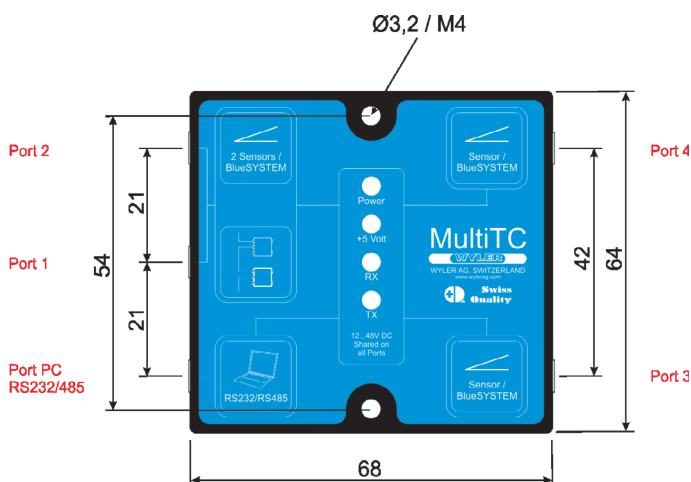
Disadvantages compared to BlueMETER:

- 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

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

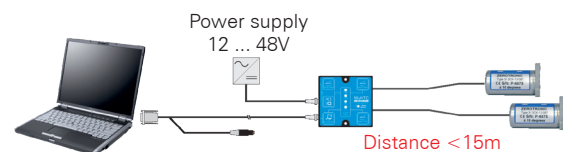


DIMENSIONS OF THE MultiTC

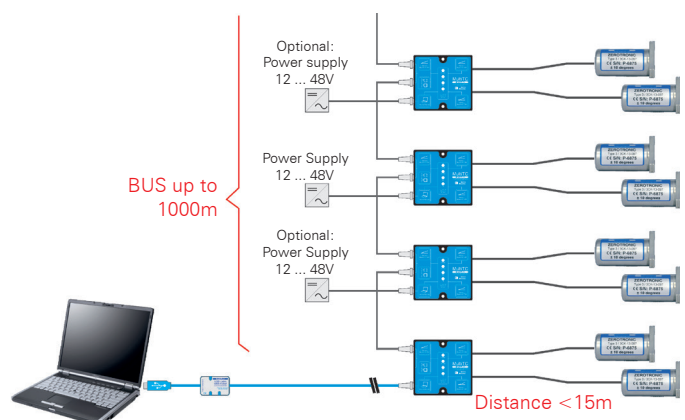


Configuration with 8 ZEROTRONIC sensors, connected to an RS232- or an USB port of a laptop, via 4 MultiTC. Power is supplied from one or several 24V power supplies.

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.



7.1.3 BlueTC (TRANSCEIVER/CONVERTER)



The BlueTC with radio data transmission.

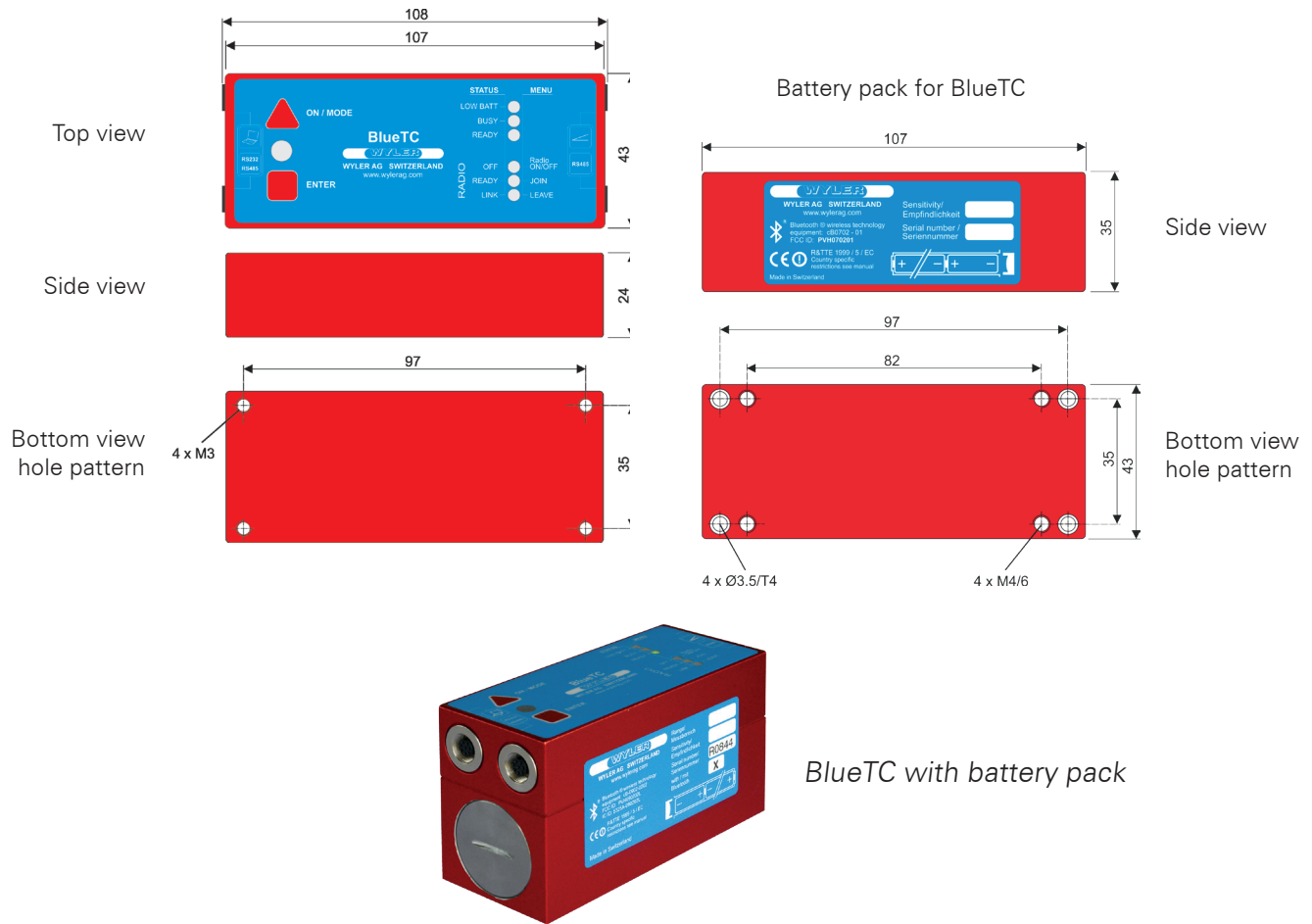
It is possible to send measured data via an RS232/485 port to a printer, a PC/laptop or the WYLER software wylerSPEC or to other software such as wylerCHART or wylerDYNAM.

- Advantage compared to the BlueMETER SIGMA connected to BlueLEVEL instruments are:
- Simple configuration; BlueTC is only an interface between instruments and PC / laptop
 - Cost effectiveness (in case of wireless data transmission)

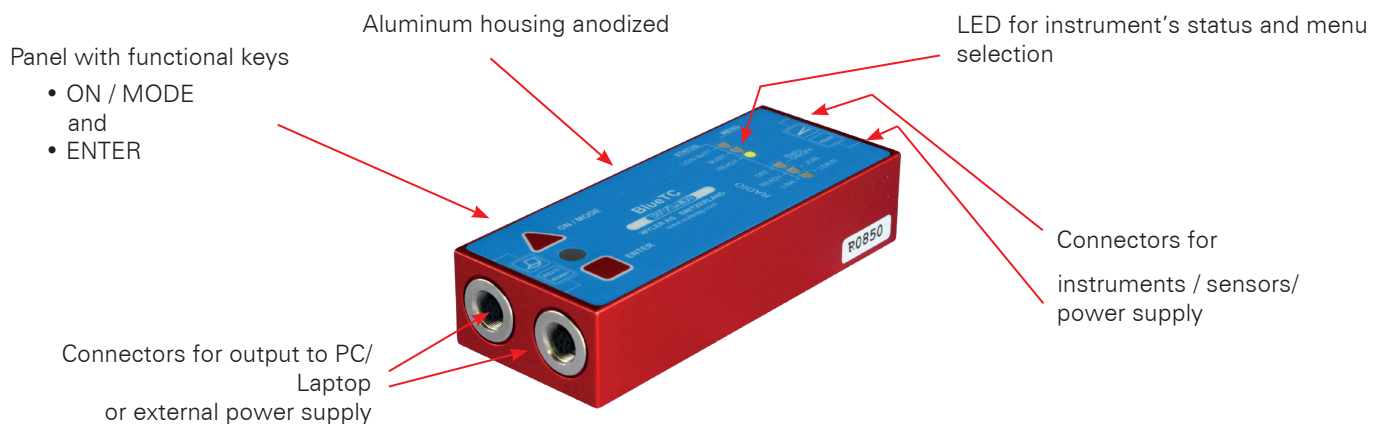
- Disadvantage compared to the BlueMETER SIGMA connected to BlueLEVEL instruments are:
- No display of the measured values of the connected instruments [A] and [B]
 - Menu less extensive and less comfortable due to missing display

TECHNICAL SPECIFICATIONS		BlueTC
External power supply		+ 5 V DC, max. 450 mW (Pin 3) 8 ... 28 V DC (Pin 1)
Format of transmission		RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 Baud
Operating temperature		0 ... +40 °C
Storage temperature		-20 ... +70 °C
Dimensions without battery pack	Length	108 mm
	Width	43 mm
	Height	24 mm
Dimensions with battery pack	Length	108 mm
	Width	43 mm
	Height	59 mm

DIMENSIONS OF THE BLUETC



OVERVIEW OF THE BLUETC

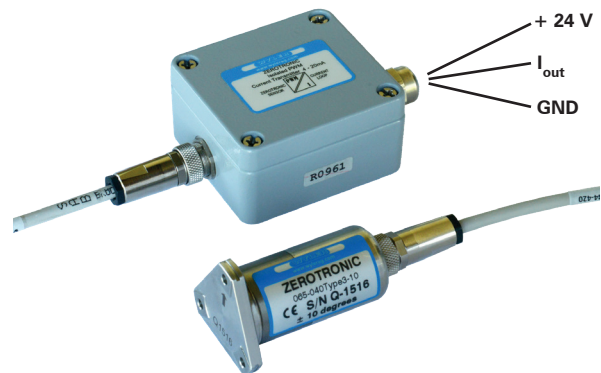


7.1.4 ZEROTRONIC SENSOR WITH ANALOG OUTPUT (PC INTERFACE WITH CURRENT TRANSMITTER)

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).

The inclination can also be transmitted through a current transmitter to a standard A/D converter card on a PC (for ZEROTRONIC 3 only).

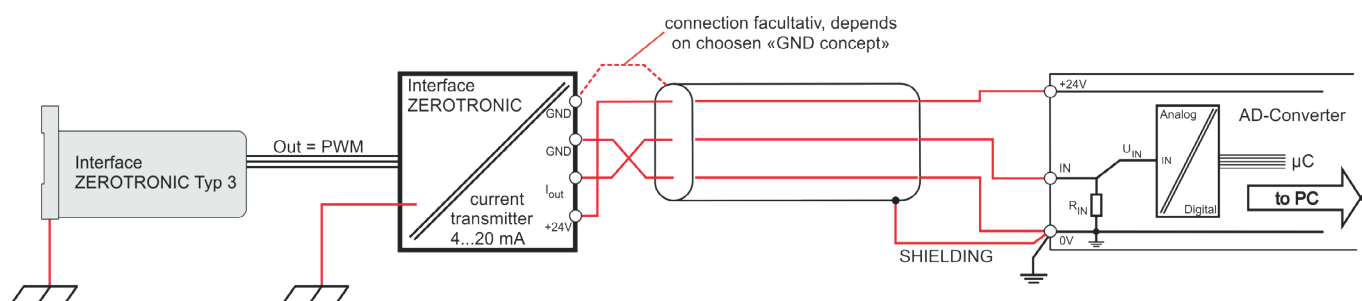
Current Transmitter 4...20 mA for ZEROTRONIC 3



SPECIFICATIONS		Current Transmitter for ZEROTRONIC 3		
Settlingtime (adjustable by user)		7.5 msec	75 msec	750 msec
Accuracy (depending on selected settlingtime)		LOW TIEF	MEDIUM MITTEL	HIGH HOCH
Output currents				
	+ Displayrange		20 mA	
	Zero		12 mA	
	- Displayrange		4 mA	
Zero at 20°C		nominal 12.0 mA, $\pm 4\%$		
Gain from -45°C ... +85°C		max. +1.0 nA/°C		
Gain Span ($-M_E$... $+M_E$) from -45°C ... +85°C		nominal 16.0mA, $\pm 5\%$		
Measuring range (ZEROTRONIC)		$\pm 1^\circ$	$\pm 10^\circ$	$\pm 30^\circ$
Display range (ZEROTRONIC)		$\pm 2^\circ$	$\pm 10.5^\circ$	$\pm 33^\circ$
Output current /°		4 mA	0.7619 mA	0.2424 mA
Power supply		18 ... 36 V DC 50 mA at/bei 24 V		

M_E = Full scale

Connection to current interface



7.1.5 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 right shows ZEROTRONIC-sensors, which are mounted in a 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 RS485 bus.

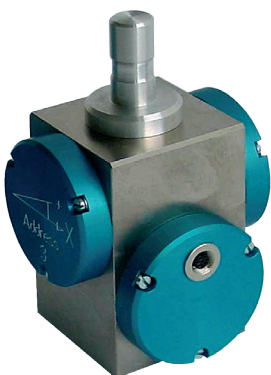
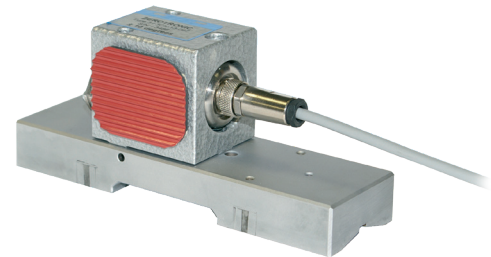
*Two ZEROTRONIC-sensors mounted on top of each other
One sensor measures the X axis, the other sensor the Y axis
Diameter of the unit is less than Ø 35 mm*

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 the BlueMETER SIGMA or can be further treated with software

- **wylerSPEC**
- **wylerCHART**
- **wylerDYNAM**

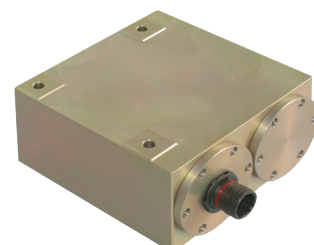
on a PC/laptop.



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 can be used to protect the 2D sensor completely.

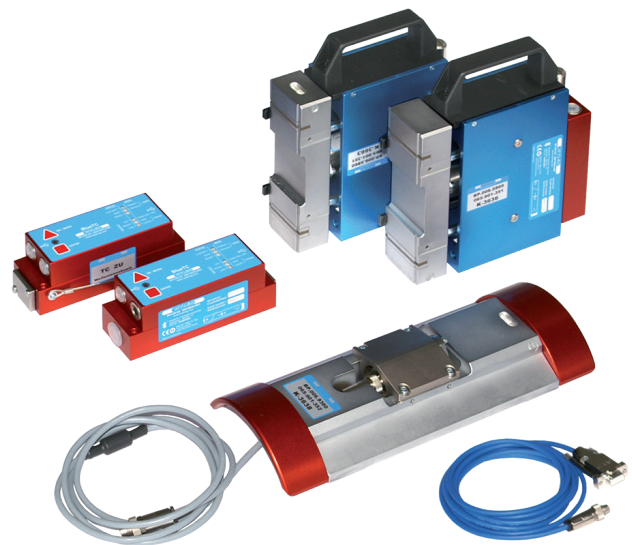
Fullfills special EMC requirements. Available with galvanic isolated excitation.





