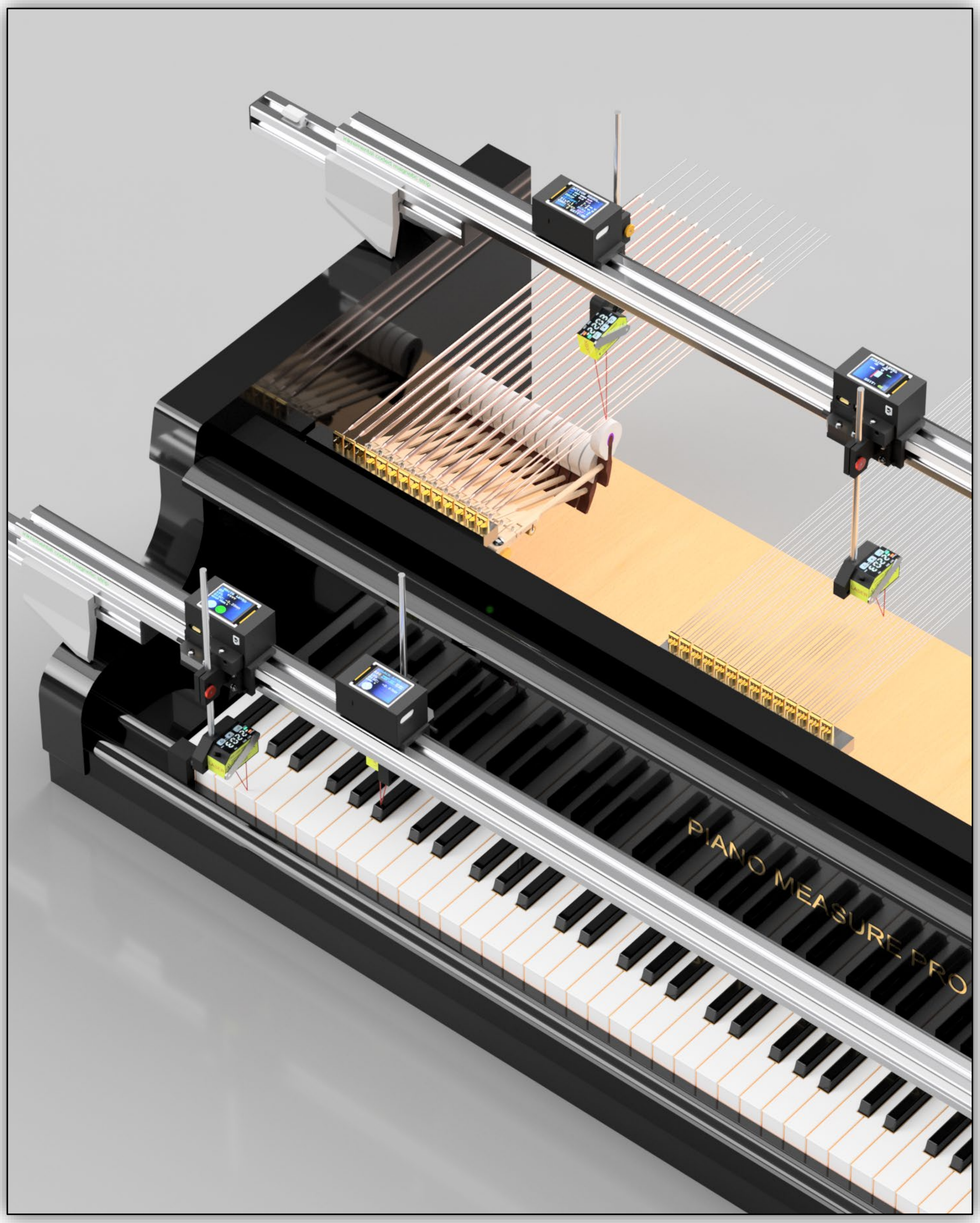
piano measure pro™

LASER PRECISION | Innovation for piano makers

Digital Measuring System for Non-Contact Height and Length Measurement

User Manual



1 Contents

2 Description

2.1 Pitch notation system

For tone representation, this measuring system uses scientific pitch notation.

Each note consists of a letter (A–G) and a number for the octave.

On a modern standard piano with 88 keys, the range extends from A0 to C8.

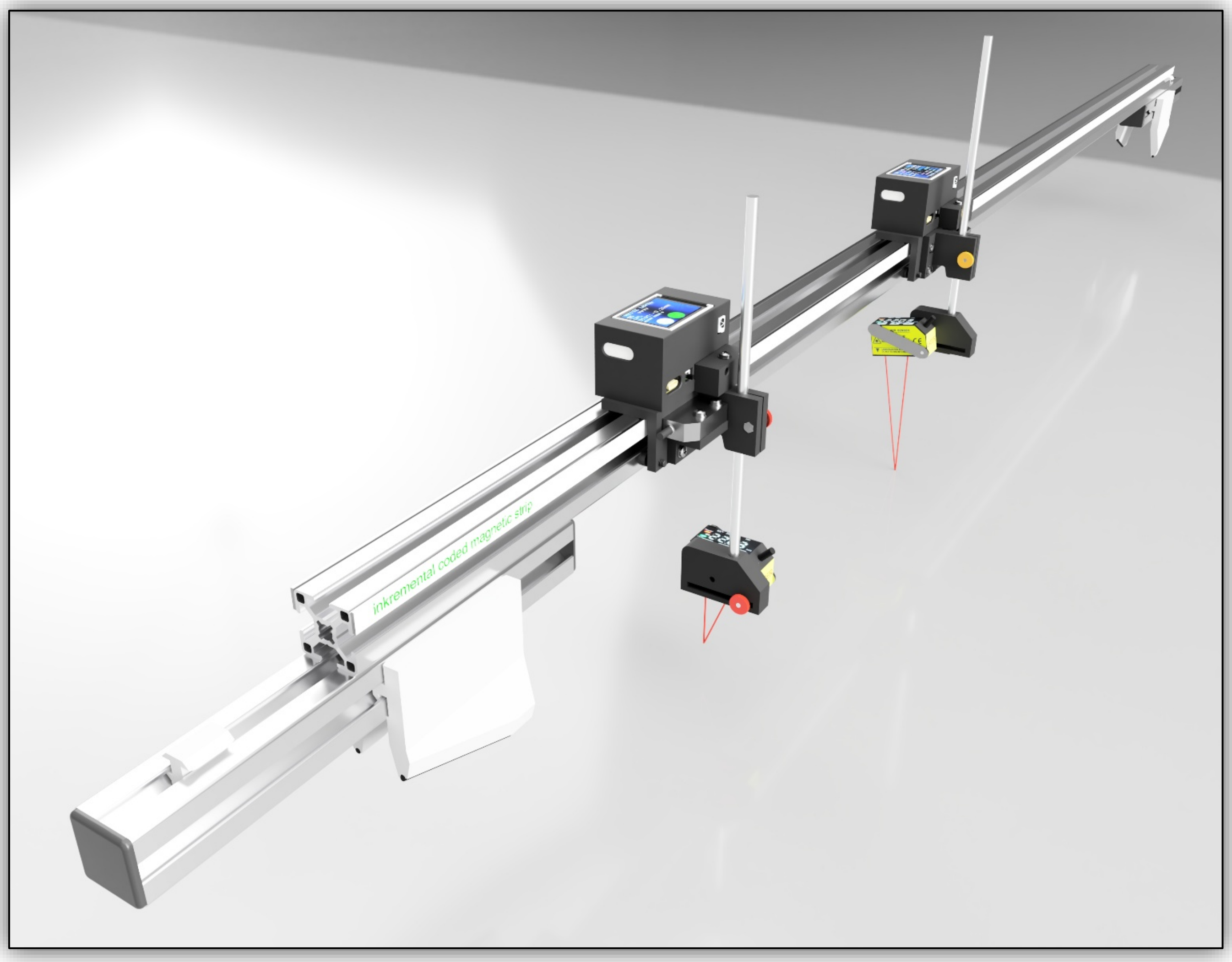
The standard tuning pitch a1 is designated as A4.

Extended keyboards:

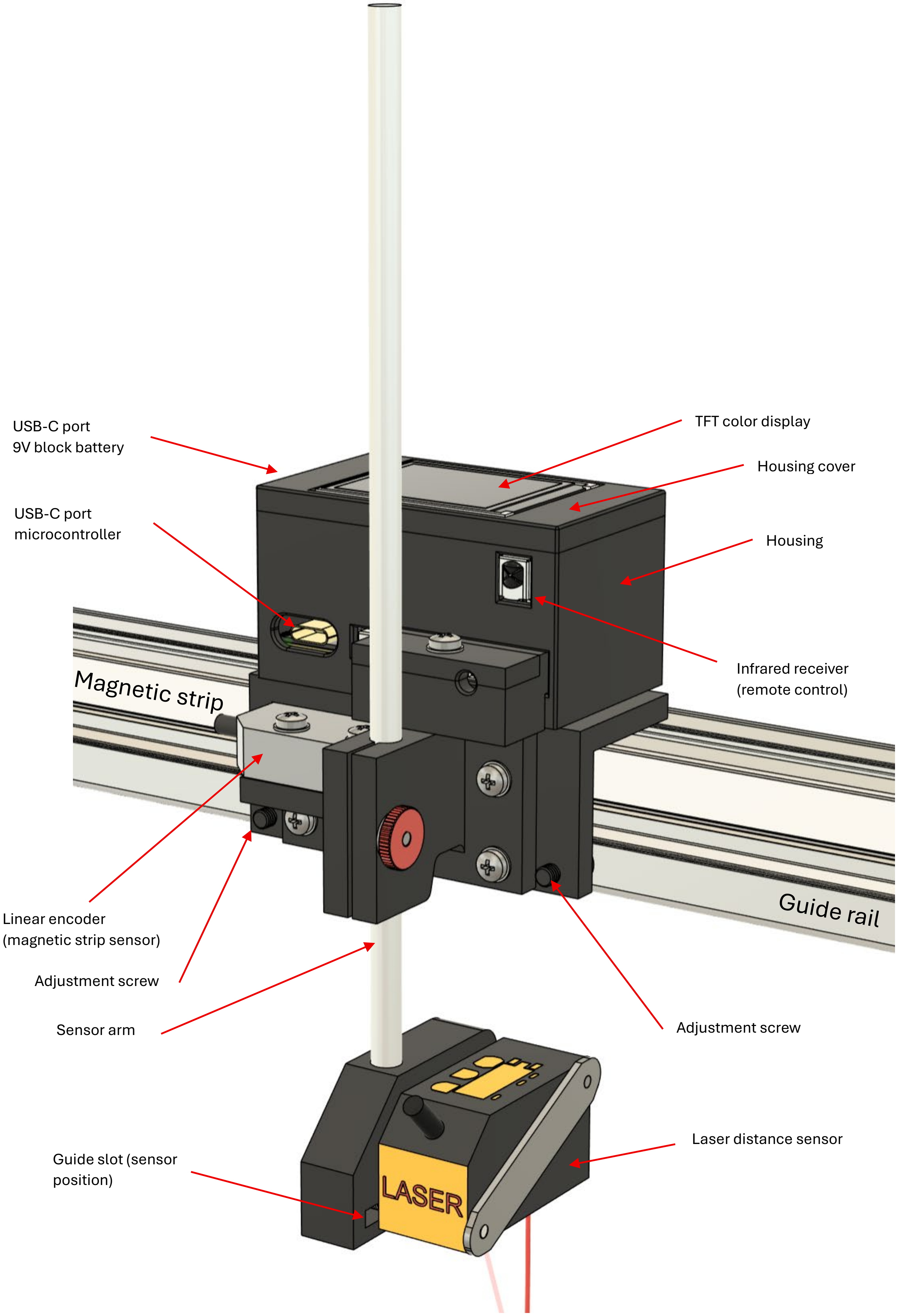
On the Bösendorfer Imperial, the range extends down to C0 (extra black keys to the left of A0).

On the Bösendorfer 275, the range extends down to F0 (extra black keys to the left of A0).

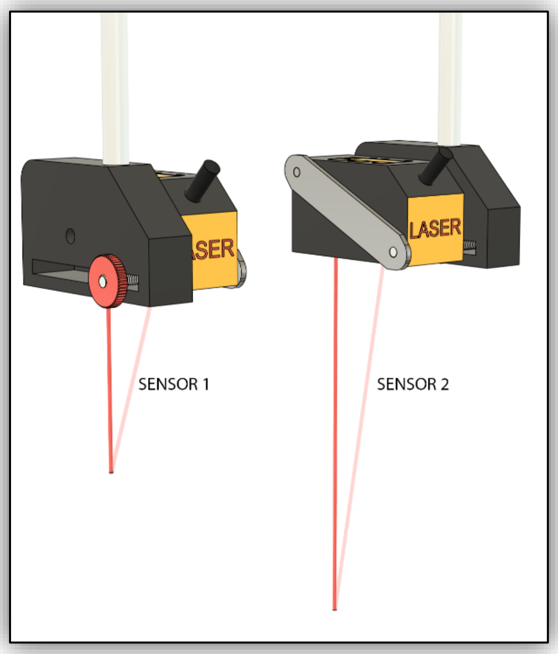
This system is internationally used, unambiguous, and avoids confusion with the traditional German Helmholtz notation.



2.2 Complete Assembly



2.3 Laser distance sensors



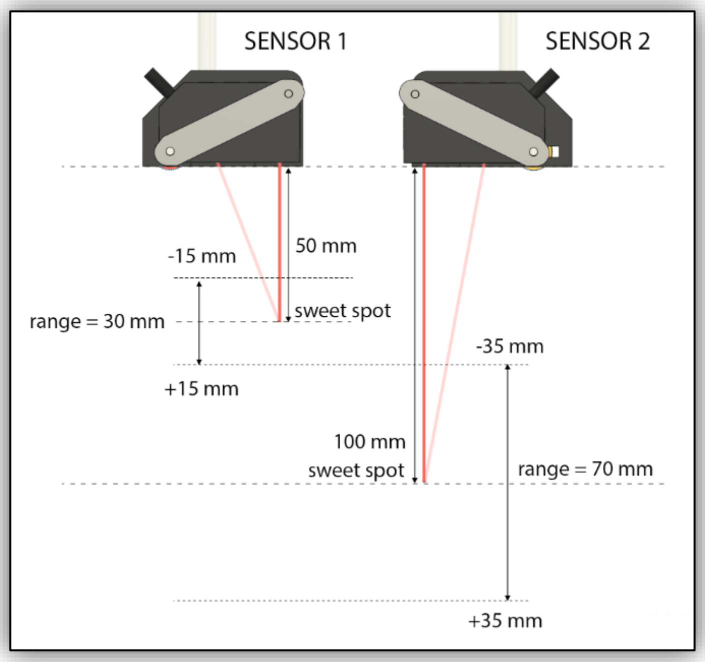
Different applications and measurement tasks place varying demands on measuring range and accuracy. For precise measurement of string heights, higher accuracy is required than, for example, when measuring blow distance, which is the distance from the hammer at rest to the string, or when measuring letoff. By contrast, recording regulation parameters generally requires a larger measuring range than measuring string heights.

Two sensors are available for this purpose, referred to here as Sensor 1 and Sensor 2:

- **Sensor 1: Measuring range 30 mm (± 15 mm around the sweet spot at 50 mm, range 35 - 65 mm)**
- **Sensor 2: Measuring range 70 mm (± 35 mm around the sweet spot at 100 mm, range 65 - 135 mm)**

The following table shows which sensor is best suited for the respective measurement tasks:

	SENSOR 1	**SENSOR 2**
Sweet Spot	50 mm	100 mm
Measuring Range	30 mm (+-15 mm)	70 mm (+- 35 mm)
Measuring Accuracy	30 µm (0.03 mm)	70 µm (0.07 mm)
Key height / key dip Function **key level**	*** very suitable	** suitable
Regulation parameters blow, letoff, drop, check Function **action regul.**	* conditionally suitable	*** very suitable
String heights Function **string level**	*** very suitable	- not suitable
Scale / downbearing measurement Function **scale design**	both involved front (agraffes / capo bar)	 back (bridge, hitch pin)



The sensor display is generally used to position the sensor within the correct measuring range with the help of the guide rod. It shows the distance between the sensor and the object being measured. A value of 0 means that the sensor is exactly at the sweet spot. Positive values indicate that the sensor is closer to the object, while negative values indicate that the object is further away. The important point is simply to bring the sensor into the appropriate range; small deviations do not matter. What matters is that the sensor operates within the correct measuring range for the intended application.

2.4 Linear position encoder (magnetic strip sensor)

The device uses a high-precision linear encoder in combination with a magnetic strip on the guide rail.

A linear encoder essentially works like a very large caliper. By continuously scanning the magnetic strip, it generates impulses from which the exact position on the rail can be calculated at any time.

The measurement accuracy is impressive, within just a few micrometers, allowing for extremely precise position determination.

The position encoder is indispensable to always know exactly which key the sensor is currently above during a measurement ("key level" function).

In the "scale design" function, two devices operate in parallel on the guide rail. Each device continuously records its own position. The distance between the devices is calculated from these positions and exchanged via WiFi. In this way, for example, scales and string lengths can be measured with great precision.

From time to time, the proper magnetic coding of the strip should be checked.

Checking proper coding:

The LED on the sensor lights blue if the coding is intact and the distance to the strip is correct.

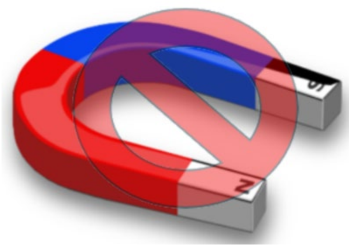
To check, move the sensor slowly along the entire guide rail. The LED must remain constantly blue. If it flickers at any point, the strip is damaged at that spot and accurate position detection is impaired.

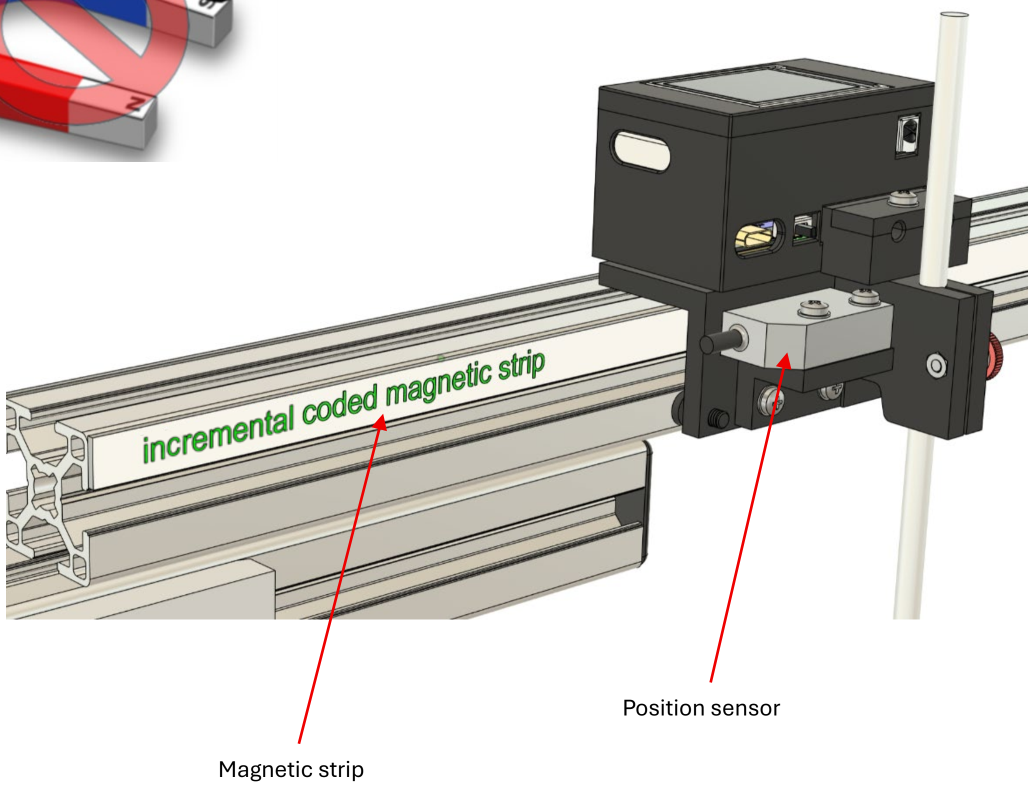
However, the strip can be easily replaced: It is glued onto the rail and can simply be peeled off. Remove any adhesive residue with acetone or isopropyl alcohol, then attach a new strip (Replacement strips are available on request).

External magnetic fields:

The magnetization of the magnetic strip may be lost. In particular, no magnetic fields (e.g. holding magnets, permanent magnets, or magnets in smartphones such as MagSafe) must come into direct contact with the magnetic strip. The commonly used bevel box (digital angle gauge) often has magnets on its underside and must never be placed directly on the guide rail!

<u>Always protect the magnetic strip from external magnetic influences.</u>





2.5 9V Block Battery (rechargeable)

The device is powered by a rechargeable 9V lithium-ion block battery. The battery can be charged directly via its integrated USB-C port using any standard USB-C cable and does not need to be removed for charging. An LED indicator on the battery shows the current charging status.

Alternatively, a standard non-rechargeable 9V battery can also be used.

Battery replacement:

The battery is replaceable. To do this, remove the top cover of the device and carefully fold it to the side. The display is permanently attached to the cover and connected to the circuit board inside the device via two plug connectors. The cable is long enough to safely fold the cover to the side.

The battery can now be removed and disconnected from the power supply. When removing or inserting the battery, special care must be taken to avoid damaging any cables or connectors. Finally, insert the new battery, reconnect it, and close the cover.

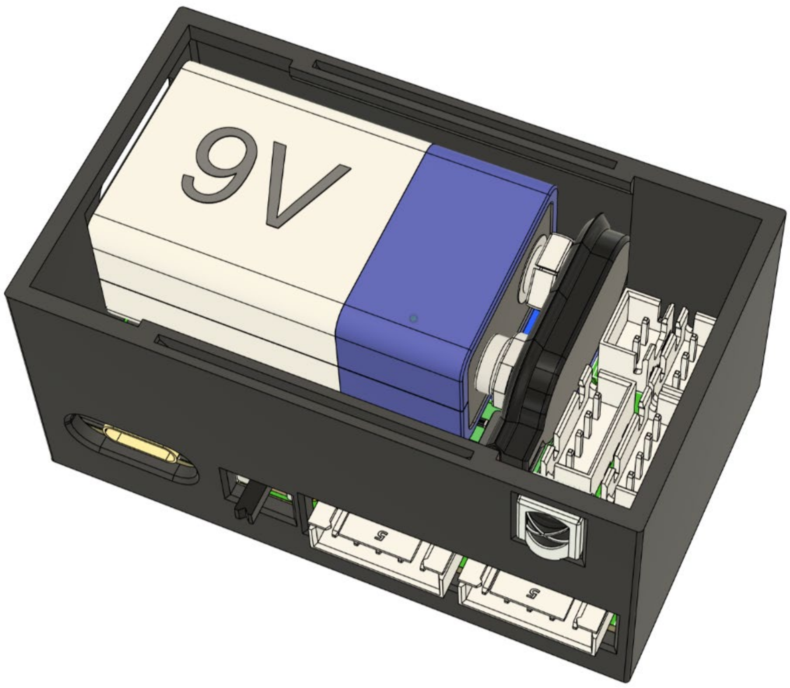
IMPORTANT NOTE:

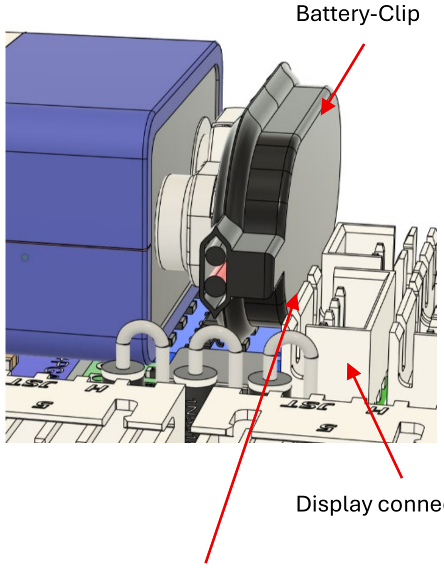
When removing the housing cover, lift it on the left side and take it off. When reattaching, first insert the right side into the housing guide (notch) and then press down the left side.

To remove the battery, lift the battery on the right side at the battery clip, disconnect the clip, and take out the battery.

When inserting the battery, first reconnect the battery clip. Then insert the battery at an angle on the right side so that the outer side of the battery clip is flush with the white connector on the circuit board. After that, gently press down the left side of the battery until it clicks into place.

Under no circumstances should the battery clip rest on top of the connector, as this would prevent the housing cover from being closed!





2.6 IR Remote Control (Infrared)

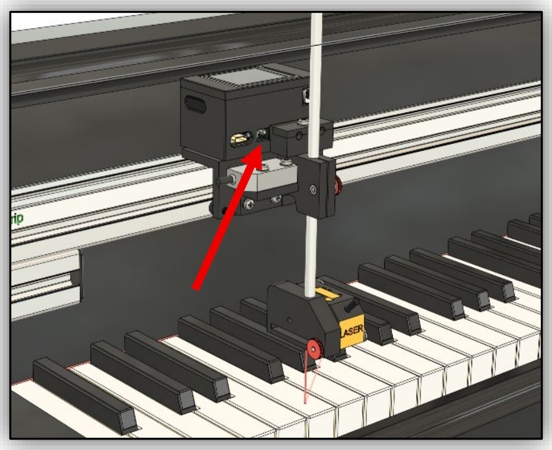
Piano-Measure-Pro is operated exclusively with an infrared remote control. There are no control buttons on the measuring unit itself, since the sensitive sensors are located there. Even a slight press on a button directly on the device could affect the high-precision measurement results. Contactless operation via infrared is therefore the optimal solution.