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



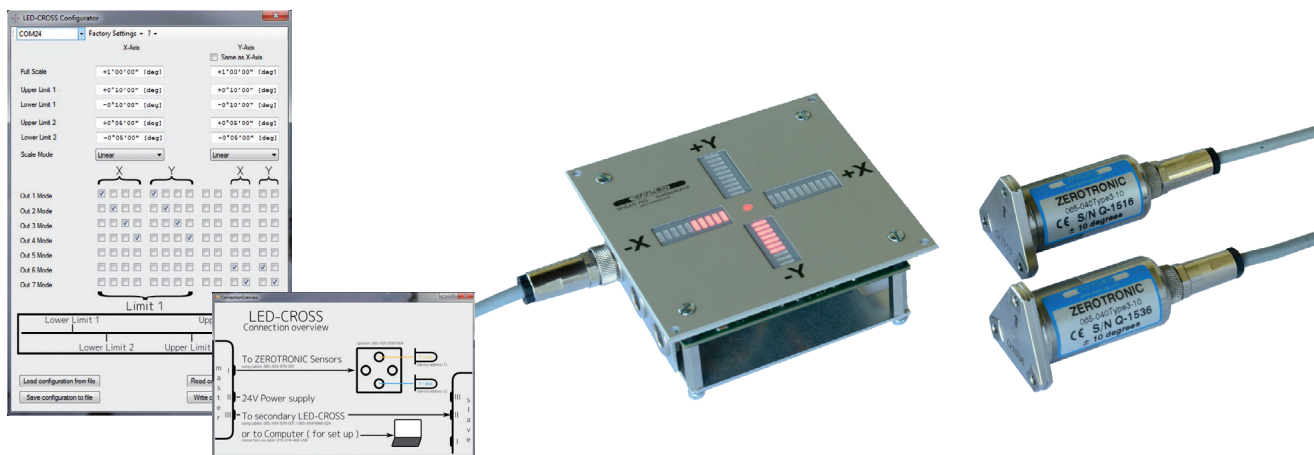
The above examples show that the application of **ZEROTRONIC sensors** is **very flexible**. Our engineers are interested in discussing your special applications and defining customer specific solutions for you.

7.1.6 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



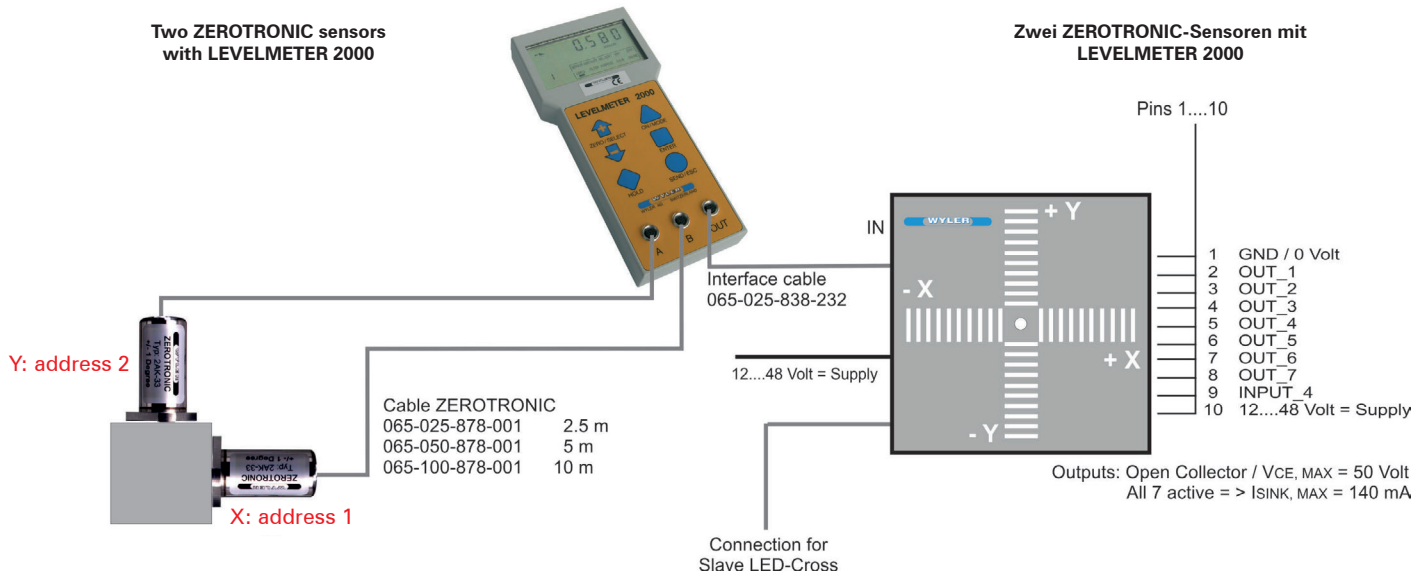
The instrument has the following features:

- 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

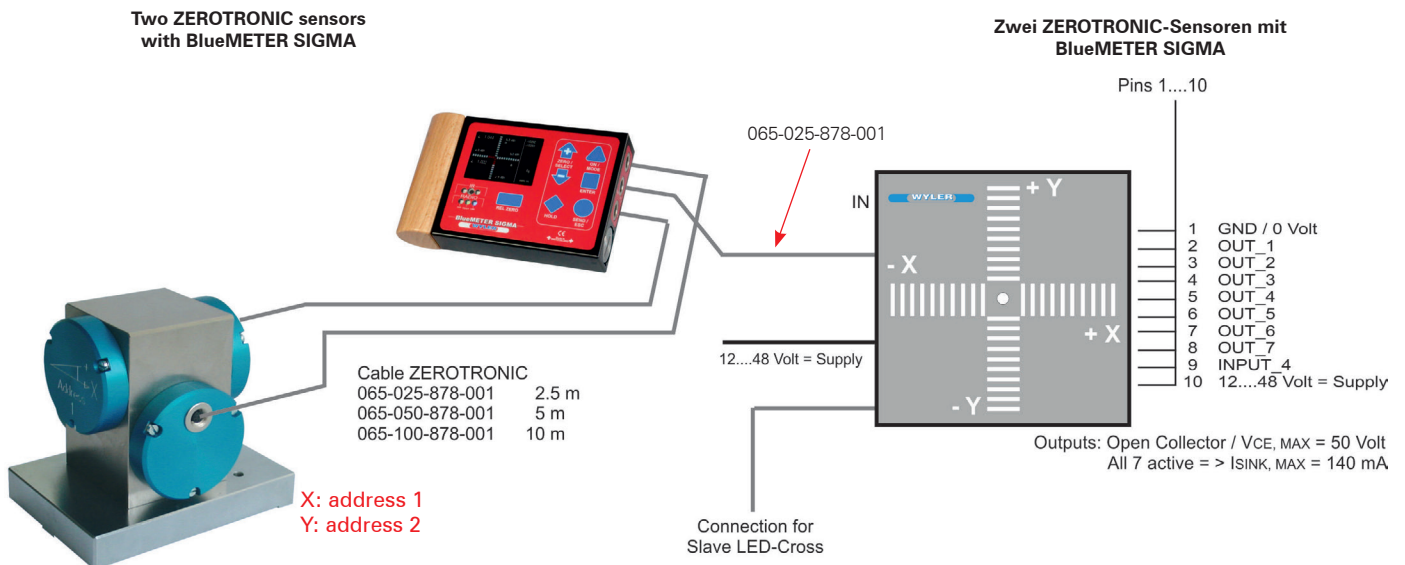
TECHNICAL SPECIFICATIONS	LED CROSS
Update speed of the display	2 - 3 Hz
External power supply	12 ... 48 V DC (200 mA / 24 V DC)
Operating temperature	- 20 °C ... + 85 °C
Communication protocol for X- and Y-axis sensors	According to our „WYBUS“ specification / Gemäss der Spezifikation des „WYBUS“: RS485, asynchr., 7 DataBits, 2 StopBits, no parity, 9600 bps
Net weight	171 g
Dimension of plate L x W	96 x 96 mm
Height approx.	40 mm
Hole-Ø / hole center distance	Ø 3 mm / 89 x 89 mm

CONFIGURATIONS LED CROSS

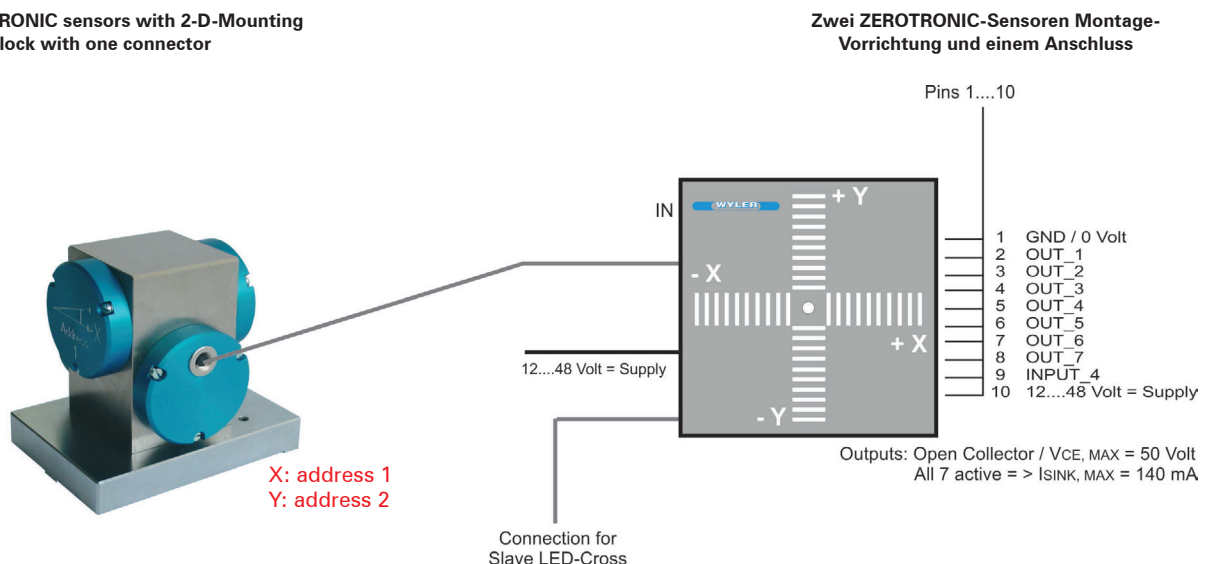
Two ZEROTRONIC sensors
with LEVELMETER 2000



Two ZEROTRONIC sensors
with BlueMETER SIGMA



Two ZEROTRONIC sensors with 2-D-Mounting
block with one connector



7.1.7 TWO-DIMENSIONAL INCLINATION MEASUREMENT SENSORS ZEROMATIC

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 2/2** has **two inclination sensors**. They can 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.

The **ZEROMATIC 2/1** has **one inclination sensor**. It can therefore only provide continuous values in either X or Y axis. At defined intervals it will perform a reversal measurement and compensate for any offset. After such a reversal measurement the sensor will provide one set of precise and absolute inclination values in the X and Y axes.



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
- Measuring range $\pm 1^\circ$
- Display range $\pm 5^\circ$
- Rugged precision aluminum housing for protection against external influences
- Internal sensors with HTR compensation
- LEDs showing the status of the instrument
- Data transmission to PC/laptop
- Optional connection to an external BlueMETER SIGMA display unit

TECHNICAL SPECIFICATIONS		ZEROMATIC
Measuring range		$\pm 1^\circ$
Display range		$\pm 5^\circ$
Stability of Zero	Limits of error	± 1 arcsec
Linearity	Limits of error	0.5 % M_w
Temperature error / °C M_E = full scale		0.08 % M_E
Operating temperature		- 10 °C - + 60 °C
Time for one reversal measurement		< 2 minutes < 2 Minuten
Interval between two reversal measurements, definable by the user		> 2 min
Power supply		24 V $\pm 10\%$ DC

7.1.7.1 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

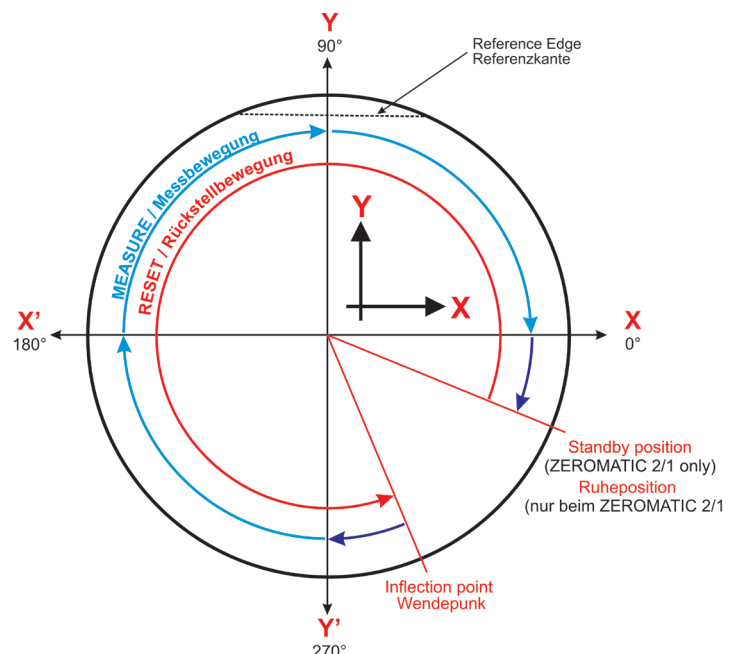
When starting a reversal measurement, the rotor first seeks the standby position. Then it turns to the measuring positions:

ZEROMATIC 2/1:

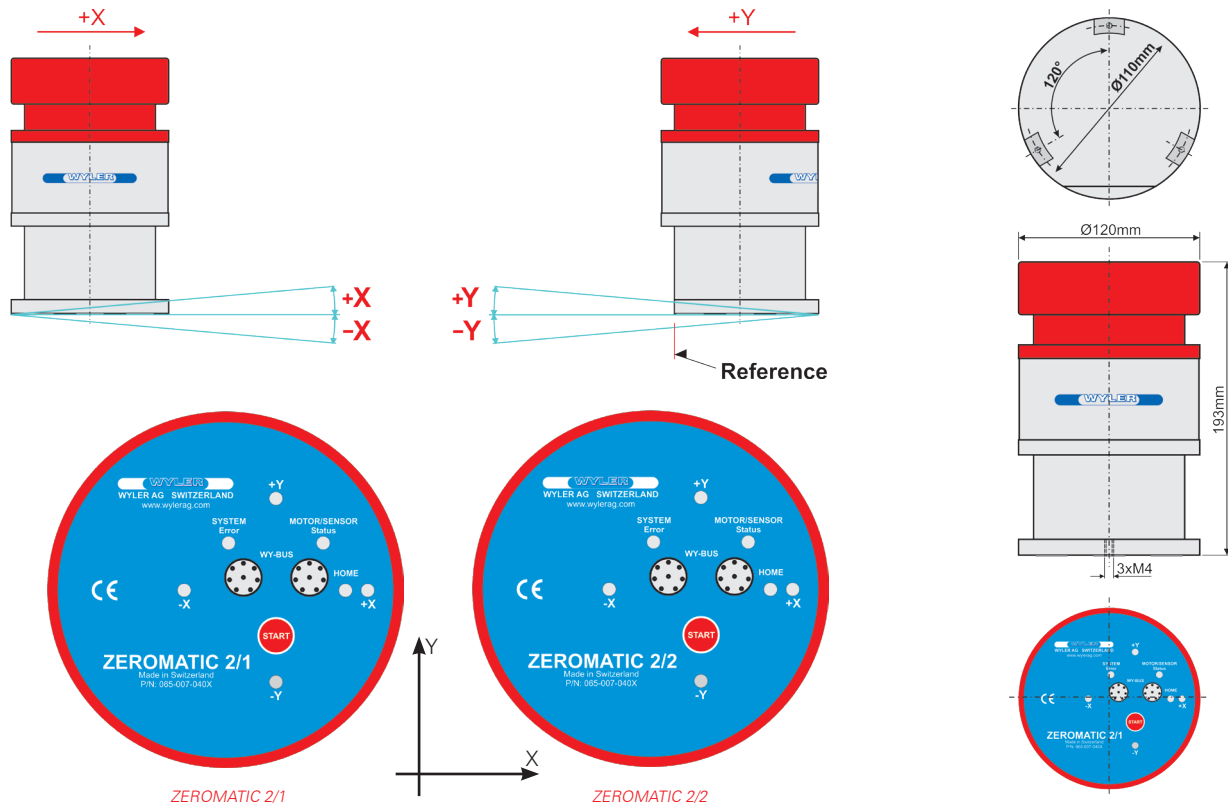
270° / 180° / 90° / 0°. After the last measurement, the rotor moves to the standby position and remains there until the next reversal measurement starts.