The supplied remote control has ten number keys, four arrow keys (up, down, left, right), a confirmation key OK, and two special keys (* and #).

If the keys no longer respond reliably, the battery (coin cell) should be replaced.

When both devices are used simultaneously, for example in the "scale design" function, they both respond in parallel to key inputs. If only one device is to be controlled, the other can simply be moved slightly to the side on the guide rail.

2.7 Switching on the device



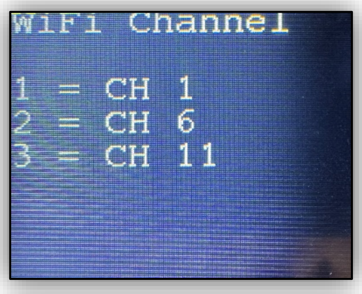
The device is switched on using the power switch on the front of the controller. Before starting a full session, it should be ensured that the battery is fully charged.

2.7.1 Start screen

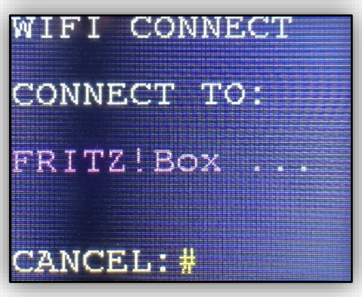
After switching on, the start screen appears and an acoustic signal is played. Device 1 with Sensor 1 produces a single tone, while Device 2 with Sensor 2 produces two short tones (low and high).

On the start screen, a WiFi channel can be selected using IR-key 1 on IR Remote Control "SOFT AP". In environments with many WiFi networks, the channel can be changed if connection problems occur. This is only relevant in DUAL mode, where both devices communicate with each other and exchange measurement values. At present, this is used only in the "scale design" function. In this mode, both devices are placed on the guide rail: the laser spot of Device 1 is positioned exactly at the front start of the speaking length of the string (e.g. at the agraffe), while the sensor of Device 2 is positioned at a rear point of the string (bridge pin or hitch pin). The distance is then calculated from both positions. The devices communicate via their own WiFi connection, independent of the home WiFi. If connection issues occur, the WiFi channel can be changed during startup (IR-key 1-3).

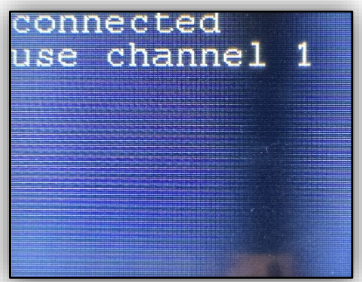
It is also possible to rotate the display by 180° using IR-key 9. This function is frequently assigned to key 9, for example in the main menu, on the main screen of the "action regul." function, or in the "scale design" function.



By pressing OK, the dialog is closed and the device attempts to connect to a WiFi network, provided that a password has already been stored.



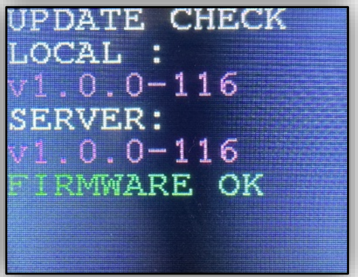
2.7.2 Checking for firmware updates



Piano Measure Pro is continuously being developed: New functions are added, and existing functions are further improved.

At each startup, after a successful WiFi connection, the device briefly checks whether a new update is available. For this purpose, a connection to the Klaviaratelier server is established. If the server version is newer than the device version, a message appears showing both version numbers.

The following options are available:



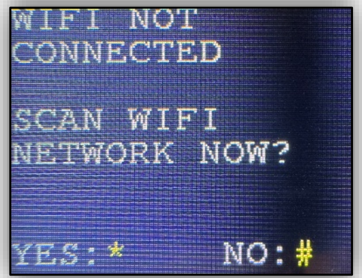
Install with IR-key *

Skip installation with IR-key #

If this dialog is not confirmed within 10 seconds, the device automatically proceeds to the main menu without updating.

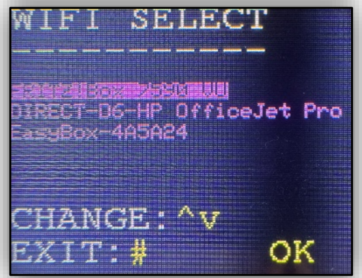
If the update is started with *, it will be downloaded and installed. The device then restarts automatically. If no update is available, the message “Firmware OK” appears.

2.7.3 Connecting to WiFi Network



If no WiFi connection can be established, a dialog appears asking whether all available networks should be scanned. This process can be canceled with IR-key # for example, when working at a customer’s location where no WiFi connection is needed.

Data can also be transferred without an external WiFi network by using the Direct SOFT AP connection, where the PC/laptop connects directly to Piano-Measure-Pro (see later chapter).

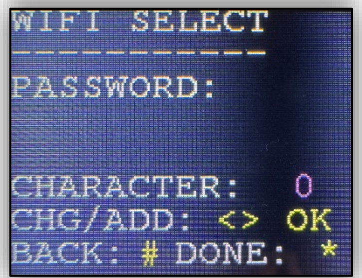


In “scale design” mode, the two devices communicate directly with each other via WiFi, without requiring an external network.

An external WiFi network is primarily needed for two purposes:

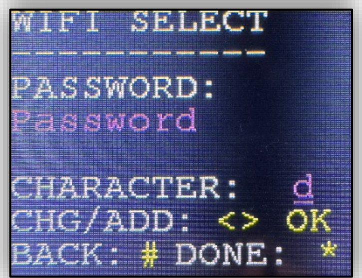
- to check for new firmware updates,
- and to conveniently transfer datasets to a PC/Laptop in the workshop without having to connect it directly to the device each time.

When working at a customer’s location, an external WiFi network is therefore not necessary; all functions remain fully available without it.



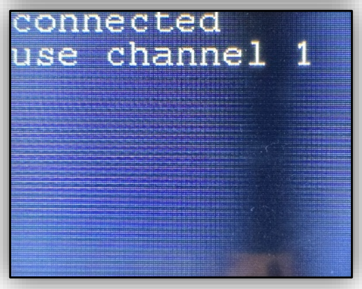
To scan for all available WiFi networks, press the * key. After a short moment, a list of all detected networks will appear. Use the up/down arrow keys to select the desired network and confirm with OK.

The password dialog will then open. The password must be entered character by character:



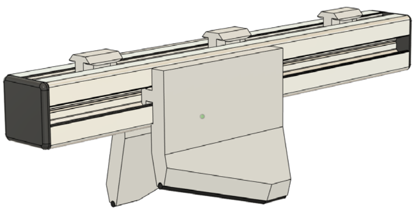
- Use the left/right arrow keys to select the required letter, number, or special character (shown next to CHARACTER).
- Press OK to add the selected character to the current password.
- Use BACK (IR-key #) to delete characters.
- Use DONE (IR-key *) to finish entering the password.

If the password is correct, the connection will be established. The password is stored permanently in the device and does not need to be re-entered at the next startup.



3 Placing the Guide Rail

To position the guide rail above the keyboard - or, in the case of grand pianos, above the hammer heads (action regul.) or the strings to be levelled (string level) - two short rails are inserted on the left and right into the lower profile groove of the long guide rail.

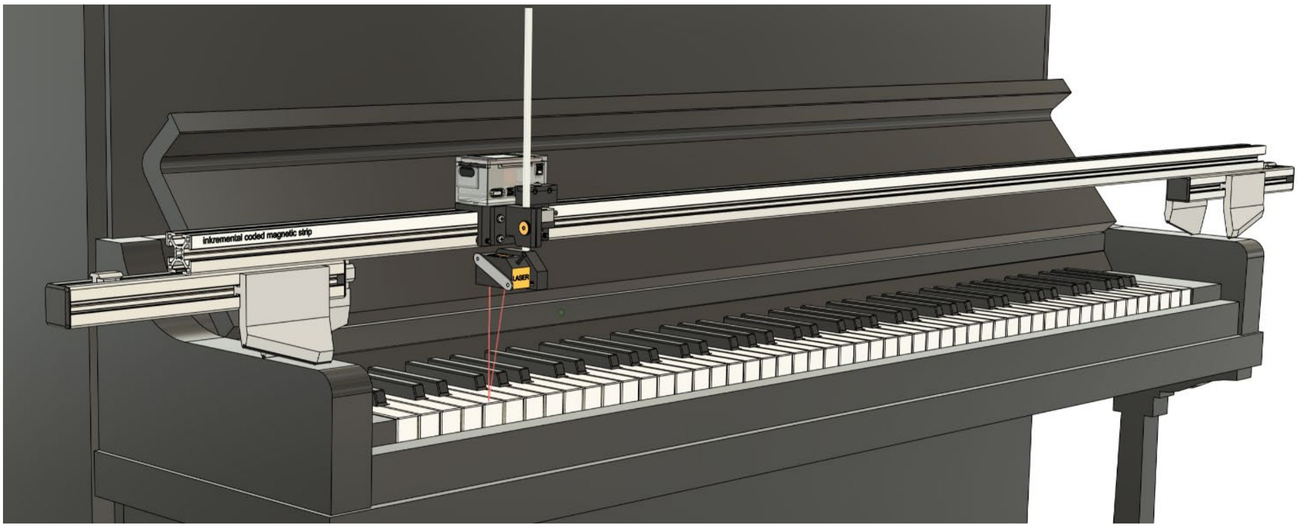


Each of these short rails carries two supports: one at the front and one at the rear. In the illustrations, the front supports are marked with “R” (right) and “L” (left). These markings are for illustration purposes only. In practice, the supports can be clearly identified by their mirrored shape.

The short rails are positioned so that the supports rest near the side areas of the rim. The front supports serve as contact surfaces and are aligned so that the flat horizontal section of the rubber pad rests evenly on the rim of the instrument. The angled rubber pad of the right support is placed on the right-hand rim, the left one accordingly on the left-hand rim.

One of the rear supports is used to fine-tune the tilt of the entire guide rail along its longitudinal axis. The other rear support is then gently moved toward the rim so that the guide rail rests securely and without any wobble.

4 "Key Level" function - Levelling the Keyboard / Setting Key Dip



4.1 Preparing the keyboard / action

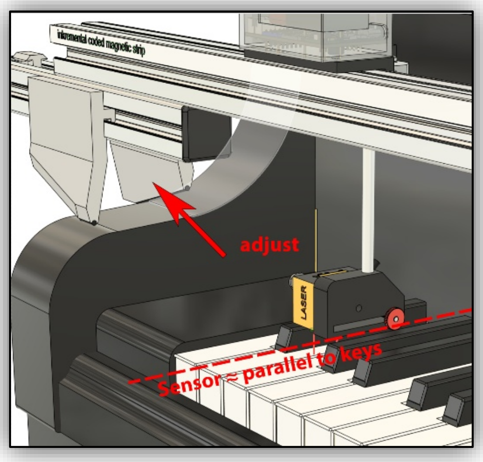
Before starting the measurements, the keyboard and the action should be carefully prepared to ensure high repeatability for each key. Repeatability means that a key always returns to exactly the same starting position after being depressed – regardless of whether it is played with strong or light touch, staccato or legato.

Repeatability is influenced by the following factors:

- Key bushings: They must be in perfect condition. Worn bushings or overly tight new felt bushings will impair accuracy.
- Key alignment: Before leveling, slightly skewed keys should be adjusted at the balance pin so that they stand perfectly straight and level at the front. This is checked with a short straightedge. The spacings between the keys should also be balanced as well as possible by adjusting the front rail pins.
- Key fall: The hole in the key for the balance pin should be large enough for the key to slide down slowly and evenly when placed on the pin. The balance pin bushing must not hinder this movement. If keys are too tight, it often helps, as part of service, to degrease the key pins (e.g. with acetone or isopropanol), polish them if necessary, and finally treat them with a PTFE-based lubricant. If this is not sufficient, the hole must be slightly enlarged with a key easing tool.
- Capstan regulation and action conditions: In uprights, the capstans must be regulated so that the keys, with the weight of wippen, hammer shank, and hammer head, rest correctly on the key baize strip and stand in proper upper position at the front. Alternatively, the hammer rest rail can be removed so that all keys are in direct contact with the hammer but via the jack. In grands this is not necessary; it is only important to ensure that all hammer shanks float freely above the hammer rest rail and do not rest on it, as this could otherwise affect the front position of the keys.

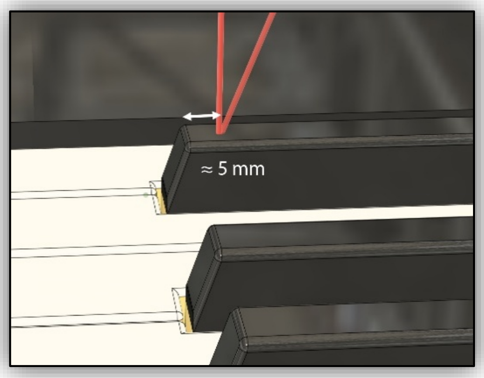
Repeatability can be checked at the beginning of the measurement: move the laser over a key and strike the key several times with varying force. If the same measurement value is shown each time, the preparation has been carried out correctly.