ZEROMATIC 2/2:

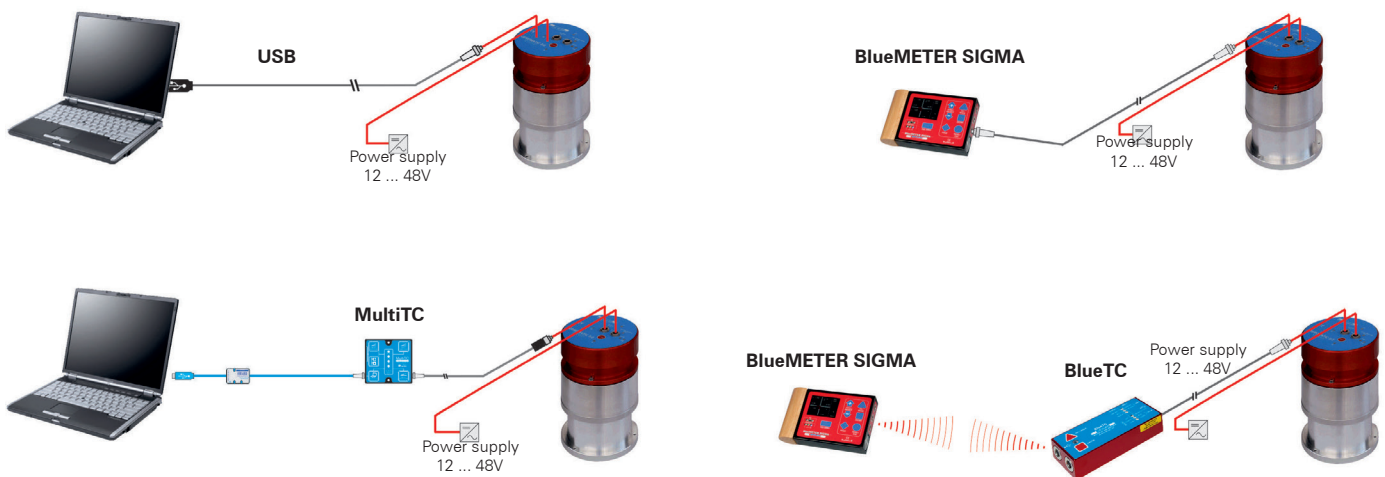
180° / 0°. The rotor remains (afterwards) in the 0° position. Sensors start to measure continuously.

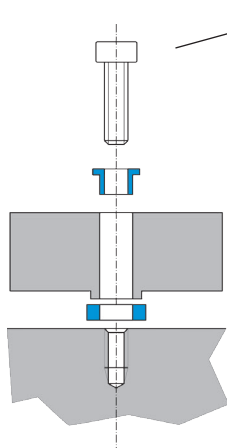


7.1.7.2 DIMENSIONS OF ZEROMATIC 2/1 AND 2/2



CONFIGURATIONS





M3

Insulation kit for ZEROMATIC sensor consisting of finely lapped ceramic discs, grommets, screws with thread M3 and washers.

Remark:

The threads M4 have to be drilled to $\varnothing 4,0$ mm.



RECOMMENDATION FOR THE MOUNTING OF THE ZEROMATIC

Usually when measurements are done on buildings a rectangular mounting bracket is required. With the ZEROMATIC instruments high precision inclination measurements can be done. It is however important to consider the following recommendations:

TEMPERATURE

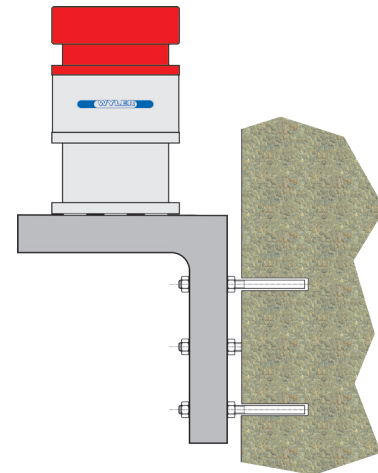
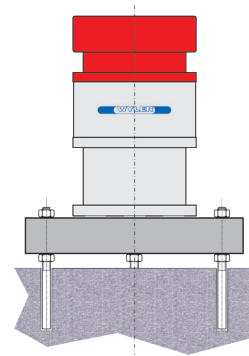
Temperature changes may have a great influence on the measured results. All around the ZEROMATIC the same temperature must be applied.

MECHANICAL TENSIONS

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.

THREE-POINT MOUNTING / DESIGN

Whenever possible, use a three-point mounting jig. Use the same geometry and homogenous material all over. Make a „center symmetrical“ design.

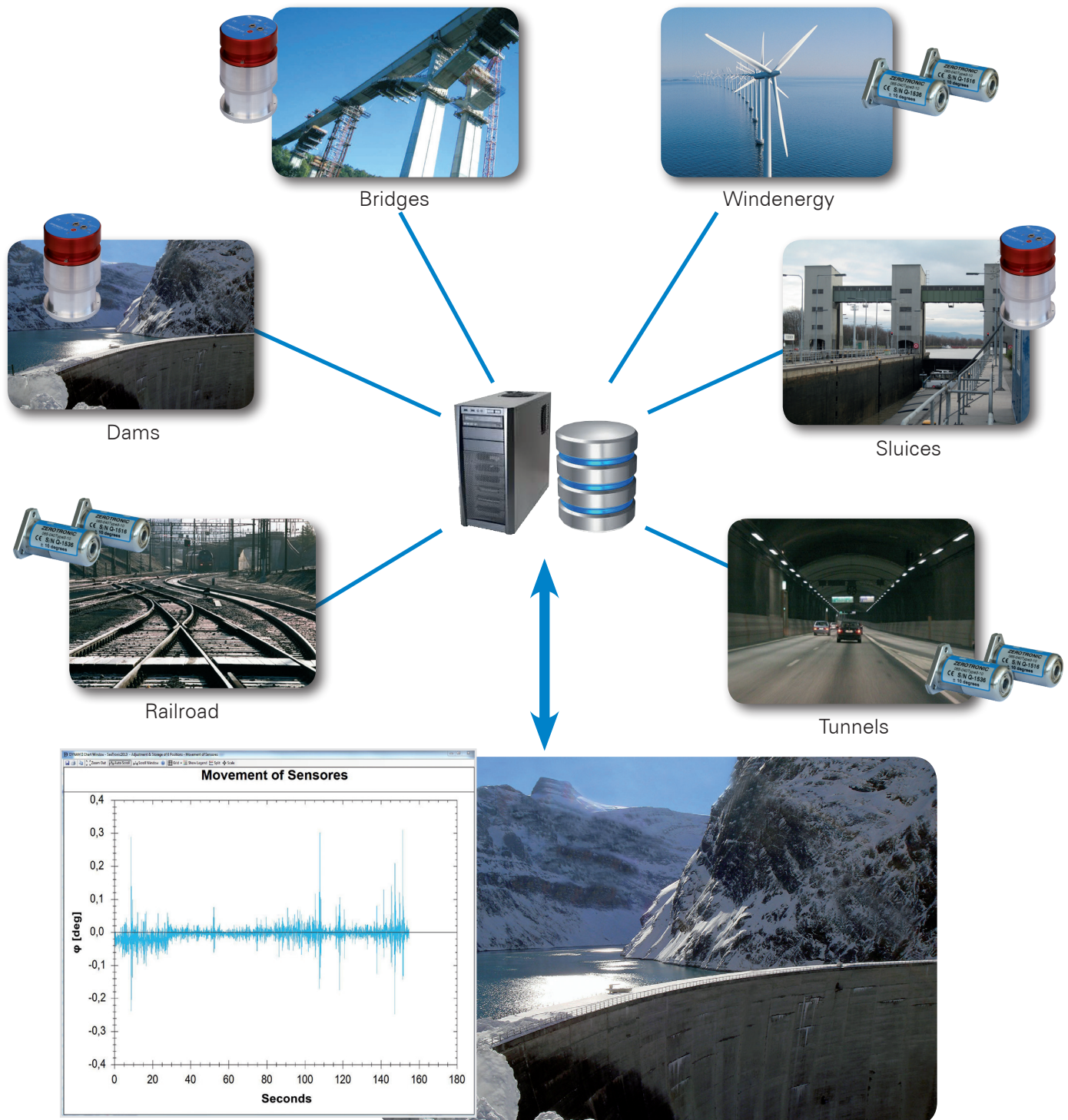


Protection cover IP67 wylerSOLID for ZEROMATIC including humidity absorber.

7.2 LONG-TERM MONITORING OF DAMS, BRIDGES OR BUILDINGS

For more complex applications one of the many Geo-Monitoring Systems available on the market can be used. Many of these systems already have established interfaces to WYLER sensors or their interfaces can easily be programmed.

Such systems are very well suited for short- or long-term monitoring of objects when several parameters like temperature, dilatation, inclination or others, have to be automatically registered, analyzed and graphically visualized. Typical objects are dams, bridges, buildings, tunnels or e.g. windmills. The collected data can then be analyzed and visualized either locally or remotely.



Webbased illustration of monitoring instruments

7.3 LONG-TERM MEASUREMENTS / MONITORING WITH ZEROMATIC

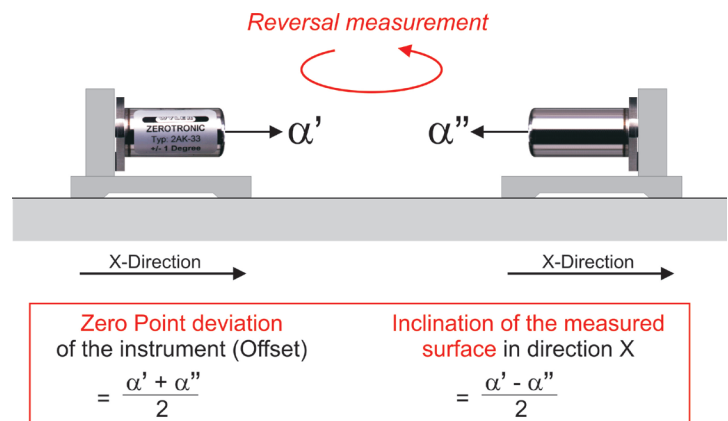
Inclination measuring devices and sensors operate according to Newton's law of gravitation (gravitational acceleration). Thanks to this law, it is possible to identify the absolute zero with a so-called reversal measurement.

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.

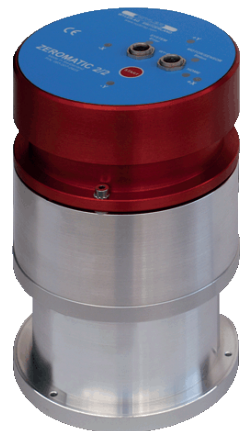
The limit of error of the entire system with a measurement range of ± 1 degree is **less than ± 1 Arcsec** for several months. The new inclinometer has successfully passed an extensive series of tests in varying conditions.

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.



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.

7.4 DATALOGGERS OPTIMALLY MATCHED TO WYLER MEASURING 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 objects:
 - Process-technology
 - Sluices
- Monitoring of machines:
 - Monitoring of machines running 24h a day
 - Monitoring of machines during commissioning
 - Measuring of errors on a machine

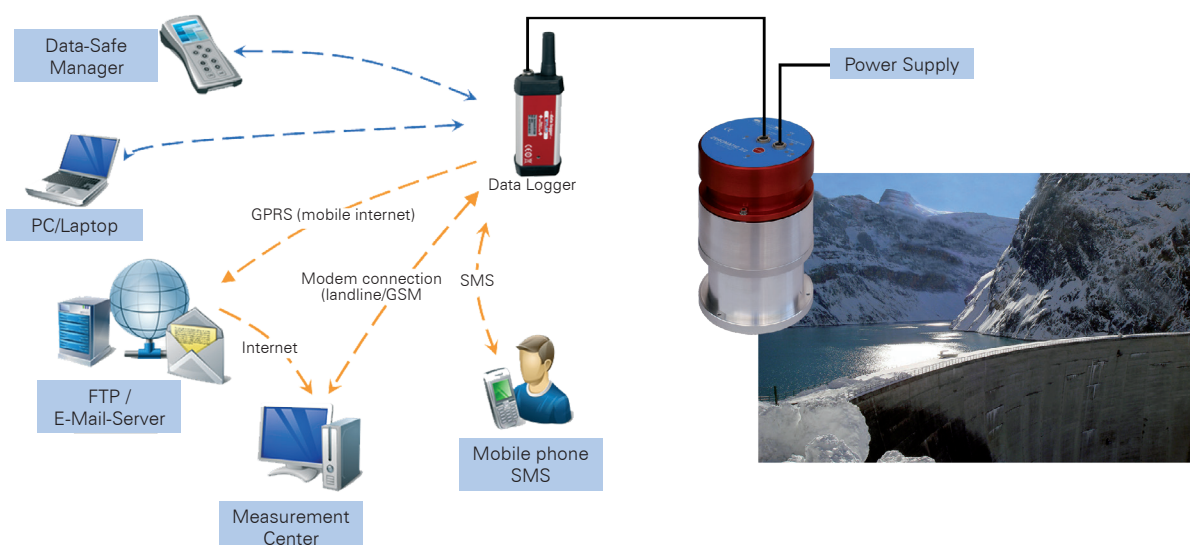


Key features:

- 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
- The ZEROMATIC cannot be configured with the Datalogger itself. Either a BlueMETER or the configuration software provided with the ZEROMATIC has to be used.

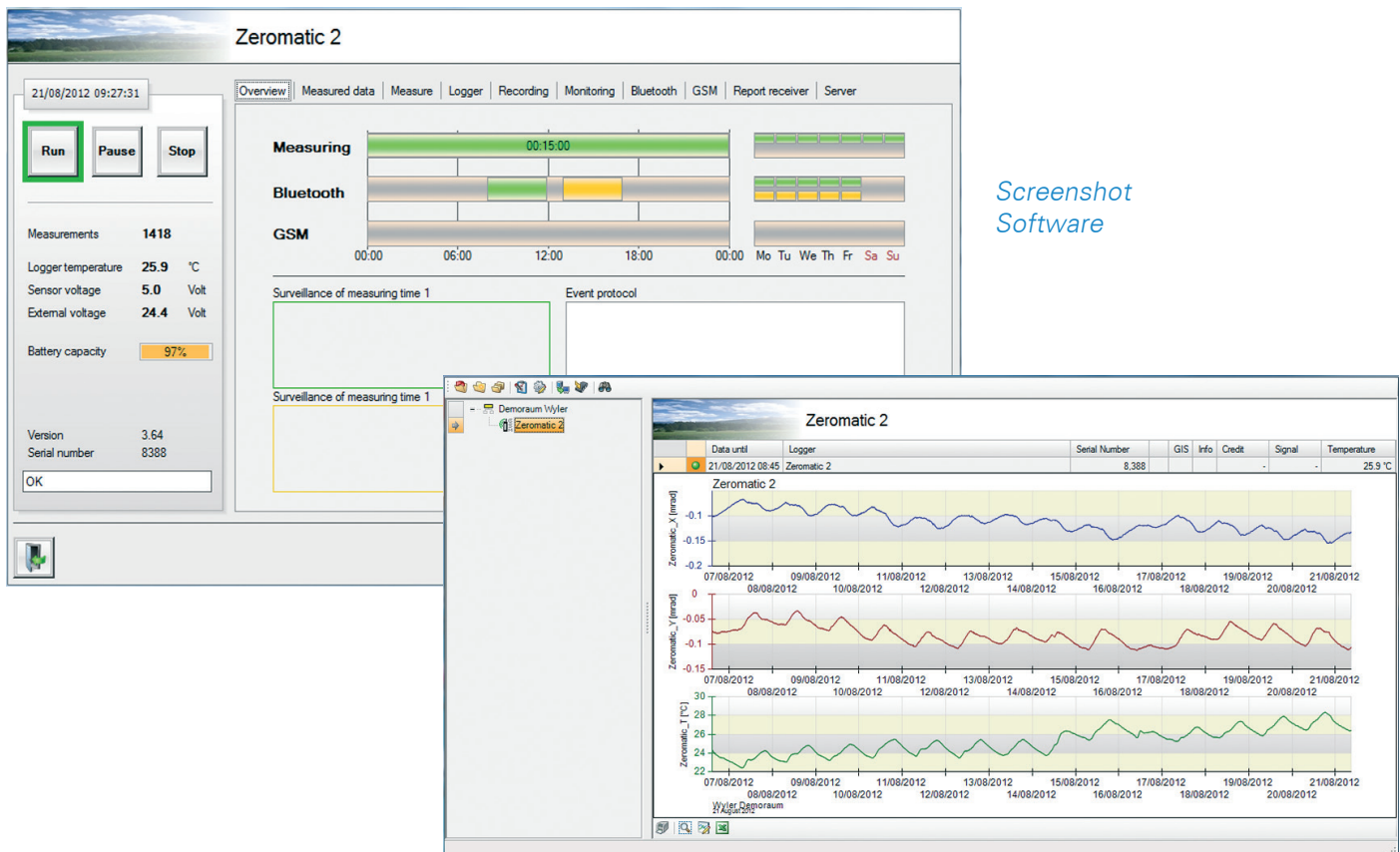
Possible configuration:

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.