4.2 Guide Rail Alignment



To align the guide rail, place the device on it so that the laser sensor is behind the rail, in the area of the black keys.

The guide rail is aligned so that the laser beam hits the surface of the white keys as perpendicularly as possible. The sensor arm (round rod) can be lowered considerably for this purpose. The lower edge of the sensor serves as a reference line and is visually aligned parallel to the white keys. Small deviations are not critical. To adjust, move the rear support; this will tilt the guide rail along its longitudinal axis. Subsequently, the other rear support is moved so that the guide rail stands without wobbling (see also chapter "Placing the Guide Rail"). Next, the horizontal position of the laser is adjusted. For this, the sensor is moved back up so the position of the laser spot can be assessed on the first and last black key.



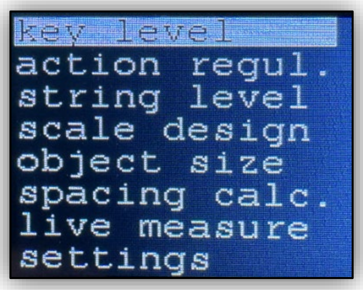
The guide rail is now moved slightly forwards or backwards until the spot hits the black key as far forward as possible - ideally about 5 mm from the front edge (this corresponds to the highest point of the key). After that, you turn the unit and check where the spot hits the white key. If it's about 5 to 15 mm behind the front edge of the key, the position is correct. If not, the sensor can be shifted horizontally in the slot at the bottom of the sensor arm. To do this, loosen the wing nut and move the sensor slightly forwards or backwards. This readjustment is particularly useful for older instruments with different key dimensions.

Once the spot position on the first and last key has been correctly adjusted, set the height of the laser so that the sensor display shows a value close to zero when the laser spot hits the front area of the key surface, approximately 5 to 15 millimeters behind the key front. Negative values mean the laser is too high above the keys, while positive values mean the laser is too low. It is not necessary to achieve exactly zero; the goal is simply to bring the sensor into its optimal measuring range.

For key measurements, it is recommended to use a sensor with a measuring range of 30 millimeters. This allows 15 millimeters upwards for the black keys, which are typically about 12 millimeters higher than the white keys, and 15 millimeters downwards for the dip of the white keys, which usually averages around 10 millimeters.

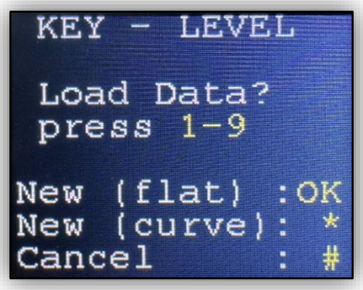
At the end of the setup, it is advisable to check again whether the guide rail stands firmly or shows any signs of wobbling. If so, stability can be improved by gently moving one of the rear supports slightly away from the case and then carefully sliding it back until it rests against it. Further details can be found in the section "Positioning the guide rail".

4.3 Starting the measurement



In the main menu, select "key level" using the arrow keys and confirm with the OK button.

In the following dialog, you can choose whether to create a new dataset or load an instrument that has already been stored. Nine memory slots are available for this purpose. After pressing a number key between 1 and 9, the start screen appears to further process the measurement data (see chapter "Retrieving data: Keyboard leveling / key dip adjustments").

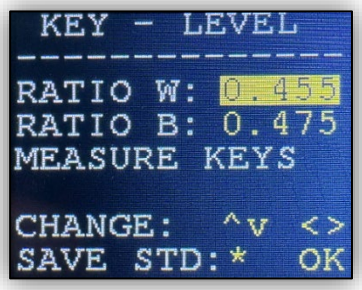


Alternatively, a new measurement can be started. In this case, there are two options: "flat" or "curve."

The "curve" option is used for keyboards that feature a slight crown in the middle, as typically found on instruments such as Steinway & Sons. In this mode, a quadratic regression is calculated, resulting in a parabolic curve that closely follows the actual key heights. The "flat" option, on the other hand, applies a linear regression, producing a straight line that serves as the reference level for the keys.

These curves provide the technician with a basis for fine adjustments, for example to increase or reduce the crown or to raise or lower the overall key level.

Press the star key (*) to select "curve," the OK key to select "flat." Use the hash key (#) to cancel and return to the main menu.



In the next dialog, the key ratio can be defined. One option is to measure the keys manually with a tape measure, calculate the values, and enter them directly. Use the up/down arrow keys to switch between the value for the white key and the black key and use the left/right arrow keys to adjust the selected value.

Alternatively, you can select "MEASURE KEYS." This opens a new dialog that allows the keys to be measured conveniently using the laser and the linear encoder (see chapter "Measuring the key ratio").

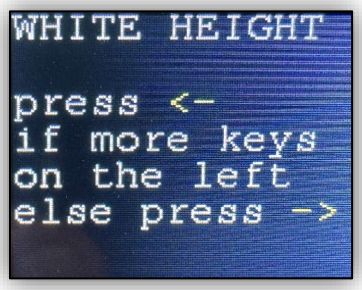
The key ratio is required to calculate the necessary punching thickness at the balance rail from the deviation measured at the front of the key. At the beginning of a measurement, any key ratio can be used, since it does not affect the initial measurement values. Because the dataset is stored in the device's internal memory, it remains available even after the device has been switched off. When the device is switched on again and the dataset is loaded, the key ratio can be adjusted at any time during the levelling of the keyboard. On a grand piano, this means that the key heights and key dip can first be measured, and the key ratio can then be determined later, after the action has been removed and the keys have been taken out.

By pressing the star key (*), the currently set values can be saved as default settings in the device. These values will then be used automatically the next time the device is switched on and the function is selected.

4.4 Key level (white keys)

Pressing the OK key opens the next dialog. The display will prompt you to position the laser spot in the center of key A0 (in most instruments this is the first key) and then press OK again. The hash key (#) cancels the process and returns to the main menu.

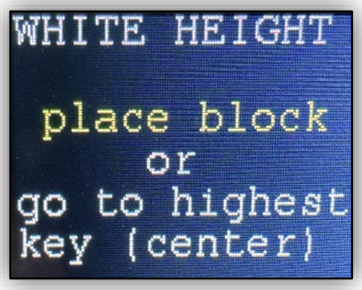
In the next step, press the "left arrow" key if there are additional keys to the left of A0, for example on a Bösendorfer Imperial with its extra black keys down to C0. Otherwise, and in most cases, press the "right arrow" key.



At this point there are two options:

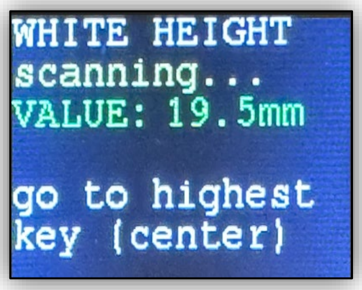
If the keyboard is already approximately at the correct height and only needs to be levelled within itself (for example during routine service), it is not necessary to determine the absolute height of the white keys above the key slip. In this case, the measurement can be started immediately and the following step can be skipped.

However, if the keyboard needs to be completely re-established as part of a major overhaul or a new instrument, the absolute height of key A0 above the key slip must first be measured. For this purpose, a measuring block is placed against the front of key A0 and lowered until it touches the key slip. After holding the block steady for a few seconds, the measurement is taken and confirmed with an acoustic signal. The corresponding value is then shown on the display.



The laser measures the height of the black measuring block, which has a defined height of 30 mm (this value can be adjusted in the device settings). Since the height of the white key was previously determined without the block, the absolute height of key A0 above the key slip can be calculated in this way.

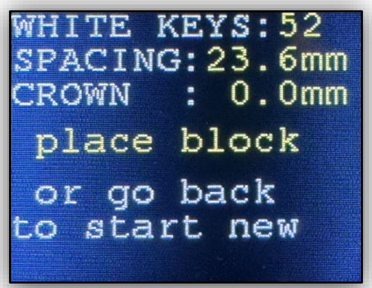
A major advantage of this method is that the guide rail does not need to be repositioned to measure the height above the key slip. It is placed and aligned only once at the beginning and then remains in the same position until all measurements have been completed.

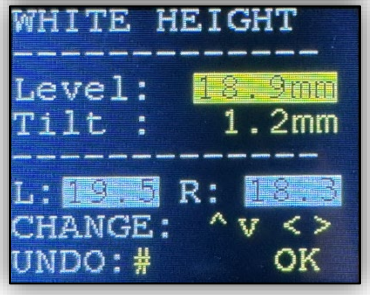


If it is necessary to measure the key height above the keybed, a 50 mm auxiliary block can be placed on the keybed and the measuring block positioned on top of it instead of on the key slip. In this case, simply add 50 mm to the displayed measurement results.

IMPORTANT NOTE:

When moving across the keys, an average value is calculated for each key. For white keys, this average is taken across ±8 mm from the center of the key. On some instruments, especially older pianos, a slight curvature of the surface (for example on ivory keyboards due to heavy use) may be present. In such cases, averaging is necessary. For black keys, the average is calculated across ±4 mm from the center of the key. Even if individual keys are slightly tilted - for example, if the right side is higher than the left - averaging ensures that the keys are leveled as accurately as possible overall.





To start the actual measurement, the sensor is moved to the right along the keyboard. The movement can be fairly quick. If the speed is too high, a yellow warning “Speed” will appear on the display. In this case, the movement should be slowed down. If the movement is much too fast, a red error message will appear and the process must be restarted from key A0.

The sensor is moved up to the top key in the center. In the upper range, the movement should be slowed down so that the exact center of the top key can be reached as precisely as possible. This is important in order to calculate the exact width of the keyboard and thus the spacing from key to key.

Caution: As soon as the sensor is brought to a complete stop, the measurement ends. If the sensor is only moved very slowly, however, the measurement remains active and is not interrupted.

As soon as the sensor is stopped at the top, a new dialog opens showing the calculated number of white keys and the spacing from key to key. In “flat” mode, the crown is displayed as 0; in “curve” mode, the calculated crown of the keyboard is shown (a parabolic curve, determined by quadratic regression and fitted as closely as possible to the measurement data).

If the height at A0 was previously measured with the measuring block, you will now be prompted to perform the same procedure with the highest key. Place the block on the key front again, hold it steady, and wait for the acoustic signal. Alternatively, the sensor can be moved back to the left; in this case, the measurement at A0 will automatically be repeated.

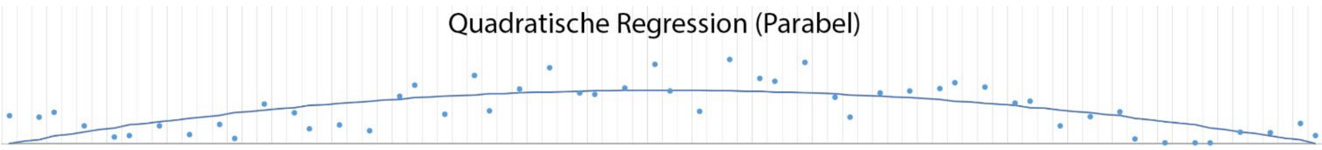
A regression curve (straight line or parabola) is then calculated from the measurement data. The height of this reference curve above the key slip is displayed on both the left and right sides. It should be noted that these values do not necessarily match the direct measurements taken on the keys themselves, since individual keys may happen to be significantly higher or lower than the rest.

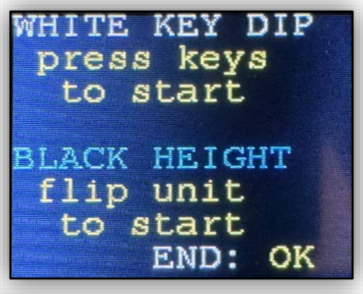
In addition, the average height (level) of the reference curve above the key slip and its slope (tilt) are displayed. The tilt indicates how much the leveling curve deviates from the key slip. A deviation of less than one millimeter is hardly visible to the eye.

A value of tilt = 1.2 mm, as shown in the example image, means that the reference curve is 1.2 mm lower on the right side than on the left side above the key slip. If the keyboard were leveled according to this reference curve, the keys on the right would be 1.2 mm lower than those on the left, resulting in a slightly slanted keyboard.

The technician can decide which values are acceptable. Both level and tilt can be adjusted at any time: use the up/down arrow keys to select a parameter and the left/right arrow keys to change its value. In principle, the automatically calculated reference curve represents the best possible leveling curve. The effort required to adjust the keys to this curve is always less than if the values were changed manually and thus deviated from this optimal curve. However, if the tilt is too great or the keys are overall too high or too low to be tolerated, a new reference curve must be defined by adjusting the values accordingly.

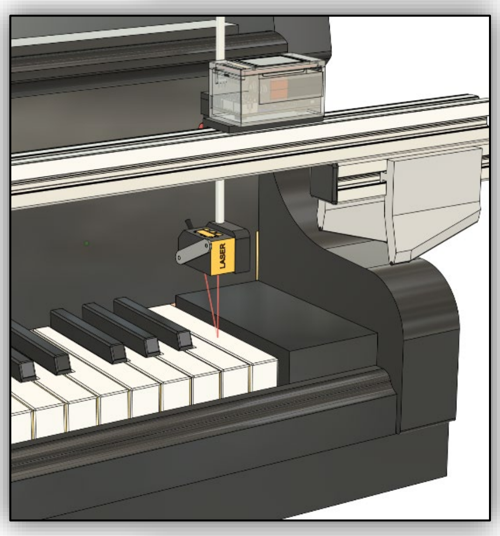
Press the hash key (#) to undo changes or press OK to confirm the values and continue the measurement.





After measuring the key heights of the white keys, there are two options to continue: either by measuring the key heights of the black keys or by measuring the key dip of the white keys. The sensor automatically detects which option is chosen.

If the key located directly under the sensor is pressed and held steady for a few seconds, the device recognizes this and starts the measurement of the key dip of the white keys - from the upper rest position down to the lower end position. If, on the other hand, the device is lifted, rotated, and repositioned so that the sensor sits behind the guide rail, the device automatically switches to the measurement mode for the key heights of the black keys.



The following section first describes the measurement of the key heights of the black keys. After that, the measurement of the key dip of the white keys will be explained.

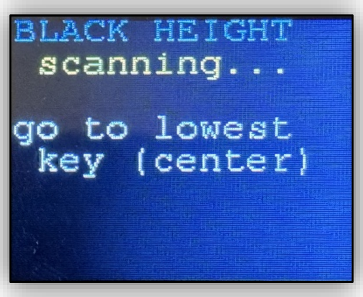
4.5 Key level (black keys)

Once the device has been rotated 180° and placed on the guide rail, the display automatically rotates so that it is readable for the technician. The laser spot is then positioned by eye in the center of the top key and confirmed with OK.

When the display shows “scanning...”, move the sensor to the left toward the first key. Slow down the movement there and stop as soon as the dialog appears, showing the measured average height and tilt of the black keys above the white keys. The movement speed should be slightly slower than during the white key measurement, since plateau detection may otherwise not function reliably.

If not all expected plateaus are detected, a message will appear and the measurement can be repeated. In that case, move more slowly across the black keys.

Once all plateaus have been detected, the technician can adjust the level and tilt parameters. The same applies here as with the white keys: changes mean additional effort when leveling the black keys. The technician must decide how much tilt of the black keys relative to the reference line of the white keys is acceptable, and how high the black keys should stand above the white keys. The reference curve is no longer the key slip (used for the white keys), but rather the reference curve of the white keys previously defined by the technician.



In the example shown in the image, the black keys on the far right stand 12.15 mm above the white keys, and on the far left 12.25 mm. This results in a tilt of 0.1 mm, corresponding to the difference between the height of the first and the last black key above the white keys.

The arrow keys can be used to change the values, the hash key (#) undoes changes, and pressing OK continues to the next measurement: the key dip of the white keys.

In the next step, the key dip of the white keys can be measured. Since the action and its regulation can influence the dip measurements, it may in some cases be advisable to remove the action before starting the procedure (in an upright) or to detach it from the keyboard (in a grand). For this, the device is taken off the guide rail, in an upright the action is removed, or in a grand the action with the keyboard is pulled out of the case, the action detached, and the keyboard pushed back into the grand.

Care must be taken that the guide rail does not shift during this process. If it does, all subsequent measurements will no longer be valid, as the reference has changed. In such a case, the measurements obtained up to this point can still be saved and used, but the measurement sequence cannot be continued.

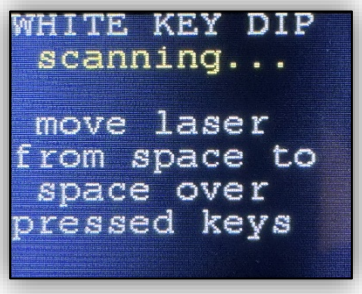
The device is then rotated 180° again, placed back on the guide rail, and the measurement of the white key dip is continued.

Pressing the OK key immediately ends the measurement and opens the save dialog (see chapter “Saving a dataset”).

4.6 Key dip (white keys)

The laser is positioned in the center of the first key (usually A0, or C0 on a Bösendorfer Imperial). Before confirming with OK and starting the measurement, the first keys should already be pressed so that the sensor records the correct key dip values. It has proven effective to press the keys in groups of three and move the laser across these keys. Care should be taken to press the keys as evenly as possible. Alternatively, a defined weight can be placed on the keys.

The laser is always moved from one gap between the keys to the next. The measurement values used are those taken at the center of the key, about 8 mm to the left and right. For this reason, it is not necessary to stop the laser exactly in the center of the gap.

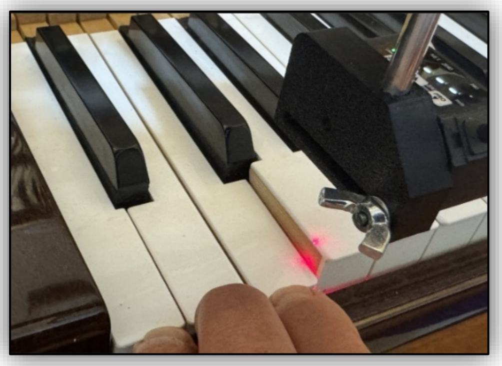


When pressing the keys, care should be taken to press them right at the front edge so that the laser does not accidentally detect a finger and distort the measurement (see images below).

A particularly elegant method is to use the weight rake. This consists of seven defined weights (brass cylinders) placed on the rear section of the keys - behind the laser spot. In this way, seven keys can be scanned simultaneously in each step. Care should simply be taken to place the rake evenly on the keys without touching the guide rail or the sensor.

Work continues upwards in this way: always pressing the keys in groups and moving the laser across the pressed keys until the next unpressed key is reached. The last key is only scanned up to its center. The display then automatically switches to the results dialog, showing the level and tilt of the newly determined reference curve for key dip, relative to the previously defined reference curve of the white keys. These values can then be adjusted by the technician.

Operation is the same as described before: hash key (#) = undo changes, arrow keys = change values, OK = confirm values and proceed with the measurement of the black key dip.

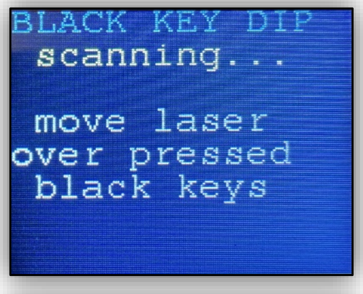



4.7 Key dip (black keys)

The next step is the measurement of the key dip of the black keys. The device is rotated 180° again and placed on the guide rail so that the sensor is positioned behind the rail. The device automatically detects the rotation and also rotates the display by 180°, ensuring the screen remains correctly readable.

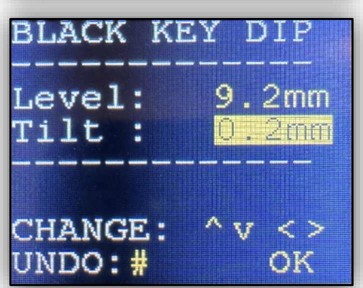
Alternatively, the entire measurement can be completed at this point. Pressing the OK key immediately opens the save dialog, and the following step for measuring the key dip of the black keys is skipped.

For the measurement, the laser spot is aligned with the center of the last white key (normally C8 or A7) and the scan is started by pressing OK. Once the display shows "scanning...", the sensor is moved across the pressed black keys. As before, two or three keys are pressed simultaneously while the sensor is guided over them. Even pressure is essential to ensure accurate measurement results.



The weight rake with the brass cylinders can also be used. In this case, five cylinders are placed on the rear part of the black keys, pressing them down simultaneously.

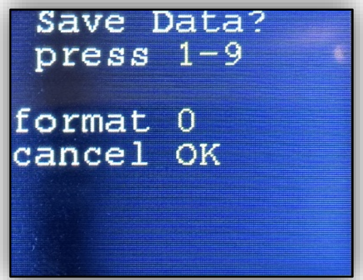
When the last black key has been fully scanned, the results dialog appears with the measured values of the generated reference curve. The reference here is the previously determined curve of the black key heights. In the example shown, the average dip of the black keys is 9.2 mm with a tilt of 0.2 mm. This means that if the black keys are leveled to this reference, the dip will be 9.1 mm on the right side and 9.3 mm on the left side.



The values can again be adjusted according to requirements. Pressing OK completes the entire measurement, and the save dialog is displayed.

4.8 Saving a dataset

There are nine memory slots available for storing a complete dataset. Note that any existing dataset will be overwritten without confirmation. The entire memory can be reformatted by pressing the 0 key; this will erase all stored datasets. Pressing OK cancels the process and continues without saving.

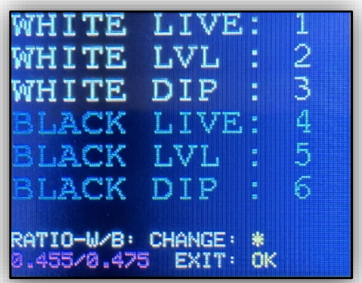


When a number key between 1 and 9 is pressed, all recorded data are permanently stored in the device's memory. These datasets remain available even after a longer period of time and can be reloaded by using the same number. This allows an instrument to be measured in several steps. For example, the keyboard of a grand piano can be measured first. The device is then switched off, the action removed and set up on the workbench, and the action detached from the keyboard. After switching the device back on, the corresponding dataset can be reloaded, and the correction of the keys can continue.

After saving, a short message appears confirming that the dataset has been stored successfully and is now available via Wi-Fi for download. This means that the dataset can be loaded into Excel using the special workbook (supplied with the device or available from the web server) and further analyzed there. In this workbook, deviations can be conveniently displayed in a large chart, and graphics can be generated at the press of a button, showing the required paper punching's for each note in color. Further details are provided later in the chapter "Analyzing datasets in Excel".

Afterwards, the start screen appears for adjusting or correcting the key heights and key dip.

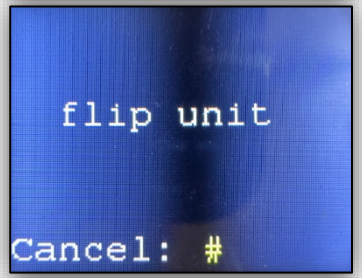
4.9 Retrieving data: Keyboard leveling / key dip adjustments



After loading an existing dataset or completing a measurement, the start screen appears for adjusting or correcting the key heights and the key dip. Depending on which measurement series have already been recorded, the corresponding menu items are shown highlighted (if available) or dimmed (if not). This screen is also displayed when a dataset is loaded after selecting the key level function from the main menu.

At this stage, it is always possible to change the key ratio of the white and black keys by pressing the star key (*) (see chapter “Measuring the key ratio”). The number keys 1–6 can be used to access the available functions, which are described in detail below. Pressing the OK key returns to the main menu.

4.9.1 WHITE LIVE (Live measurement of white keys)



Pressing 1 on the IR remote control activates the WHITE LIVE function.

If this function is selected while the device is still rotated on the guide rail in the area of the black keys, a message appears again instructing to flip the unit so that the sensor is positioned in front of the guide rail (flip unit).

The laser spot is then moved to the exact center of key A0 and confirmed with OK. The function is then activated.

From this point on, the heights of the white keys are measured live and the deviations from the reference curve previously defined by the technician are displayed.

For example, if it has been defined that the keys should be 20 mm above the key slip (or 65 mm above the keybed) with a tilt of 0 mm (perfectly level), the deviations of each individual measured key from this ideal line are shown.

Important note:

The values displayed in this function refer to the reference curves that were previously recorded and saved at exactly the same position of the guide rail on the case and with the same lowering and position of the sensor arm.

If the guide rail has been removed in the meantime and later reattached (possibly in a slightly different position) or the sensor arm has been adjusted, the sensor must be recalibrated against the previously recorded measurement.

To do this, select the WHITE LVL function by pressing 2. Then move to one of the first keys where a deviation is displayed, since the exact measurement value is shown there.

For keys where “OK” is displayed, the deviation may still be between -0.03 mm and +0.03 mm, which is not useful for calibration. Now adjust the sensor arm so that in LIVE mode (IR key 1) the same value is displayed as in WHITE LVL mode. Repeat this process for a key in the middle and in the upper range.

When the displayed live values match the recorded values as closely as possible, the calibration is complete and the live values can be used. However, the ideal procedure is to start and use the live function immediately after measuring the keyboard, without moving the guide rail or the sensor arm.

When the key is not pressed, the measurement value for the key height is displayed (LVL DISC). Negative values (shown in orange) indicate that the key is too low. In this case, paper punchings must be added. The required punchings are displayed graphically at the bottom of the screen.

Positive values (shown in magenta) indicate that the key is too high. In this case, punchings must be removed, or material must be taken off the wooden part of the key.

The device can be moved aside to perform the correction on the key. Afterwards, the sensor is placed back on the corrected key to check the measurement again.