TECHNICAL DATA

WYLER DATA LOGGER

Memory	Max. 80'000 points
Measuring frequency	Max.: 1 Hz; Min: 1 measurement per day
Operating temperature	Without / ohne GSM: - 40..+ 85 °C;
Dimensions	Ø x L : 39 x 103 / 139 mm
Weight	160g
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	Up to 2 time slots per day can be defined
IP	66

7.5 ANALOG INCLINATION SENSORS LEVELMATIC 31 AND LEVELMATIC C



LEVELMATIC 31



LEVELMATIC C

LEVELMATIC 31 and LEVELMATIC C analog sensors are analog sensors with an analog voltage / current output signal. These sensors have specifically been developed to be mounted on machines. Since the sensors are mounted in a tight, weatherproof, and shock-resistant housing, inclination measurements are possible even under difficult conditions. The sensors are easy to use, and require little technical know-how.

Family of LEVELMATIC sensors

The LEVELMATIC sensors have established themselves in the market as the benchmark when it comes to high precision measurement in demanding applications with analog output. The LEVELMATIC-family of sensors features the following characteristics:

- High resolution and high precision
- Excellent temperature stability
- Measuring range of ± 2 mRad to ± 20 mRad, respectively $\pm 15^\circ$ and $\pm 30^\circ$
- High immunity to shock
- High immunity to electromagnetic fields
- Simple handling

LEVELMATIC 31 and LEVELMATIC C

Common characteristics of the two sensors:

- The measuring element 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 sensor cell is completely encapsulated and thus protected against changes in humidity
- The output of the measuring value is a voltage which can be measured with commercially available electrical measuring instruments.

Difference in characteristics of the two sensors:

- The pendulum of the LEVELMATIC 31 is larger, which provides a significantly better signal-to-noise ratio for smaller inclinations. The LEVELMATIC 31 is therefore better suited for high precision applications where only small inclinations are measured.
- The mass of the pendulum of the LEVELMATIC C is smaller than the one of the LEVELMATIC 31. This provides a higher stability if the sensor is permanently inclined
- LEVELMATIC C has a wider measuring range
- The LEVELMATIC C has an additional current loop output with 4..20mA. The following list of characteristics should allow a proper differentiation and proper application of the 2 sensors.

The following list of characteristics should allow a proper differentiation and proper application of the 2 sensors:

LEVELMATIC 31

- High resolution, high precision for inclinations up to ± 20 mRad (roughly 1.15°)
- Excellent signal-to-noise ratio
- Excellent repeatability
- Excellent linearity
- Good temperature stability
- Maximum inclination corresponds to an output of ± 2000 mV

LEVELMATIC C

- Excellent precision for inclinations up to $\pm 30^\circ$
- Supply voltage can be chosen between ± 12 V and ± 18 V DC
- Excellent repeatability
- Excellent long-term stability in inclined position
- Excellent linearity
- Excellent temperature stability
- Maximum inclination corresponds to an output voltage of ± 1 V, ± 2.5 V, or ± 5 V and an output current of 4..20 mA

7.5.1 MEASUREMENT PRINCIPLE LEVELMATIC SENSOR (SIMILAR TO MINILEVEL NT + LEVELTRONIC NT)

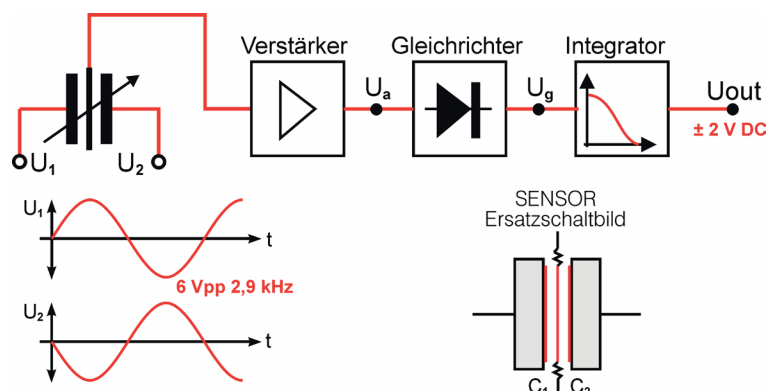
The LEVELMATIC sensor is based on the pendulum properties of a friction-free supported disc of a mass weighing less than 1 gram. A two-phase frequency (2.9 kHz) is supplied to two electrodes, which together with the pendulum disc supported in the shielded and dust-proof gap between them, build a differential 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.

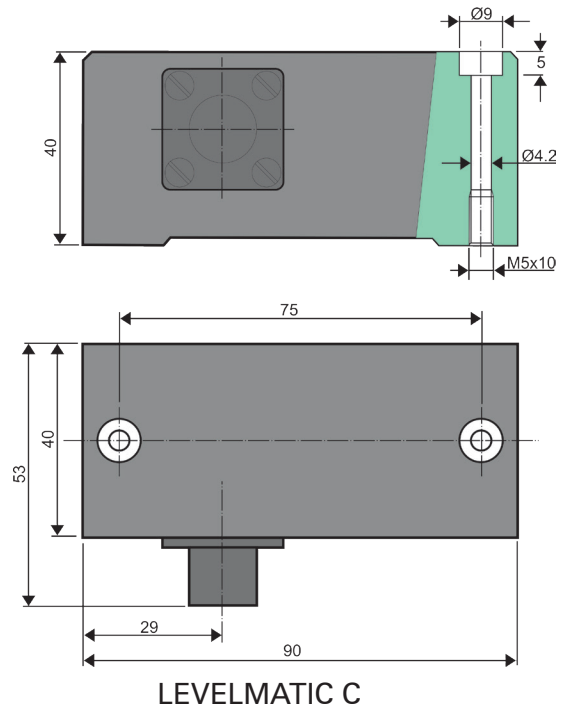
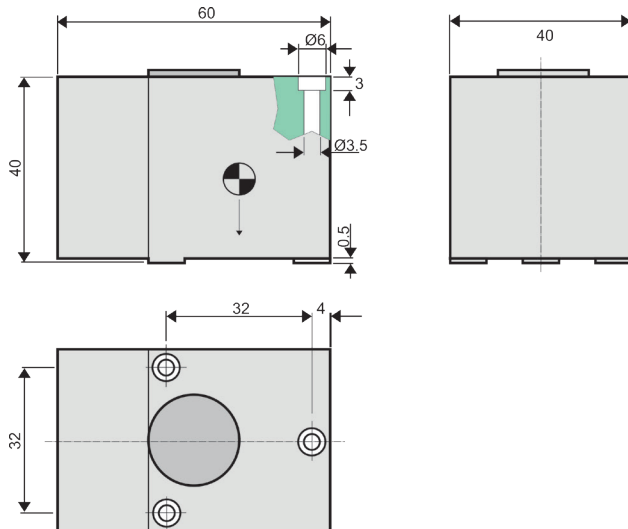


Remark:

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

LEVELMATIC 31



TECHNICAL SPECIFICATIONS LEVELMATIC 31

Sensitivity, 1 mVolt =	1 μ Rad	2,5 μ Rad	5 μ Rad	10 μ Rad	25 μ Rad
Full-scale	± 2 mRad	± 5 mRad	± 10 mRad	± 20 mRad	± 50 mRad
Power supply	± 5 V DC $\pm 1\%$, stabilisiert				
Output voltage / V	± 2000 mV DC an 100 kOhm				
Repetition	< 0,025% Full-scale				
Linearity	$\pm 0,5\%$ Full-scale				
Operating temperature	0 ... 60 °C				
Temperature error/ °C (Ø10°C)	Nullpunkt:		$\pm 0,05\%$ Full-scale / per Grad Celsius		
	Empfindlichkeit:		$\pm 0,05\%$ Read-out / per Grad Celsius		

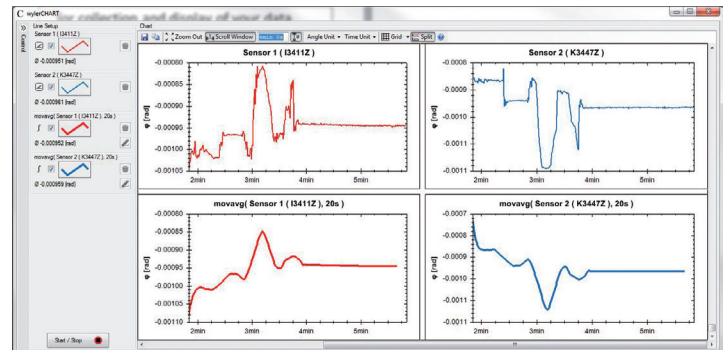
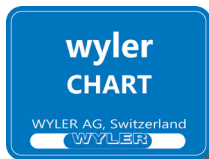
TECHNICAL SPECIFICATIONS LEVELMATIC C

	LEVELMATIC C / ±15°			LEVELMATIC C / ±30°		
Full-scale	±15°			±30°		
Output voltage / V	±1 V at/an 100 kΩ	±2.5 V at/an 100 kΩ	±5 V at/an 100 kΩ	±1 V at/an 100 kΩ	±2.5 V at/an 100 kΩ	±5 V at/an 100 kΩ
Sensitivity/mV	0.015°	0.006°	0.003°	0.030°	0.012°	0.006°
Output current / mA	4 ... 20 mA			4 ... 20 mA		
Output current/degree / mA	0.533 mA			0.267 mA		
Repetition	<0.075 % M _E			<0.08 % M _E		
Linearity	±0.4 % M _E			±0.2 % M _E		
Temperature error/ °C (Ø10°C)	Zero / Nullpunkt: ±0.03 % M _E Gain max.: -1...1[%] (-40 °C ... + 85 °C)			Zero / Nullpunkt: ±0.02 % M _E Gain max.: -1...1[%] (-40 °C ... + 85 °C)		
Response time	within 0.8 seconds / innerhalb von 0.8 Sekunden					

7.6 SOFTWARE WYLERSOFT FOR MONITORING

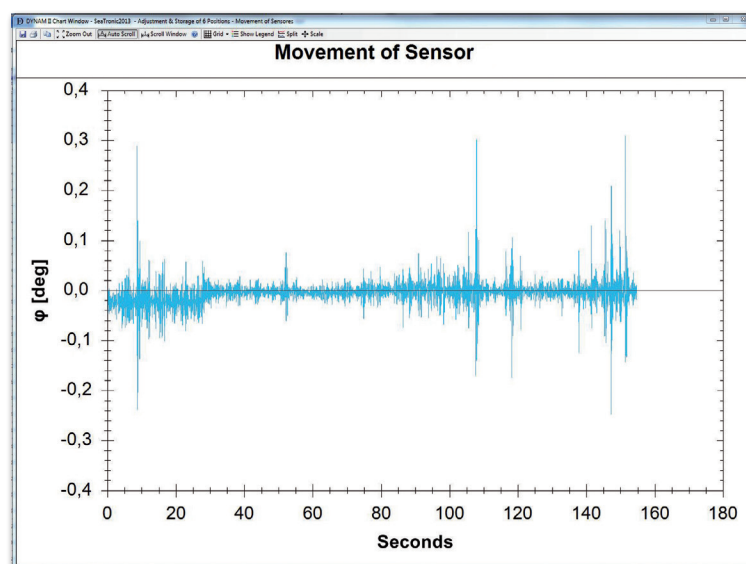
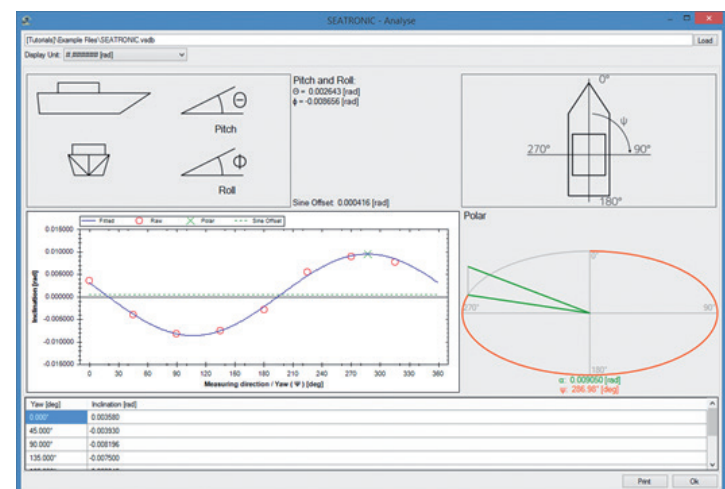
7.6.1 SOFTWARE WYLERCHART

wylerCHART collects measuring data from Wyler inclination measuring instruments as ZEROTRONIC sensors. These measuring results are automatically read in a csv file and can be further processed with EXCEL.



7.6.2 SOFTWARE WYLERDYNAM

wylerDYNAM offers a wide range of solutions adaptable to all measuring tasks. With only a few clicks simple measuring tasks can be started. Thanks to its great flexibility also complex measuring tasks can be solved.



7.6.3 MESSSOFTWARE WYLERINSERT

wylerINSERT is an easy to use yet powerful tool to read inclination values from WYLER BlueSystem devices and insert them into any program at the current position of the cursor just like the values were typed in. It can be configured that it adds a key stroke like {TAB}, {ENTER} or a combination of after each inserted value. This way it is possible to position the cursor to the next insert position.

As soon as the measurement starts wylerINSERT collapses to free the input to the desired application like Excel or Word. To stop measurement doubleclick on the wylerINSERT icon in the system tray at the lower right corner. The dialog comes up to front and the measurement can be stopped. wylerINSERT works with WYLER BlueSystem devices using a IR trigger (zapper) only.



7.6.4 WYLER SOFTWARE 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 WYLER sensors either direct 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

System requirements for the WYLER software interface:

[Microsoft .NET framework 2.0](#)



License with USB dongle

8. Inclination measuring instruments with digital output signal

8.1 Inclination measuring instrument CLINOTRONIC PLUS

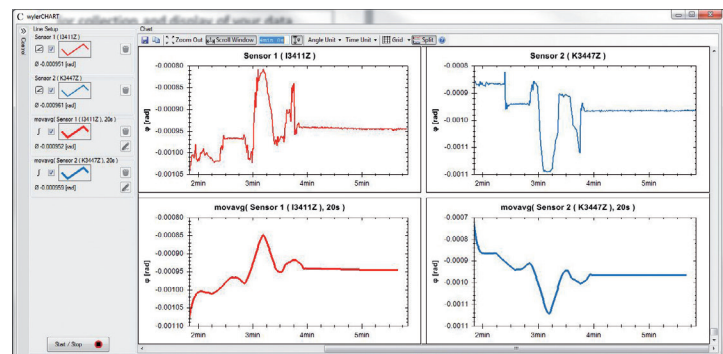
The Clinotronic PLUS provides a measuring capacity of ± 45 degrees. Four precisely machined exterior reference surfaces assure accuracy and repeatability of measurements in any quadrant. Selected by push-button, any units suitable for inclination measurement may be applied to the display. Even slope indication based on a relative base of selectable length is possible. Simple push-button operation automatically sets absolute as well as relative zero.