As soon as the key is pressed, the display switches and the key dip value is shown (DIP DISC). Both the absolute dip and the deviation from the target value are displayed. If the deviation is between –0.03 and +0.03 mm, the value is shown in white, indicating a neutral result.

At the top, TARGET DIP shows the current reference value for key dip. If the dip has been measured, the device always displays the actual measured value here. If a tilt greater than 0 is present, the values gradually increase or decrease as the sensor is moved further up the keyboard. If the dip has not been measured, a fixed standard value is shown, which can be adjusted using the arrow keys (up/down) and then used as the reference.

CURVE indicates the curvature of the reference curve at the currently measured key. This is only relevant if the keyboard was measured in CURVED mode (see chapter “Starting a measurement”).

At any time, the star key (STORE function) can be used to overwrite the previously measured, recorded, and saved value displayed in WHITE-LVL or WHITE-DIP mode with the current LIVE measurement value.

In this way, all keys can gradually be corrected using the LIVE mode – for those who prefer this method. This provides precise control for each key, showing exactly how the measurement value changes when punchings are added or removed.

Another method for adding punchings to all keys at once can be carried out using the WHITE-LVL / WHITE-DIP or BLACK-LVL / BLACK-DIP functions. In this case, either all keys are removed from the keyboard frame, or in the case of a grand piano keyboard the action is detached for correction. These functions will be described in detail later.

4.9.2 BLACK LIVE (Live measurement of black keys)

Pressing IR key 4 activates the LIVE mode for the black keys. If the sensor is still positioned in the area of the white keys, in front of the guide rail, a prompt will appear to flip the unit. The laser spot should then be positioned in the center of key A0 and confirmed with OK.

All black keys can now be measured. This function works in the same way as the previously described WHITE-LIVE function for the white keys.

Note: Black keys are detected within a range of ±4 mm around the center of the key. If detection is shifted slightly to the right or left, meaning the black key is recognized too early or too late, the free mode can be activated by pressing the hash key (#). In this mode, the sensor can be moved freely. First, move to the position where the black key is currently detected on the display, press the hash key, then move the sensor to the correct position (approximately 4 mm to the left of the center of the black key) and press the hash key again.

This situation usually occurs if, when activating the BLACK-LIVE function, the laser was not positioned exactly in the center of key A0.

4.9.3 WHITE LVL / WHITE DIP / BLACK LVL / BLACK DIP (Retrieve recorded measurements)

The functions are accessed using IR keys 2 (WHITE LVL), 3 (WHITE DIP), 5 (BLACK LVL), or 6 (BLACK DIP). They display the previously measured, recorded, and possibly stored values, i.e. the deviations from the defined reference curve.

If the sensor is not yet positioned on the correct side of the guide rail (front for white keys, back for black keys), the message “flip unit” will appear again. In this case, proceed in the same way as described earlier.

As the sensor moves across the keys, the name of the currently scanned note is shown at the top, e.g. “A0,” “G5,” or “F#3.” If the sensor is moved beyond the keyboard range to the left or right, the message OUT OF RANGE will be displayed.

To the right of the note name, small arrows are displayed depending on the deviation: upward arrows (magenta) or downward arrows (orange).

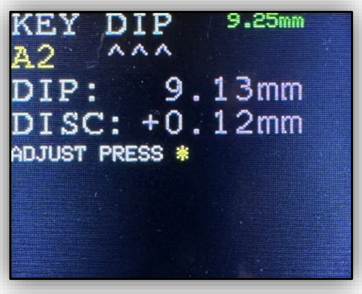
Upward arrows indicate that the key is higher than the desired reference curve (LVL functions), i.e. too high and must be corrected downward. In DIP mode, upward arrows indicate that the key dip is smaller than the reference, i.e. insufficient dip. To correct this, punchings must be removed or material taken off the wooden part of the key.

Downward arrows indicate, conversely, that the key is lower than the reference curve. In LVL mode, the key is therefore too low and must be corrected upward. In DIP mode, downward arrows indicate that the key dip is larger than the reference, i.e. excessive dip. To correct this, punchings must be added. The required punchings are shown at the bottom of the display.

Negative values are displayed in orange, corresponding to the downward arrows. Positive values are displayed in magenta, corresponding to the upward arrows. If the measurement lies within ±0.03 of the reference, “OK” is shown and no correction is required.

The more arrows are displayed, the greater the deviation from the reference value.

In the DIP functions, the reference value for the key dip valid for the current key is additionally displayed at the top in green. This value may vary from key to key if tilt > 0 is present; otherwise, it remains constant across all keys.



ADJUST MODE:

By pressing the star key (*), the Adjust mode for the currently selected key is activated. The laser sensor measures the present height of the key and sets this value as the reference for the subsequent corrections.

On the display it can be seen that the indicated measurement value and the corresponding punching combination changes immediately as soon as the key is slightly raised or lowered. In this way, the key can be corrected by inserting the required punchings. To do this, the sensor is moved aside to allow the key to be removed. Adjust mode remains active for this key. When the sensor is moved back onto the same key, the achieved correction is displayed immediately. Once the key shows no deviation, Adjust mode ends again by pressing the star key (*), and the value is saved in the dataset.

This procedure is particularly helpful for correcting keys that stand too high when it is unclear which punchings were originally inserted, or whether any punchings are present at all. In the latter case, minor corrections can also be made by removing a small amount of material from the wooden part of the key.

On grand pianos, the keys to be corrected are weighted at the back with a lead weight so that they remain in the upper position. Since the action must be removed to insert punchings, the Adjust mode is then activated and the key is leveled.

In this way, all keys that stand too high can first be corrected. Afterwards, the keys that are too low are adjusted by inserting the punching combinations shown on the display. It is not necessary to check every single key again in Adjust mode. If the work is done carefully, the results will be accurate.

Work can be carried out either in groups, for example by removing and adjusting all the keys of one octave at a time, or by removing the entire keyboard and inserting all the required punchings at once.

Typical sources of error:

If old felt punchings are reused, they should be reinstalled in the same orientation; otherwise, the measurement result may change simply by turning the felt.

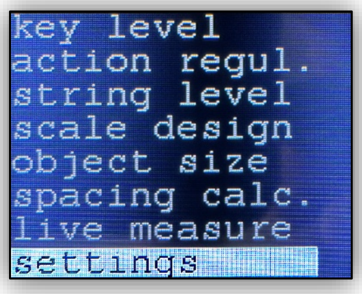
Thin punchings sometimes stick together due to the punching process. Instead of one, two or even three may be inserted by mistake. After new punchings are inserted, the keys at the balance rail (LVL functions) or at the front (DIP functions) should therefore be pressed lightly to moderately and moved up and down several times. Due to punching burrs, punchings can initially have a small ridge that distorts the measurement result and only settles after extended playing.

It is also crucial to determine the actual thickness of the available punchings, e.g. with a digital caliper. In practice, the actual dimensions often differ from the nominal values. In one case, the green punchings were not 0.12 mm as specified, but 0.15 mm. The pink punchings measured 0.19 mm instead of the specified 0.20 mm. This check should be carried out once. The values for balance rail and key dip can then be stored in the device settings (see chapter “Defining / changing punching thicknesses”).

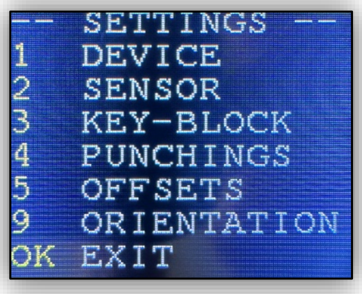
IMPORTANT NOTE:

In Adjust mode, only relative changes are displayed, i.e. how much the height changes compared to the previous measurement value. This procedure is highly accurate. The absolute height differs slightly when a lead weight is placed at the back of the key compared to the installed action, since the forces act differently. However, this is irrelevant for the adjustment process, as only the relative change to the previously measured value is required (for example, in a grand piano with the action inserted and cheek blocks mounted).

4.10 Defining / changing punching thicknesses

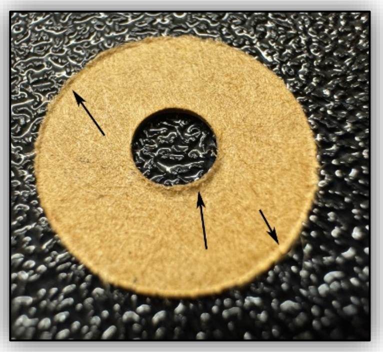


In the main menu, select “settings”. This opens the settings menu, where IR key 4 is used to select “punchings”. A submenu then opens, allowing the punching thicknesses to be defined separately for the balance rail and the front rail (IR key 1 or 2).



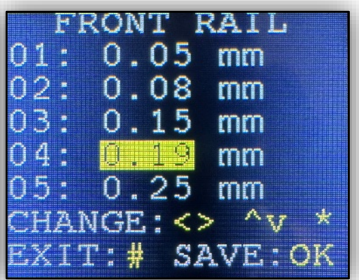
Within the dialog, use the up/down arrow keys to move to the next punching position. The left/right arrow keys adjust the currently selected value.

It is recommended to measure several punchings of each thickness precisely with a digital caliper. Within a single batch, values are usually fairly consistent, but they may differ from the nominal specification. For example, green punchings specified as 0.12 mm may actually measure 0.15 mm. When measuring, ensure that the burr from the punching process does not distort the reading; punchings should be lightly smoothed beforehand, e.g. with a small roller. The caliper pressure must be applied carefully – not too strong and not too weak – in order to determine the actual value.



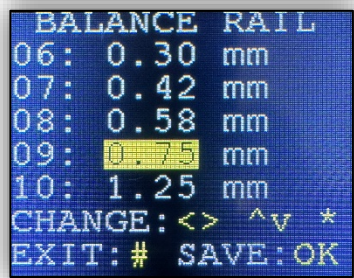
Because of the burr created during the punching process, it is especially important to press the punchings firmly against the balance rail during leveling so that the burr is eliminated immediately. If a punching with a burr is inserted and the key is placed loosely on the pin without being pressed down firmly, the key will initially stand slightly higher at the front. Only after extended playing will the punching settle and the key sink lower. This results in additional work later, since the entire keyboard would then have to be leveled again.

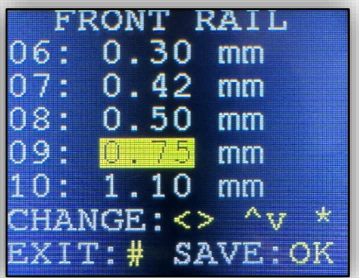
It is also important to ensure that the paper punchings are sufficiently dry. High humidity naturally affects the thickness of the punchings. It is recommended to place small silica gel packets in the storage containers. These absorb excess moisture, keeping the punchings dry and dimensionally stable.



If, during leveling, it becomes apparent that a certain punching thickness consistently results in values that are too high or too low despite the correct key ratio being set, the punching values should be adjusted accordingly.

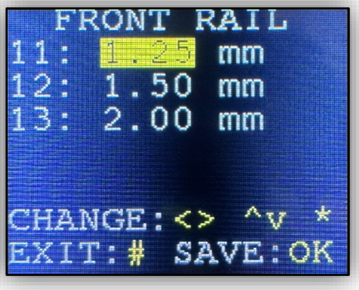
Pressing OK saves all values permanently in the device, making them available again after the next power-up.





Important note:

Older datasets of key height and key dip measurements always retain the punching thicknesses that were stored in the device at the time. When a dataset is saved, the currently defined punching values are saved along with it. These values will later be reloaded exactly as they were, even if the punching thickness settings have since been modified.



BALANCE-RAIL-PUNCHINGS												
0,05	0,08	0,15	0,19	0,25	0,30	0,42	0,58	0,75	1,25			

FRONT-RAIL-PUNCHINGS												
0,05	0,08	0,15	0,19	0,25	0,30	0,42	0,50	0,75	1,10	1,25	1,50	2,00

4.11 Measuring the key ratio

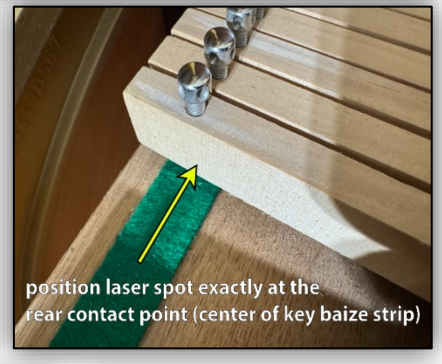
Whenever the key level function is called - regardless of whether an existing dataset is loaded or a new measurement is started - the key ratio can be adjusted.

The values currently stored in the device, separately for white and black keys, are displayed and can be edited using the arrow keys. To calculate the required punching thickness from the measured deviation at the front of the key, the key ratio is needed. It is defined as rear length / total length.

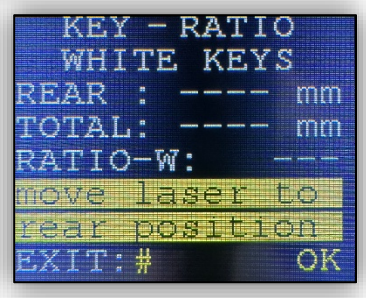
$$\text{Ratio} = \frac{\text{rear len}}{\text{total len}}$$

Rear Len: Distance from the rear contact point of the key (center of the key baize strip) to the hole for the balance pin.