The RS485 interface allows the connection to other WYLER instruments or directly to a PC using a special cable. All indicated values are computed prior to display, by interpolation of calibration values stored. If required, an integrated calibration mode may be actuated in order to replace the stored calibration data. For this purpose, the Clinotronic PLUS $\pm 45^\circ$ 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. The latest version of the reliable inclination measuring instrument comes with a number of new interesting advantages. The most important of them are:

- Aluminum housing, hard anodised, with heavier walls for more stability,
- Fulfills the strict CE requirements (immune to electromagnetic smog)
- Powered by standard 1.5 V batteries, allowing cost-efficient reliability all over the world
- Various connecting possibilities to a PC
- All the well known functions remain the same such as e.g.:
 - Easy zero-point adjustment
 - Wide variety of different units displayed
 - Absolute and relative measurement
- As options magnetic inserts and threaded holes are available



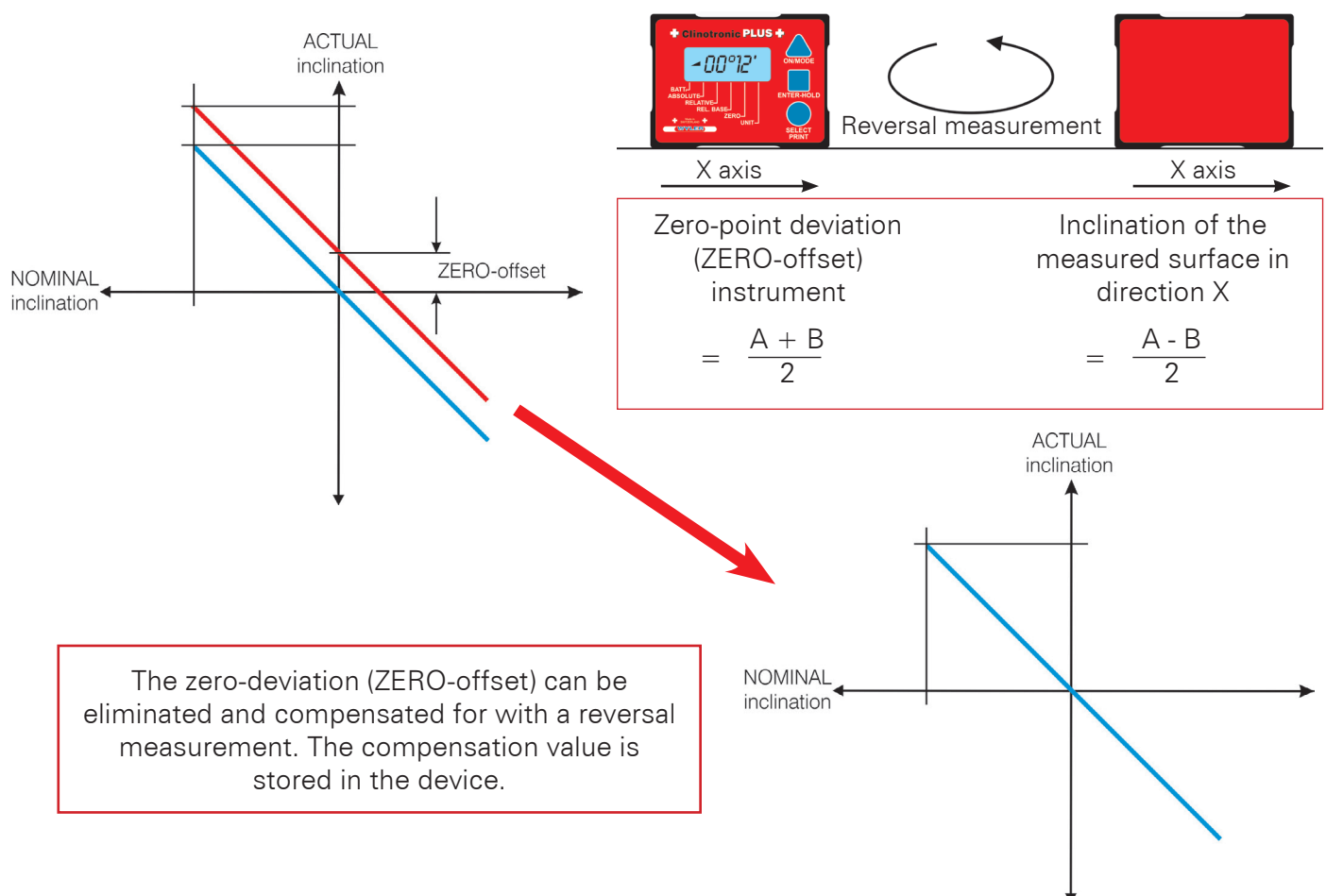
Die dazugehörige Software
wylerCHART

TECHNICAL SPECIFICATIONS CLINOTRONIC PLUS

Measuring range	$\pm 45^\circ$		
Sensitivity depends on units set	5 arcsec		
Within the range of ...	0 ... 10°	10 ... 30°	30 ... 45°
the valid Limits of error is	<1 arcmin + 1 digit	<1.5 arcmin + 1 digit	<2 arcmin + 1 digit
Response time (DIN 2276/2)	< 5 sec		
Digital output	RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps		
Batterie - Size AA	1 x 1.5 V Alkaline		
Optional (rechargeable)	1 x 1.2 V NiMH		
CE conformity			
Meets emission and immunity requirements			

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.



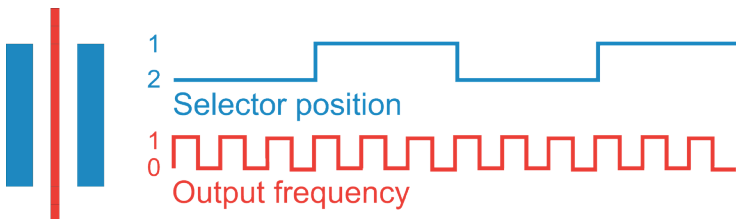
CLINOMASTER FOR THE CALIBRATION OF THE CLINOTRONIC PLUS WITH MEASURING RANGE OF $\pm 45^\circ$

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.

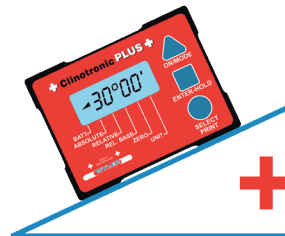
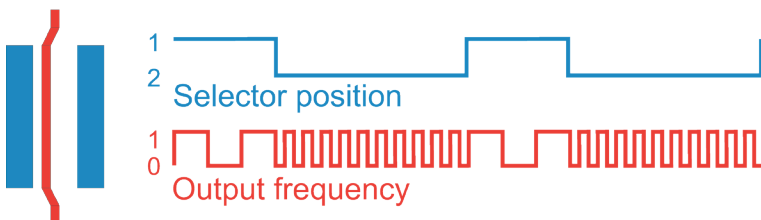
Note: Traceability is the ability to chronologically interrelate uniquely identifiable entities in a way that is verifiable.



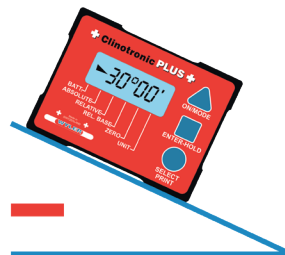
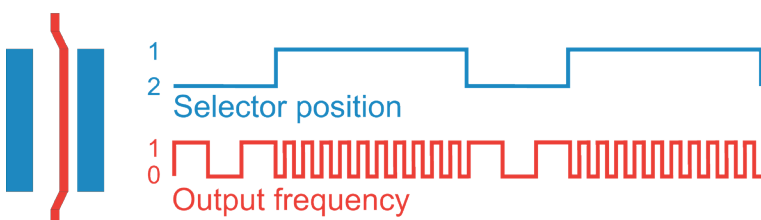
INCLINATION OF THE INSTRUMENT - DEFLECTION OF THE PENDULUM - CHARACTERISTIC OF THE FREQUENCY



No inclination
Pendulum in
ZERO Position



Positive inclination
Pendulum closer to
the left electrode

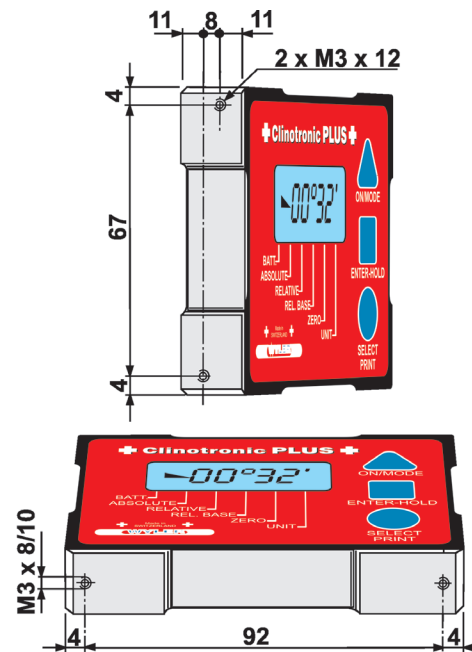
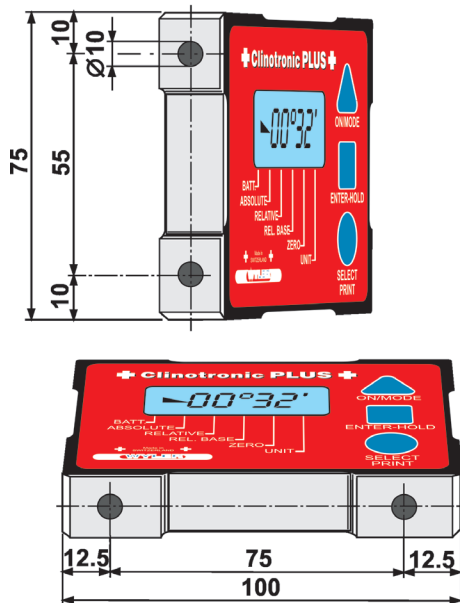
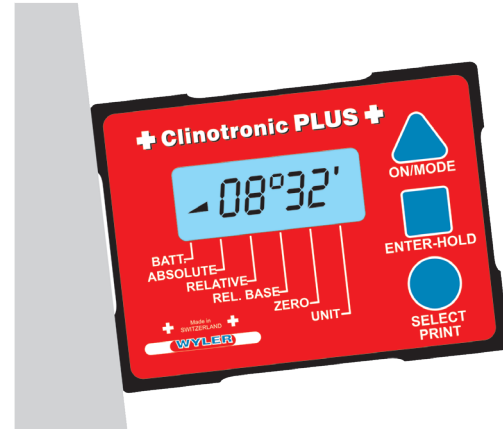


Negative inclination
Pendulum closer to
the right electrode

THE FOLLOWING MEASURING UNITS MAY BE SELECTED:

mm/m (2 Dec)	00.00 mm/m	Milliradian (2 Dec)	00.00 mrad	Degrees / Arcmin	00° 00'	mm / rel.Basis	00.00 mm/m
Inch / 10 Inches	.00 00 "/10"	Milliradian	00 00 mrad	Arcmin / Arcsec	00' 00"	mm / rel.Basis	.00 00 mm/m
Inch / 12 Inches	.00 00 "/12"	Degrees (2 Dec)	00.00°	GON Grad (2 Dec)	00.00 gon	Inch / rel.Basis	.00 00 "/10"
artillery per mille	00 00	Degrees (4 Dec)	.00 00°	GON Grad (4 Dec)	.00 00 gon		

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 INCLINATION MEASURING INSTRUMENT CLINOTRONIC S

Clinotronic S is building on the success of the Clinotronic PLUS. It keeps those features of the Clinotronic PLUS, which made it famous, like its reliability, accuracy, and easiness to use - and adds latest technology to it:

- **Wireless functionality**
- **Excellent display**
- **User friendly**
- **Adjusted to local gravity**

Clinotronic S



WIRELESS FUNCTIONALITY

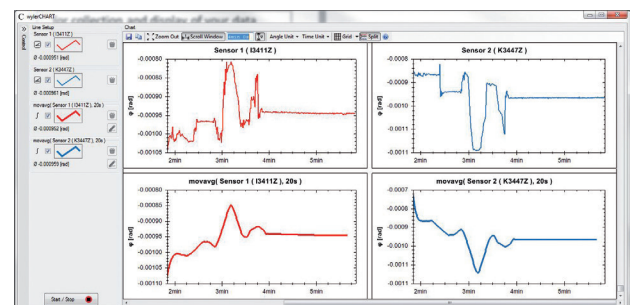
Clinotronic S can be connected to an Android™ or iOS™ device, which can then be used as remote displays. This new feature makes the instrument much more versatile and opens up new applications.



MEASURING PRINCIPLE OF DIGITAL MEASURING SYSTEMS

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. The latest version of the reliable inclination measuring instrument comes with a number of new interesting advantages. The most important of them are:

- Aluminium housing, hard anodised, with heavier walls for more stability. Fulfils the strict CE requirements (immune to electromagnetic smog)
- Powered by standard 1.5V batteries, allowing cost-efficient reliability all over the world
- Various connecting possibilities to a PC, also via wireless data transmission
- All the well known functions remain the same such as e.g.:
 - Easy zero-point adjustment
 - Wide variety of different units displayed
 - Absolute and relative measurement
- As options magnetic inserts and threaded holes are available



Die dazugehörige Software
wylerCHART

Excellent display

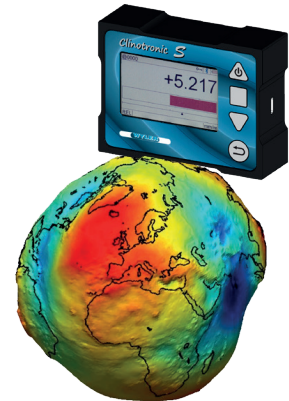
The large color display is backlit and has a high contrast. It therefore provides excellent readability even under adverse conditions like a workshop or under a machine..

User friendly

The completely redesigned Man-Machine-Interface allows a very intuitive handling.

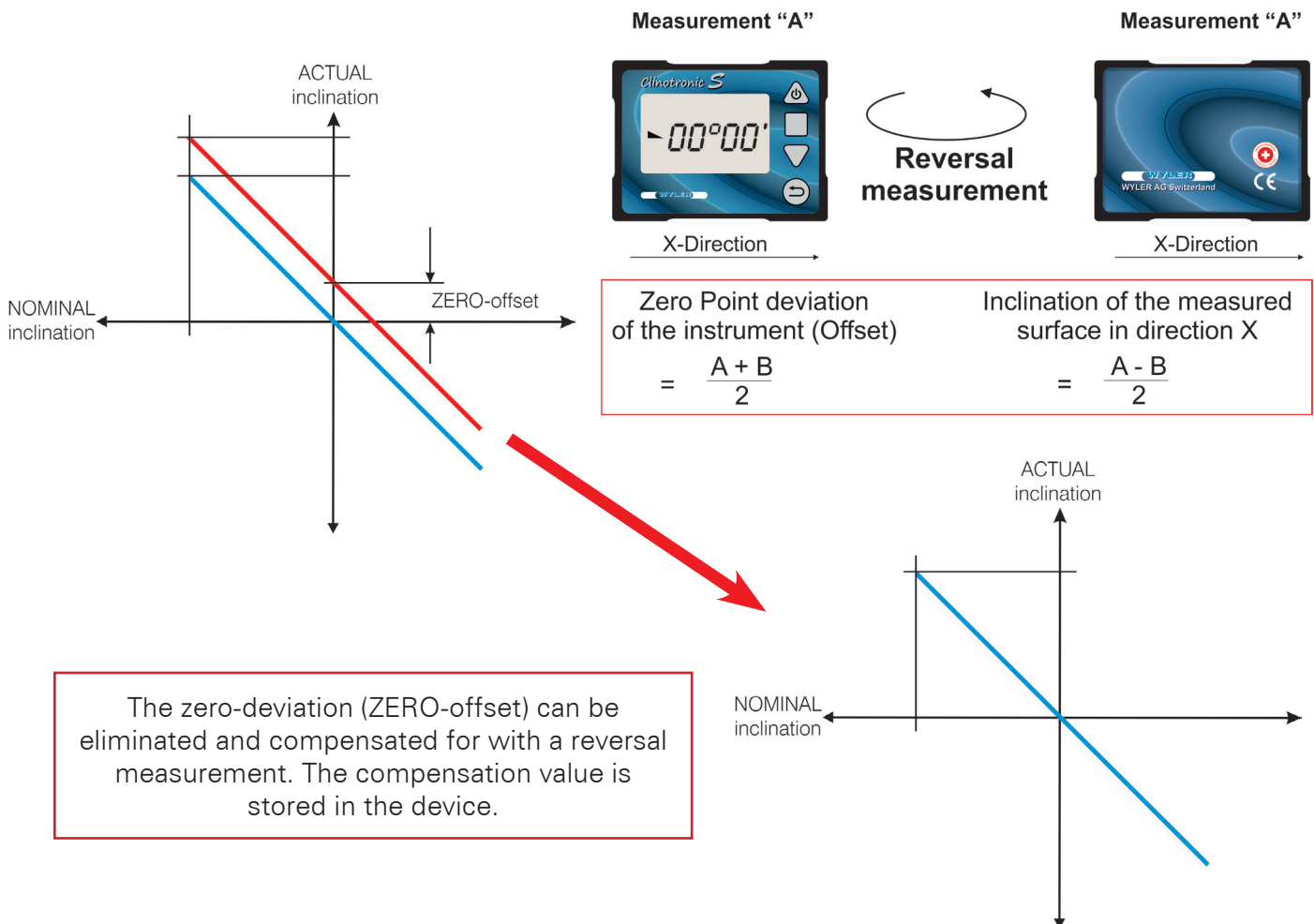
Adjusted to local gravity

To ensure best possible accuracy the Clinotronic S can be adjusted to local gravity.



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

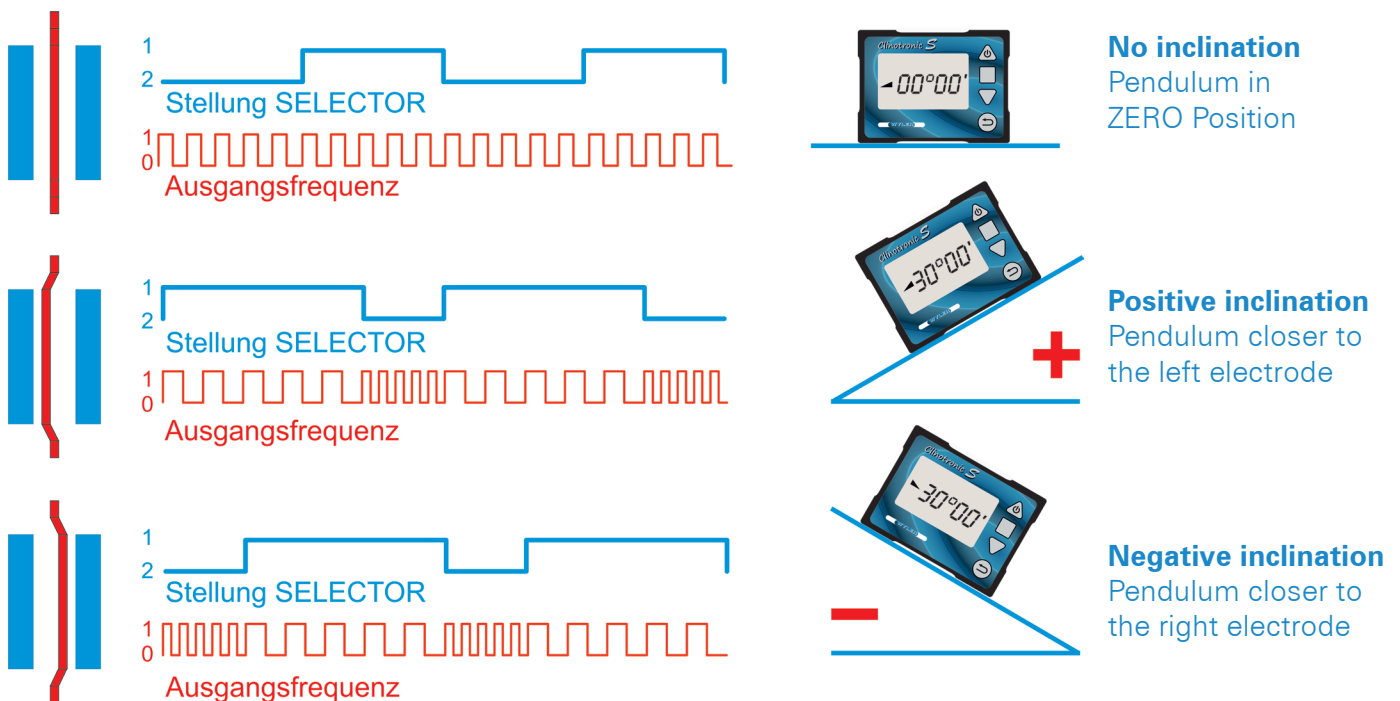
Each instrument has, with increasing duration of use, a so-called drift and a ZERO-offset. This "error" may be compensated for by a reversal measurement on a CLINOTRONIC S. If the ZERO-OFFSET as well as the linearity are out of tolerance, the instrument must be recalibrated.



TECHNICAL SPECIFICATION CLINOTRONIC S

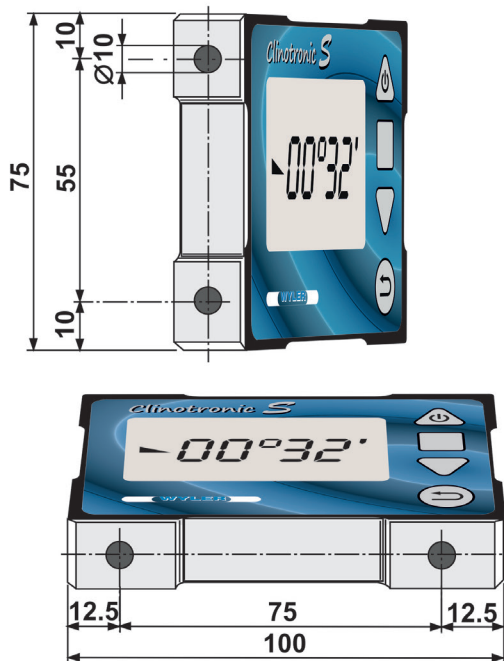
Measuring range	$\pm 45^\circ$
Resolution	5 arcsec
Limit of errors M_w = Measured value	10 arcsec + 0.03% M_w
Power / Battery	Battery: rechargeable External Power supply: 5V via USB-C
Dimensions L x W x H	100 x 75 x 30mm
Weight	ca. 400g (depending on inserts)

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

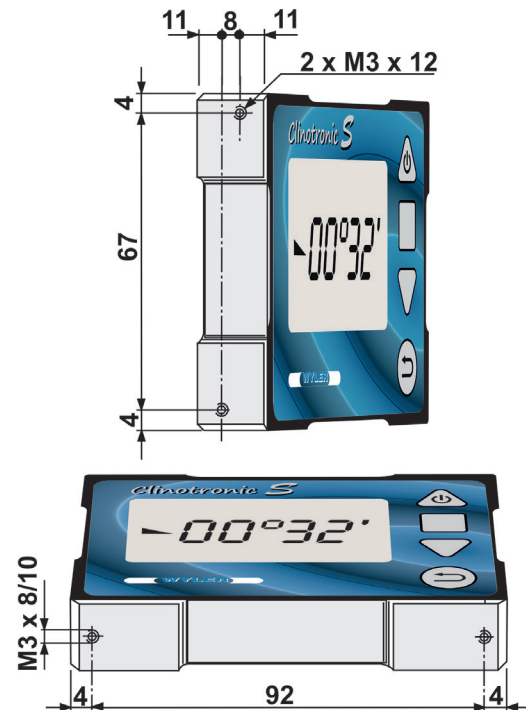


THE FOLLOWING MEASURING UNITS MAY BE SELECTED:

mm/m (2 Dec)	00.00 mm/m	Milliradian (2 Dec)	00.00 mrad	Degrees / Arcmin	00° 00'	mm / rel.Basis	00.00 mm/m
Inch / 10 Inches	.00 00 "/10"	Milliradian	00 00 mrad	Arcmin / Arcsec	00' 00"	mm / rel.Basis	.00 00 mm/m
Inch / 12 Inches	.00 00 "/12"	Degrees (2 Dec)	00.00°	GON Grad (2 Dec)	00.00 gon	Inch / rel.Basis	.00 00 "/10"
artillery per mille	00 00	Degrees (4 Dec)	.00 00°	GON Grad (4 Dec)	.00 00 gon		



Left:
CLINOTRONIC S with magnetic inserts
left and bottom



Right:
CLINOTRONIC S threaded holes M3
left and bottom

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:

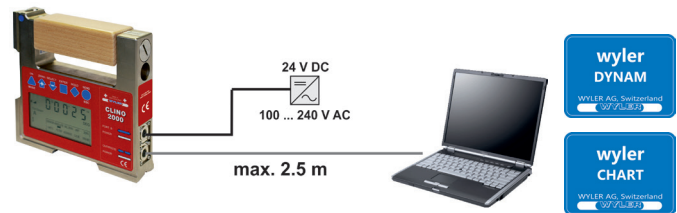
- A highest possible precision over the large measuring range of $\pm 45^\circ / \pm 60^\circ / \pm 30^\circ / \pm 10^\circ$, with integrated temperature compensation
- Effortless zero adjustment by using the integrated software and a reversal measurement
- Easy calibration due to implemented software guidance and the calibration aids as part of the delivery (for the CLINO 2000 / $\pm 45^\circ$ 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
- Fulfills the strict CE requirements (immunity against electromagnetic smog).
- As an option, magnetic inserts are available

The following **measuring units** may be selected:

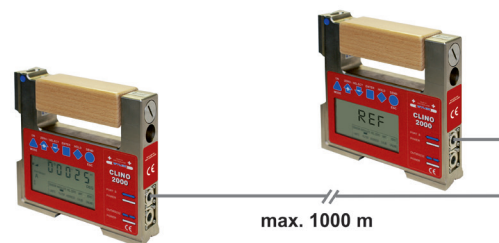
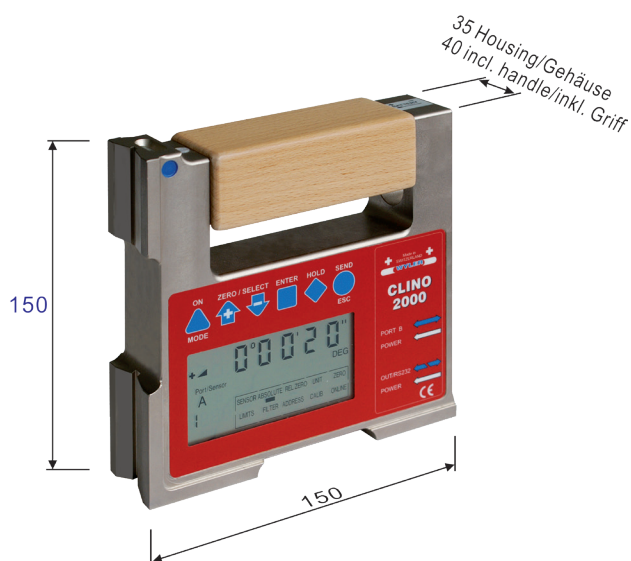
mm/m (2 Dec)	xxxx.xx mm/m	mm/ relative basis	xxx.xx mm/ REL	Degrees/Arcmin/ Arcsec	xx° xx' xx"	GON / Grad (3 Dec)	xx.xxx gon
Inch / 10 Inches	xx.xxxx"/10"	Zoll/ relative basis	xx.xxxx "/ REL	Arcmin / Arcsec	xxx' xx"	per mille	xxx.xx‰
Inch / 12 Inches	xx.xxxx"/12"	Degrees/ Arcmin	xxx° xx'	Degrees (3 Dec)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

TECHNICAL SPECIFICATIONS CLINO 2000

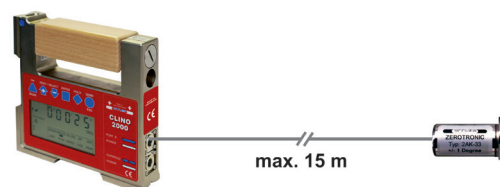
Measuring range	±45 degrees
Sensitivity	5 arcsec
Response time (DIN 2276/2)	<5 seconds
Limits of error within 6 months / Gain (20 °C) M_W = Measured value	<10 arcsec + 0.03% M_W
Quick calibration	Correction of gain by simple three-point-method with built-in Software
Limits of error after quick calibration M_W = Measured value	<10 arcsec + 0.03% M_W max. 30 arcsec
Data connections	RS232 / RS485, asynchr., 7 DataBits, 2 StopBits, no parity, 9600 bps
External power supply	+ 12 ... + 48 V DC / 200 - 500 mW
CE conformity	Fulfills emission and immunity requirements



CLINO 2000 connected to a PC / RS232



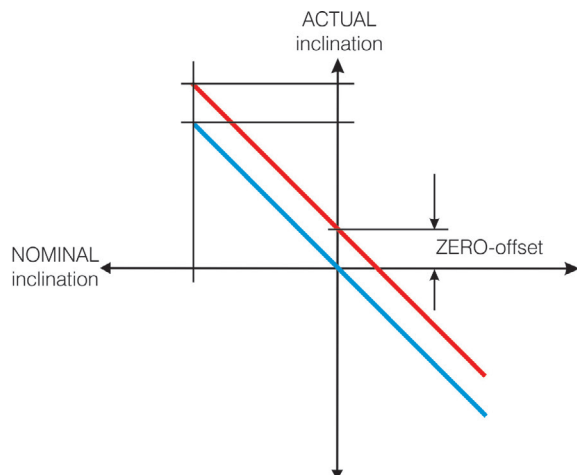
Two CLINO 2000 connected to each other; one instrument used as measuring instrument, the other as reference instrument



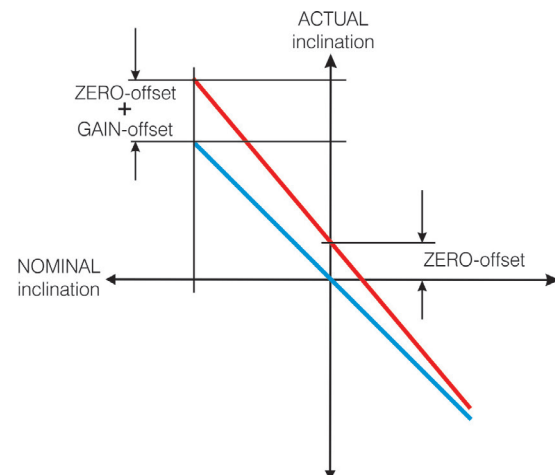
CLINO 2000 connected with ZEROTRONIC-sensor / max. 15 m

**CORRECTION ZERO AND GAIN ERROR (ZERO-OFFSET AND GAIN-OFFSET) FOR
HANDHELD INSTRUMENT CLINO 2000**

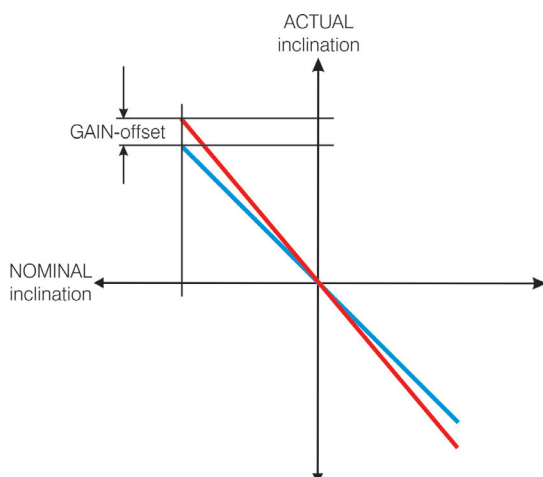
Each instrument has, with increasing duration of use, a so-called drift and a ZERO-offset. This "error" may be compensated for by a reversal measurement on a CLINO 2000. If the ZERO-offset as well as the linearity are out of tolerance, it is **easy to calibrate the CLINO 2000 $\pm 45^\circ$** thanks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



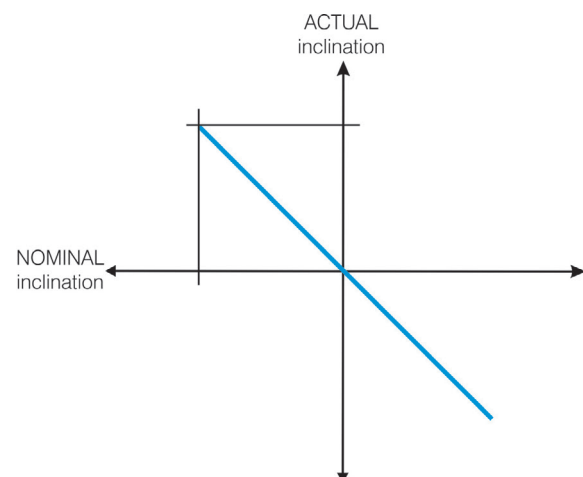
The zero-deviation (ZERO-offset) can be eliminated, or compensated for with a reversal measurement.