Total Len: Distance from the rear contact point to the measuring position at the front of the key (where the laser spot measures the key height).

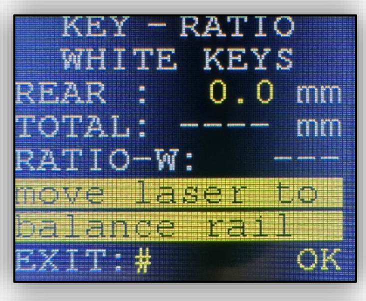


This ratio has less influence than one might expect. Even with a standard value of 0.42 - which approximates well for most instruments - the punchings are already calculated with good accuracy. For maximum precision, however, the exact key ratio should either be measured manually with a tape measure and entered directly in the menu or determined using the convenient "MEASURE KEYS" - function.

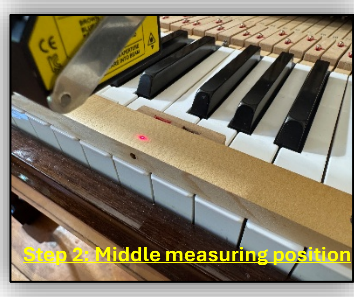


To do this, select the corresponding entry in the menu using the arrow keys. A straight, unbent key is placed on the keyboard so that the laser can be positioned at three points in sequence:

Step 1: Rear: Rear contact point of the key on the key baize strip (center). Position the laser spot there and confirm with OK. The display will show 0.00 mm (position zeroed).



Step 2: Middle: Hole for the balance pin. Position the laser spot in the center of the hole and confirm with OK. The display will show the rear length (REAR).

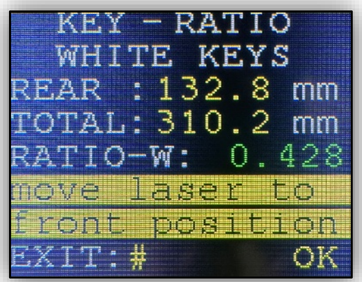


Step 3: Front: Measuring position at the front of the key, where the key height is measured during leveling. After positioning the laser here, the total length (TOTAL) will be displayed.

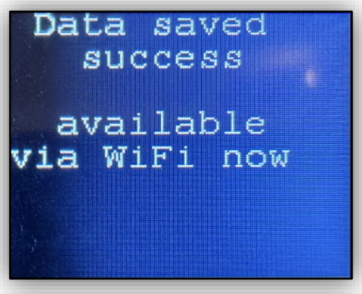
The resulting key ratio (RATIO_W) is automatically calculated and also displayed. By pressing OK, the value is accepted. The same procedure is then repeated for a black key. In most cases, the key ratio of the black keys is slightly higher than that of the white keys.

By pressing the star key (*), the entered values can be saved as default values in the device settings. These default values are then automatically applied after each restart. However, if a previously stored dataset is loaded, the values that were saved at the time of storing that dataset will, of course, be restored.

Pressing OK ends the dialog.



4.12 Analyzing datasets in Excel



After a new dataset has been measured or an existing dataset has been loaded, a message appears indicating that the data is available via WIFI. The data can then be transferred to an Excel spreadsheet over a WLAN connection.

The measurement results can be visualized and further processed in diagrams. In addition, graphics can be generated showing, octave by octave, the required punchings for each note in color.

These graphics can, for example, be transferred to a smartphone or tablet as a screenshot, making them readily available at the instrument in the workshop.

4.12.1 WiFi connection setup

The connection between the device and the computer can be established in two ways:

Connection via an existing home network (NORMAL WIFI MODE):

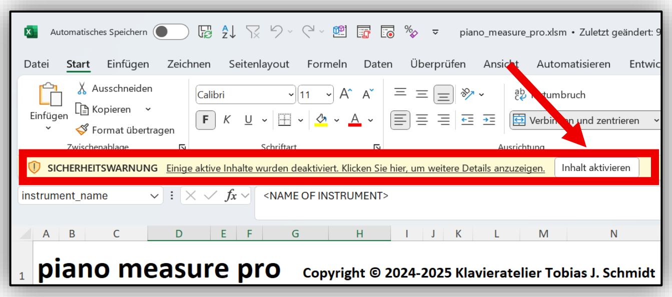
At startup, the device automatically connects to the available WiFi network. The initial setup, including entering the WiFi password, is described in the chapter “Connecting to home WiFi”. Afterwards, the PC or laptop running the Excel spreadsheet only needs to be connected to the same WiFi network.

Direct connection without a home network (DIRECT SOFT AP):

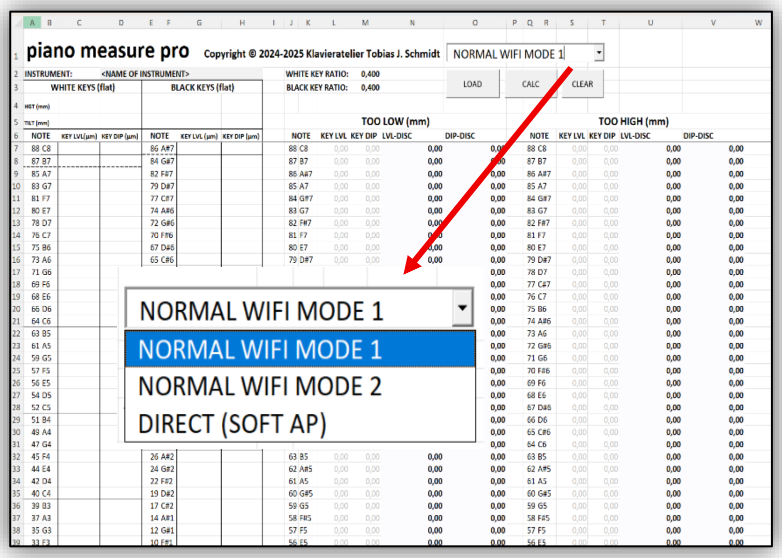
If no WiFi network is available, a direct connection between the device and the PC/laptop can be established. On Windows, open the WiFi settings from the taskbar icon and access the network list. On macOS, open the WiFi menu from the menu bar at the top right of the screen. In both cases, the device will appear as “piano-measure-pro” (Device 1 with Sensor 1) or “piano-measure-pro-2” (Device 2 with Sensor 2).

After selecting the corresponding network, the PC is directly connected to the device, and the data can be transferred as described in the following chapter.

4.12.2 Retrieving data from the device



After the Excel workbook is opened, it must be ensured that macro functionality is enabled. When the file is opened in Excel, a yellow message bar usually appears with the option “Enable Content”. This option must be activated; otherwise, data transfer is not possible. If this notification does not appear, macros are most likely completely disabled. In this case, they can be enabled in the Excel settings: Menu File → Options → Trust Center → Macro Settings. After changing the settings, Excel must be restarted for the changes to take effect.



On the “DATA” worksheet, a selection box is located in the upper right corner. Here it is specified whether Device 1 or Device 2 is connected via the home WiFi (NORMAL WIFI MODE 1 or NORMAL WIFI MODE 2). If a direct connection between PC and device is used, DIRECT (SOFT AP) must be selected.

By clicking the “LOAD” button, the entire dataset is then automatically loaded into the Excel sheet. If the transfer does not succeed on the first attempt, the process can simply be repeated.

4.12.3 Worksheet "DATA"

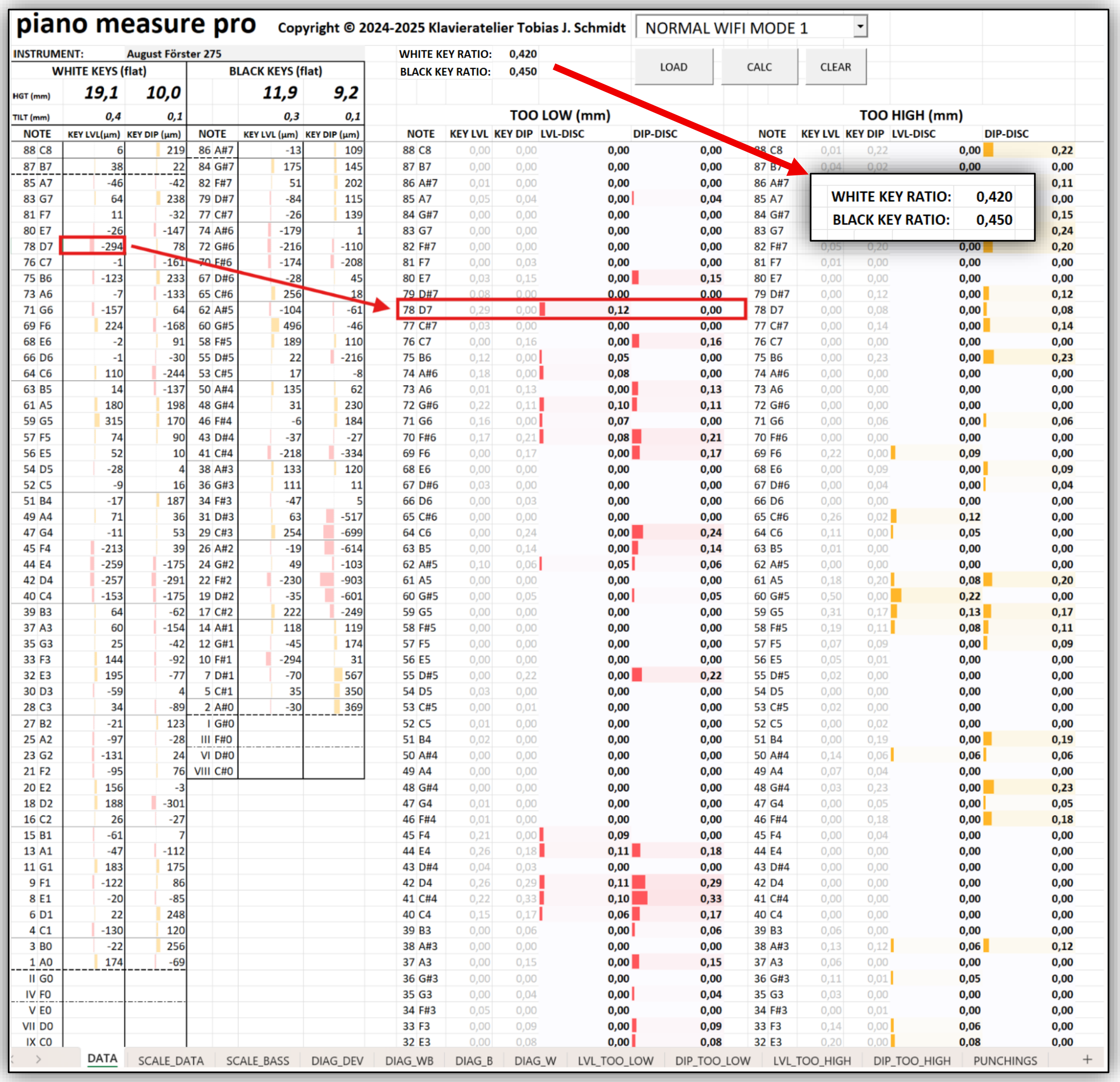
After the measurement data has been loaded, it is displayed in tabular form.

- Deviations downward (keys too low or key dip too large) are indicated by red bars.
- Deviations upward (keys too high or key dip too small) are indicated by yellow bars.

In the left columns, the deviations are displayed in micrometers (1/1000 mm).

A value of -294, for example, corresponds to a deviation of -0.294 mm downward, meaning that the key is too low.

With a WHITE KEY RATIO of 0.42, this results in a calculated punching thickness of 0.123 mm. This thickness must be added so that the front of the key is raised by 0.294 mm and aligns exactly with the reference curve.



On the right-hand side, there are two blocks:

“TOO LOW” (deviations in red)

“TOO HIGH” (deviations in yellow)

In these blocks, the measurement results from the left columns are converted using the key ratio values for white and black keys (KEY RATIO) and displayed as millimeter values (LVL-DISC / DIP-DISC).