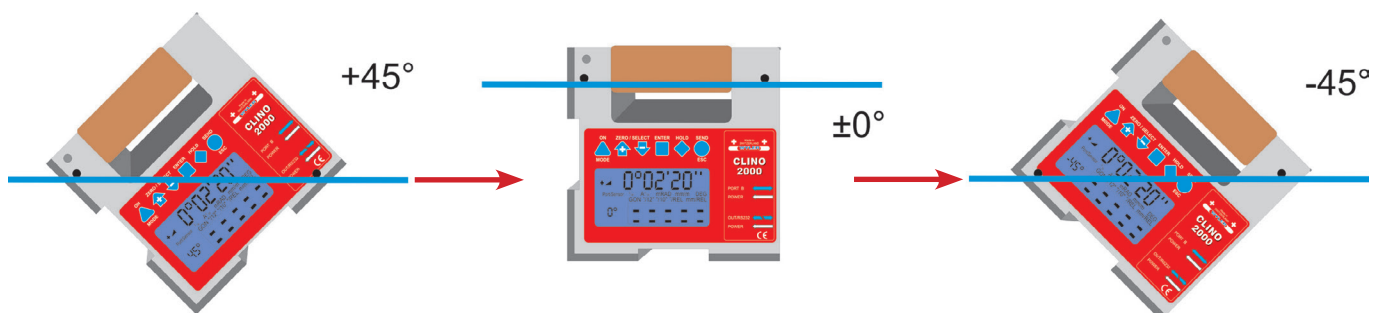
If the ZERO-offset as well as the linearity (GAIN-error) are out of tolerance, only the ZERO-offset can be compensated by a reversal measurement. The GAIN-error will remain.



The GAIN-error will remain. This error can be corrected 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 $\pm 45^\circ$.

8.4 INCLINATION MEASURING INSTRUMENT BLUECLINO

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

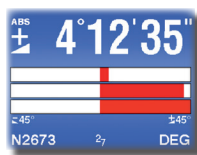
- With radio data transmission
- Large and very easy-to-read color display
- Various color profiles can be chosen
- Various display methods such as bar graphs or spirit levels can be chosen
- All current units can be indicated
- High precision over the entire measuring range of $\pm 10^\circ$ or $\pm 60^\circ$ with integrated temperature compensation
- The internal software, together with a reversal measurement, a simple zero setting
- Rugged housing, with prismatic bases made of either aluminum hard anodized or cast iron, nickel plated
- 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 1.5 V batteries, rechargeable batteries or with mains adapter
- Fulfills the strict CE requirements (immunity against electromagnetic smog)
- The instrument can be adjusted to local gravitation
- Options:
 - 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



The following display types are available in the BlueCLINO:



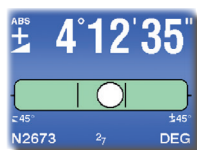
Numeric display plus
bar graph



Numeric display plus
3 bars



Numeric display plus
LED-display



Numeric display plus
simple vial



Numeric display plus vial



Numeric display plus pin

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

The instrument is available in two versions:



BlueCLINO with prismatic bases made of cast iron, rust protected



BlueCLINO with prismatic bases made of hard anodized aluminum

TECHNICAL SPECIFICATIONS BLUECLINO

Measuring range	± 10°	± 60°
Sensitivity	2 arcsec	5 arcsec
Limits of error within 6 months Gain TA = 20 °C M _w = measured value	< 3.6 arcsec + 0.06 % M _w	< 12 arcsec + 0.027 % M _w
Temperature error (DIN 2276/2) / °C (Ø 10 °C) M _w = measured value	max. 0.03 % M _w	
Response time (DIN 2276/2)	< 5 sec	
Digital output	RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps	
Batteries - Size C Optional (rechargeable)	2 x 1.5 V Alkaline 2 x 1.2 V NiMH	
External power supply	+5V DC / +24 V DC	
Radio module Frequency	Bluetooth ISM Band / 2.4000 ... 2.4835 GHz	
Two prismatic measuring basis, left and bottom, for shafts with ... one flat measuring base, right	Ø 19 ... 108 mm	
CE conformity: Meets emission and immunity requirements		

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‰				



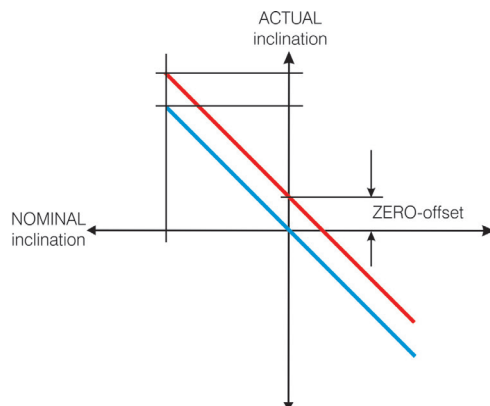
Easy to calibrate (option)

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

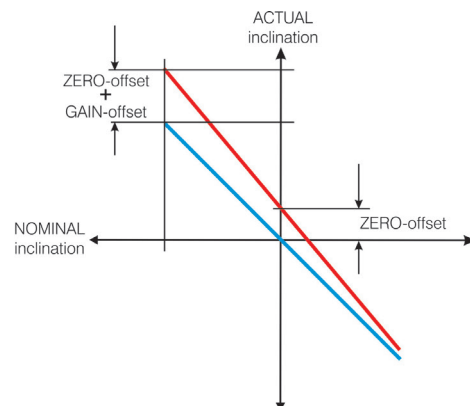
Technical drawing BlueCLINO

CORRECTION ZERO AND GAIN ERROR (ZERO-OFFSET AND GAIN-OFFSET) FOR HANDHELD INSTRUMENT BLUECLINO

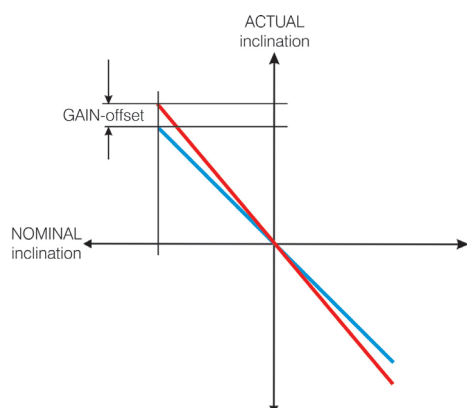
Each instrument has, with increasing duration of use, a so-called drift and a ZERO-offset. This "error" may be compensated for by a reversal measurement on a BlueCLINO. If the ZERO-offset as well as the linearity are out of tolerance, it is **easy to calibrate the BlueCLINO** (option) thanks to implemented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



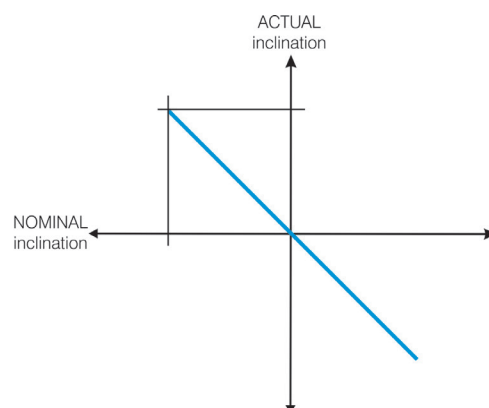
The zero-deviation (ZERO-offset) can be eliminated, or compensated for with a reversal measurement.



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 corrected thanks to implemented software guidance and the calibration aids.



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

8.5 INCLINATION MEASURING INSTRUMENT **BlueCLINO High Precision**

BlueCLINO *High Precision* is based on the successful standard BlueCLINO which has a measuring range of $\pm 60^\circ$. This huge measuring range has opened new and interesting applications for the standard BlueCLINO as e.g. the construction of antennas or road and railroad construction. But, when it comes to the precise alignment of parts of a machine tool, the standard BlueCLINO quickly reaches its limits. This is exactly where the new BlueCLINO *High Precision* comes into the picture: with a measuring range of $\pm 20\text{mm/m}$ (approx. $\pm 1^\circ$) and scraped bases (left and below), this instrument provides the necessary precision for small inclinations which is required in precision machine tool building.

Therewith the BlueCLINO *High Precision* combines the accuracy of an angular 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 specifically interesting with the help of the additional vertical base on the right hand side of the instrument
- Squareness-measurement
- The BlueCLINO *High Precision* belongs to the BlueSYSTEM SIGMA family and can be easily integrated



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

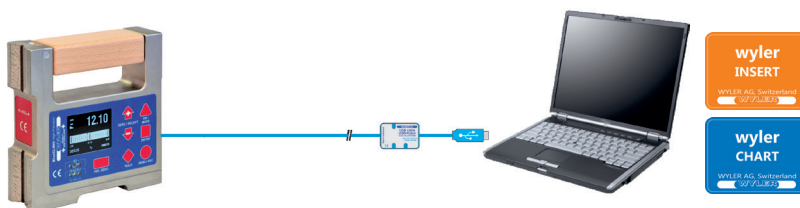
- Large and very easy-to-read color display
- Various color profiles can be chosen
- Various display methods are available, e.g. bar graphs or spirit levels can be chosen
- All current units can be indicated
- Measuring range of $\pm 1^\circ$ (corresponds to approximately $\pm 18\text{ mm/m}$)
- High 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 1.5 V batteries, rechargeable batteries or with mains adapter
- Fulfills the strict CE requirements (immunity against electromagnetic smog)
- The instrument can be adjusted to local gravitation

TECHNICAL SPECIFICATIONS **BLUECLINO High Precision**

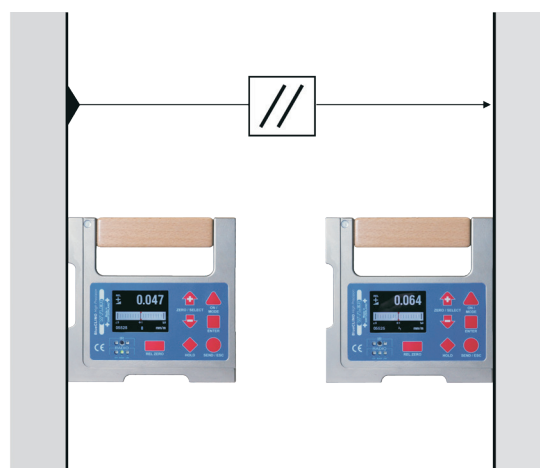
Measuring range	$\pm 20 \text{ mm/m}$
Sensitivity	0.005 mm/m 1 arcsec
Limits of error (DIN2276/2)	$M_W \leq 0.5 M_E$ max. 1 % M_W min. 1 digit
M_E = full-scale M_W = measured value	$M_W > 0.5 M_E$ max. 0.01 (2 M_W - 0.5 M_E)
Temperature error (DIN 2276/2) / °C (Ø 10 °C)	max. 0.1 % M_E
M_E = full-scale	
Response time (DIN 2276/2)	< 5 sec
Digital output	RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
External power supply	+5V DC / +24 V DC
Net weight, including batteries	3450 g
Dimensions L x W x H	150 x 150 x 40 mm
Two prismatic measuring basis, left and bottom, for shafts one flat measuring base, right	Ø 19 ... 108 mm
CE conformity:	Meets emission and immunity requirements



BlueCLINO HP connected with
a BlueMETER SIGMA



BlueCLINO HP connected
to a PC



Simple
comparison
of a left and
a right
vertical guideway

BlueCLINO High Precision

APP



Display types

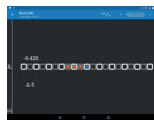
- Numbers



- Vials or needles (zoomable scale)



- LED line (zoomable scale)



Units

mm/m
° ' "
"/10"
"/12"

Einheiten

Functions

- REL zero setting of the axis-values
- Reactivate the ABS offset correction value stored in the instrument

Requirements



- Android device with Android 3.0 or above
- BlueCLINO High Precision with integrated Bluetooth
- The BlueCLINO, resp. BlueCLINO HP app is free of charge



Outdoor smartphone with preinstalled BlueCLINO High Precision APP

9 EXTERNAL DISPLAYS / INTERFACES

9.1 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 (both by means of cables only)
- CLINOTRONIC PLUS
- ZEROMATIC
- 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:

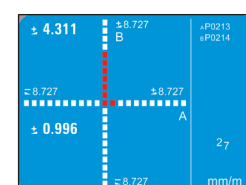
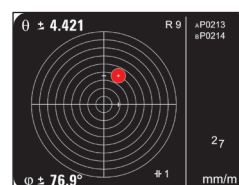
- large and very easy-to-read color display
 - Various color profiles can be chosen
 - Various display methods are available: the new graphical 2D-display allows very useful new applications!
- Measured values of up to four instruments can be displayed simultaneously. Users can choose which instrument 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-graph: A-B for the X-axis, and C-D for the Y-axis.
- The connectors for the cables are now on the right hand side of the instrument, allowing adjusting 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
- truck
- 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

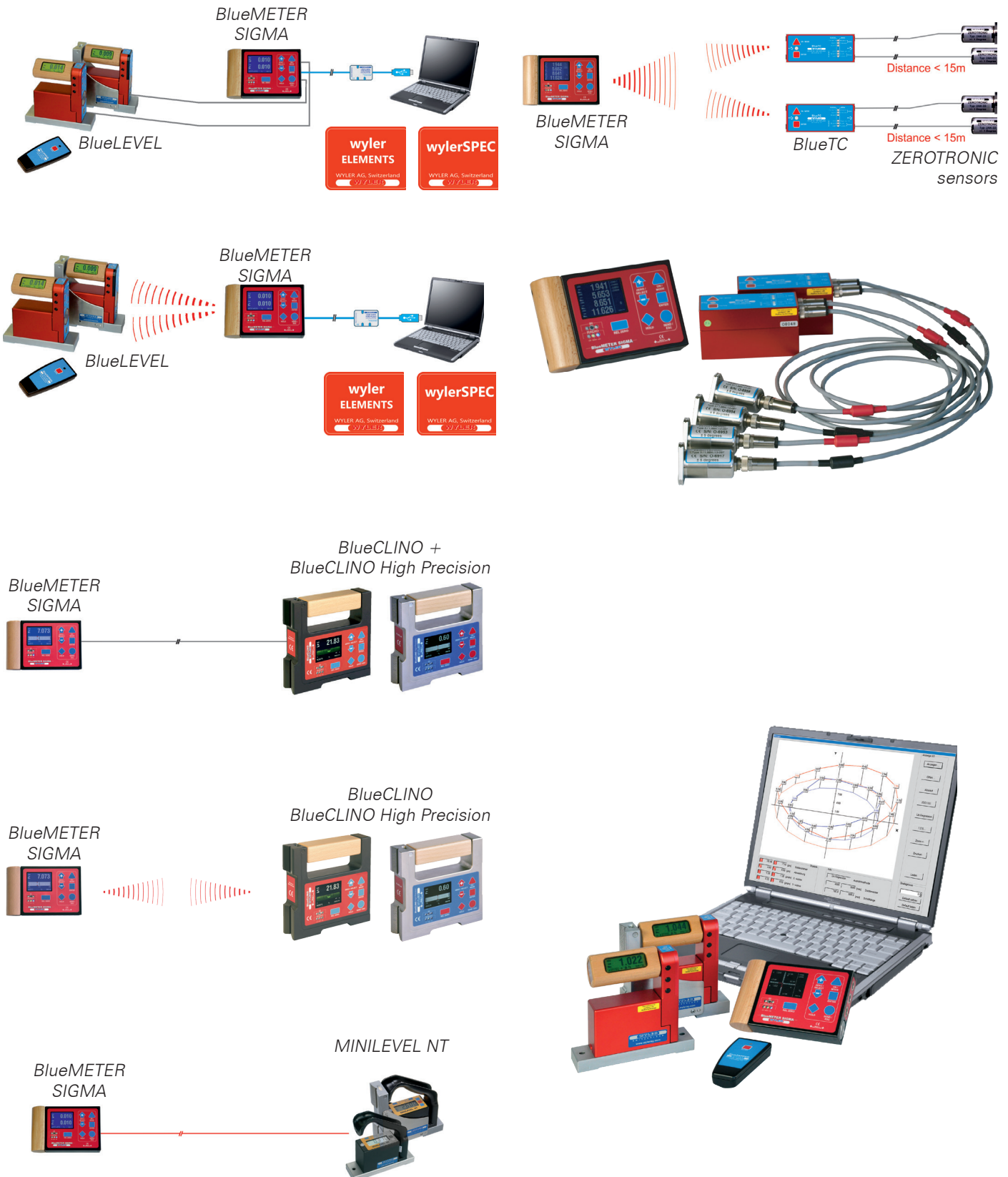
It is possible to send the measured data via an RS232 port to a PC/laptop to the WYLER software wylerINSERT, wylerCHART, wylerDYNAM and wylerSPEC.

Additional functions and features of the BlueMETER SIGMA:

- New design with aluminum housing and latest technology
- Radio communication based on Bluetooth® technology: a single worldwide standard
- Display of measuring values in various measuring units (see following list)
- Absolute measurements
- Relative measurements
- Evaluation and storage of the zero-offset of instruments/sensors
- Battery voltage indicator
- Powered by standard 1.5 V batteries size C
- CE compatible

TECHNICAL SPECIFICATIONS BLUEMETER SIGMA		
Batteries, size C / optional rechargeable		1,5 V
External power supply		+24 V DC
Digital output		RS232, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 bps
Dimensions	Length	150 mm
	Width	96 mm
	Height	34/40 mm
Net weight		
• with batteries		835 g
• without batteries		684 g

CONFIGURATIONS BlueMETER SIGMA



9.2 BLUETC WITH / WITHOUT RADIO TRANSMISSION FOR
BLUELEVEL / BLUELEVEL BASIC / ZEROTRONIC SENSORS

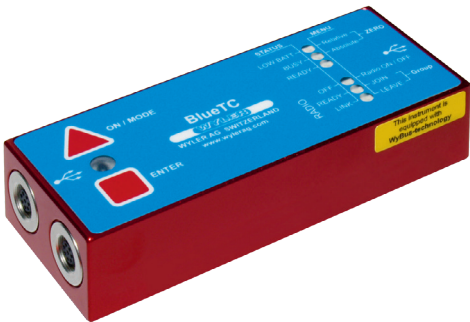
It is possible to send measured data via an RS232/485 port to a printer, a PC/laptop or the WYLER software wylerSPEC or to other software such as wylerCHART or wylerDYNAM.

Advantage compared to the BlueMETER SIGMA connected to BlueLEVEL instruments are:

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

Disadvantage compared to the BlueMETER SIGMA connected to BlueLEVEL 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



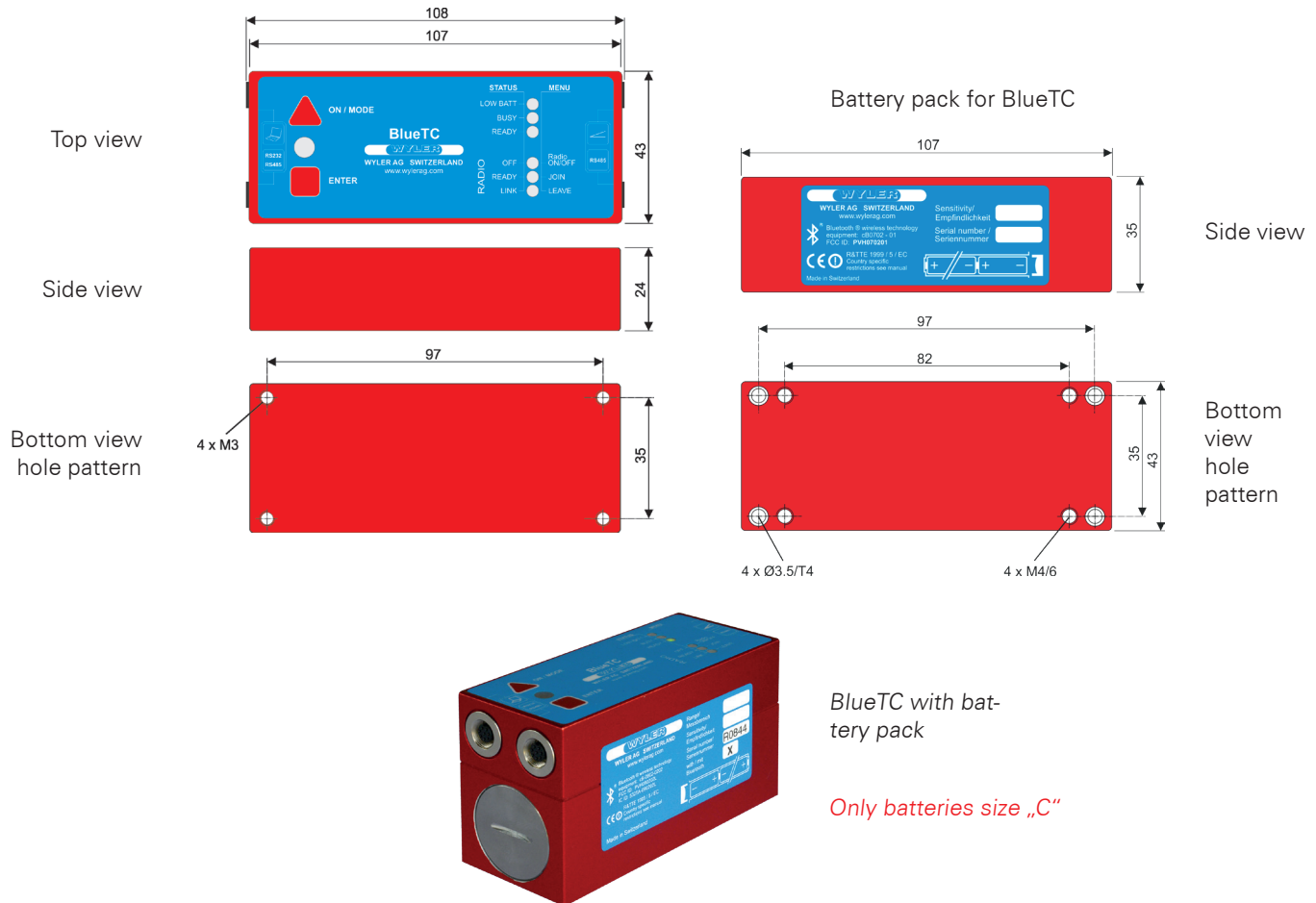
BlueTC

TECHNICAL SPECIFICATIONS		BlueTC
External power supply		+ 5 V DC, max. 450 mW (Pin 3) 8 ... 28 V DC (Pin 1)
Format of transmission		RS232 / RS485, asynchronous, 7 DataBits, 2 StopBits, no parity, 9600 Baud
Dimensions without battery pack	Length	108 mm
	Width	43 mm
	Heigth	24 mm
Dimensions with battery pack	Length	108 mm
	Width	43 mm
	Heigth	59 mm

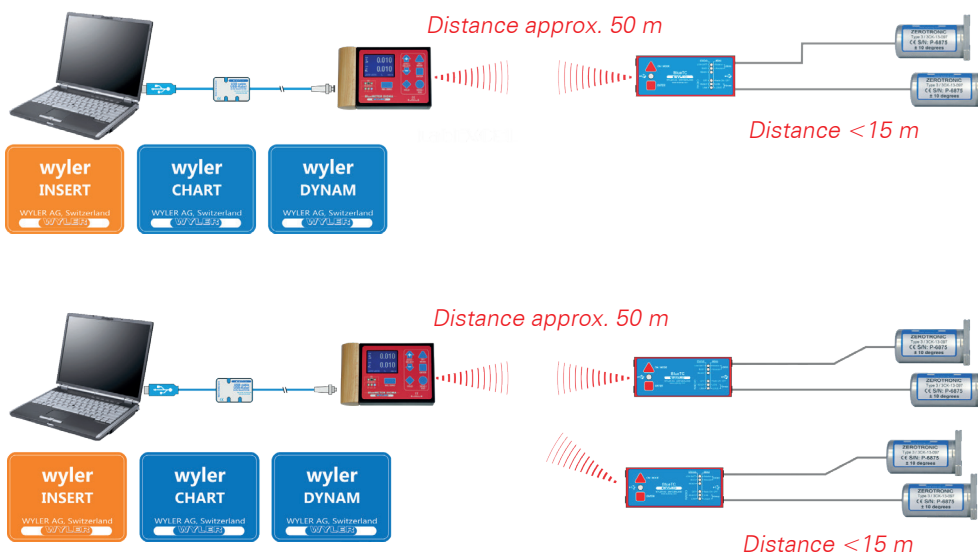


BlueTC with battery pack

OUTER DIMENSIONS OF THE BLUETC AND THE BATTERY PACK



POSSIBLE CONFIGURATIONS WITH BLUETC



Configuration with max. two **BlueTCs**, connected to max. four ZEROTRONIC-sensors. The BlueMETER SIGMA works as an interface to a PC or Laptop.

Regarding the configuration set-up, up to four sensors can be read in simultaneously.

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.

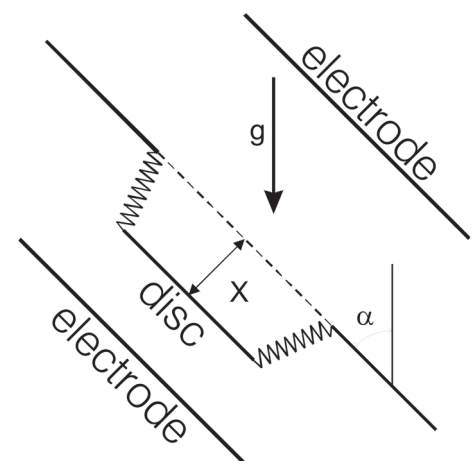
The equilibrium of the resilient and the gravitational force can be described as follows:

$$cx = mg \sin(\alpha) \quad (1)$$

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:

$$g(\phi, h) = 9.780327 \left(1 + 0.0053024 \sin^2(\phi) - 0.000058 \sin^2(2\phi) \right) - 3.086 \times 10^{-6} h \quad (2)$$

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 altitude, 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):

$$x_m = \frac{1}{c} m g_m \sin(\alpha_{eff}) \quad (3)$$

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:

$$\alpha_m = \arcsin\left(\frac{c x_m}{m g_c}\right) \quad (4)$$

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:

$$\alpha_{eff} = \arcsin\left(\frac{g_c}{g_m} \sin(\alpha_m)\right) \quad (5)$$

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.

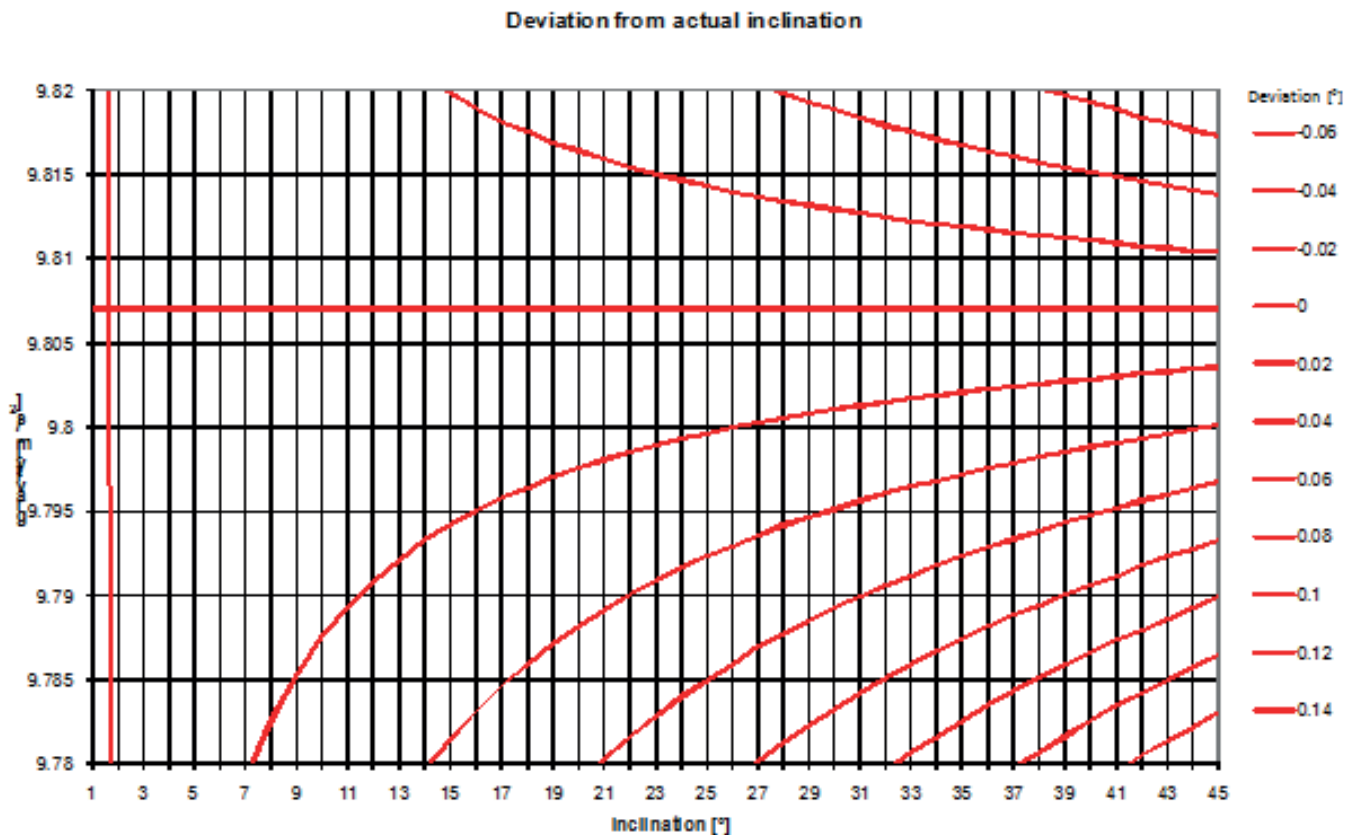


Fig. 2 Deviation of the measured angle from the effective one as a function of the gravitational force and of the effective angle

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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Quality

Service
+ Partnership

Innovation
+ Competence

Qualität

Service
+ Partnerschaft

Innovation
+ Kompetenz

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