TOO LOW (mm)					TOO HIGH (mm)				
NOTE	KEY LVL	KEY DIP	LVL-DISC	DIP-DISC	NOTE	KEY LVL	KEY DIP	LVL-DISC	DIP-DISC
88 C8	0,00	0,00	0,00	0,00	88 C8	0,01	0,22	0,00	0,22
87 B7	0,00	0,00	0,00	0,00	87 B7	0,04	0,02	0,00	0,00
86 A#7	0,01	0,00	0,00	0,00	86 A#7	0,00	0,11	0,00	0,11
85 A7	0,05	0,04	0,00	0,04	85 A7	0,00	0,00	0,00	0,00
84 G#7	0,00	0,00	0,00	0,00	84 G#7	0,17	0,15	0,08	0,15
83 G7	0,00	0,00	0,00	0,00	83 G7	0,06	0,24	0,00	0,24
82 F#7	0,00	0,00	0,00	0,00	82 F#7	0,05	0,20	0,00	0,20
81 F7	0,00	0,03	0,00	0,00	81 F7	0,01	0,00	0,00	0,00
80 E7	0,03	0,15	0,00	0,15	80 E7	0,00	0,00	0,00	0,00
79 D#7	0,08	0,00	0,00	0,00	79 D#7	0,00	0,12	0,00	0,12
78 D7	0,29	0,00	0,12	0,00	78 D7	0,00	0,08	0,00	0,08
77 C#7	0,03	0,00	0,00	0,00	77 C#7	0,00	0,14	0,00	0,14
76 C7	0,00	0,16	0,00	0,16	76 C7	0,00	0,00	0,00	0,00
75 B6	0,12	0,00	0,05	0,00	75 B6	0,00	0,23	0,00	0,23
74 A#6	0,18	0,00	0,08	0,00	74 A#6	0,00	0,00	0,00	0,00
73 A6	0,01	0,13	0,00	0,13	73 A6	0,00	0,00	0,00	0,00
72 G#6	0,22	0,11	0,10	0,11	72 G#6	0,00	0,00	0,00	0,00
71 G6	0,16	0,00	0,07	0,00	71 G6	0,00	0,06	0,00	0,06
70 F#6	0,17	0,21	0,08	0,21	70 F#6	0,00	0,00	0,00	0,00
69 F6	0,00	0,17	0,00	0,17	69 F6	0,22	0,00	0,09	0,00
68 E6	0,00	0,00	0,00	0,00	68 E6	0,00	0,09	0,00	0,09

In the upper left corner, the technician can enter the name of the instrument. Below that, the parameters of the reference curves defined during measurement are shown.

In the row HGT (Height), the following values are displayed in sequence:

- height of the white keys above the key slip (if measured), here 19.1 mm
- key dip of the white keys, here 10 mm
- height of the black keys above the white keys, here 11.9 mm
- key dip of the black keys, here 9.2 mm

INSTRUMENT:	August Förster 275				
	WHITE KEYS (flat)			BLACK KEYS (flat)	
HGT (mm)	19,1	10,0		11,9	9,2
TILT (mm)	0,4	0,1		0,3	0,1
NOTE	KEY LVL(µm)	KEY DIP (µm)	NOTE	KEY LVL (µm)	KEY DIP (µm)
88 C8	6	219	86 A#7	-13	109
87 B7	38	22	84 G#7	175	145
85 A7	-46	-42	82 F#7	51	202
83 G7	64	238	79 D#7	-84	115
81 F7	11	-32	77 C#7	-26	139
80 E7	-26	-147	74 A#6	-179	1
78 D7	-294	78	72 G#6	-216	-110
76 C7	-1	-161	70 F#6	-174	-208

Below that, the row TILT shows the slope of the reference curves. A tilt of 0.4 mm in the column KEY LVL (WHITE) means that the reference curve used for leveling is 0.4 mm lower on the far right than on the far left. This difference is not visible to the naked eye but reduces the amount of work compared to correcting the tilt to zero.

4.12.4 Worksheet “DIAG_DEV”

This worksheet contains a large chart in which the deviations are displayed graphically. Note that the values shown have already been converted using the KEY_RATIO factors. They therefore directly represent the calculated punching thicknesses.

- Key heights are displayed in blue (HEIGHT).
- Key dip values are displayed in orange (KEY DIP).

Values between -0.03 and +0.03 are shown only as bars without numbers, since they normally do not require correction (tolerance range). The buttons below the chart allow different measurement values to be shown or hidden:

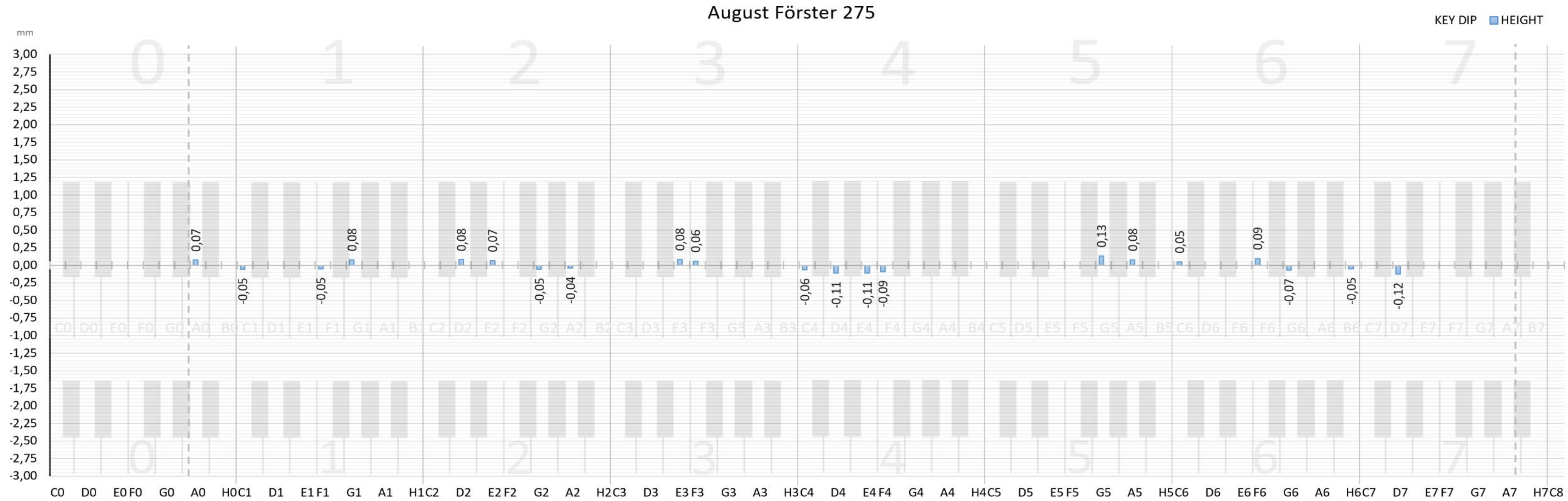
White key values can be displayed separately from black key values (“WHITE ONLY” / “BLACK ONLY”) or together (“BLACK & WHITE”).

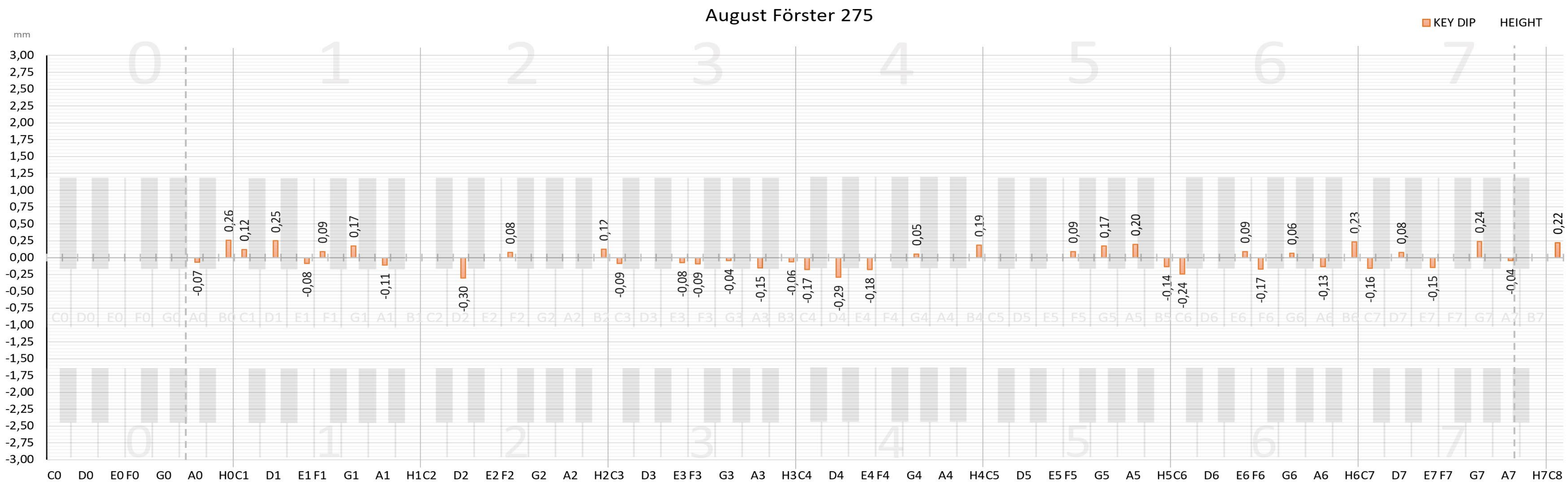
Key height (HEIGHT) values can be toggled with the “KEY LVL” button.

Key dip values can be toggled with the “KEY DIP” button.

It can also be selected whether only the bars are displayed or the corresponding measurement values as well (“LVL NUMBERS” and “DIP NUMBERS”).

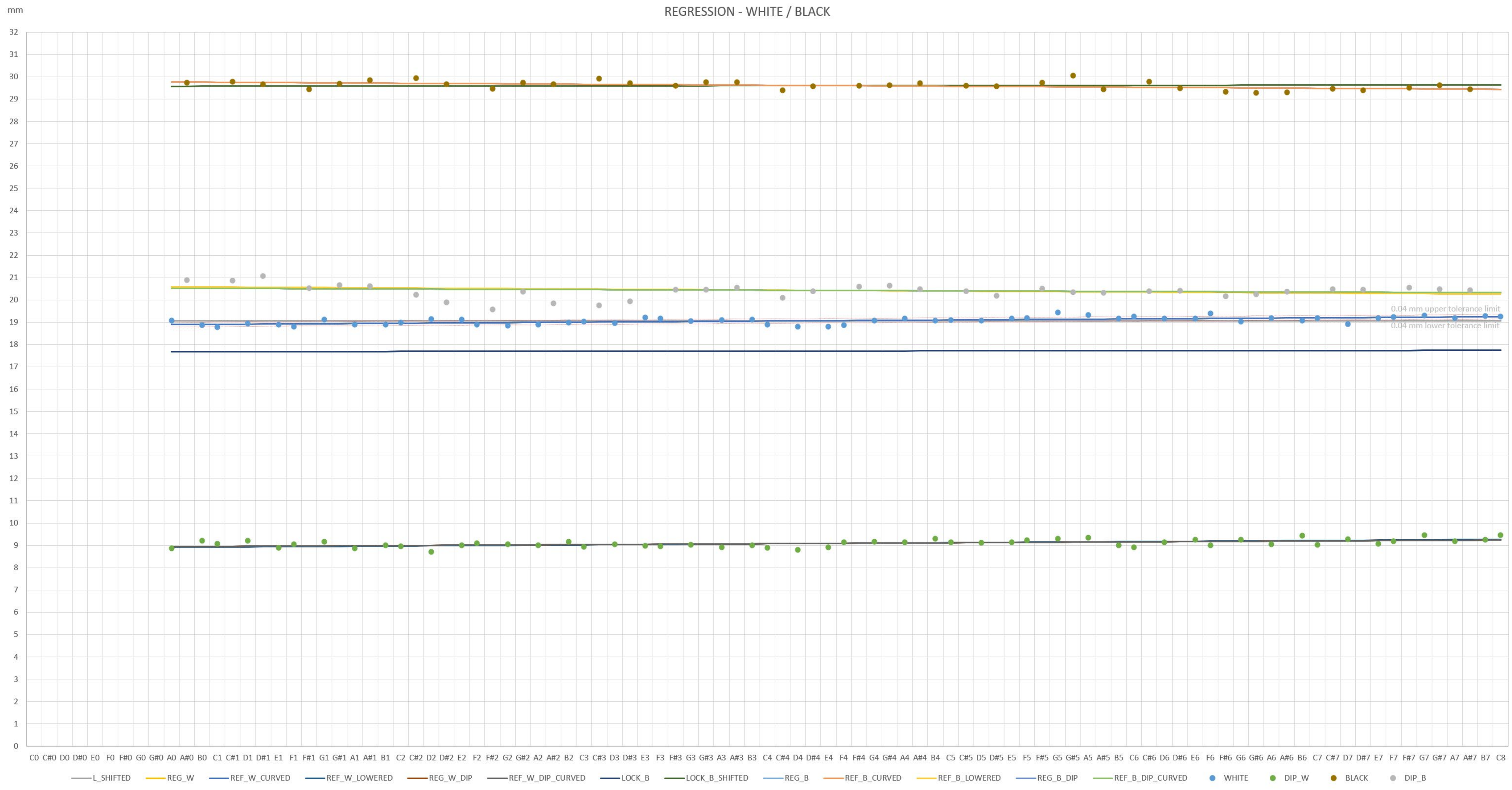
BLACK & WHITE | WHITE ONLY | BLACK ONLY | KEY LVL | LVL NUMBERS | KEY DIP | DIP NUMBERS


August Förster 275
KEY DIP
HEIGHT
mm
0,07
-0,05
-0,05
0,08
0,08
0,07
-0,05
-0,04
0,08
0,06
-0,06
-0,11
-0,11
-0,09
0,13
0,08
0,05
0,09
-0,07
-0,05
-0,12

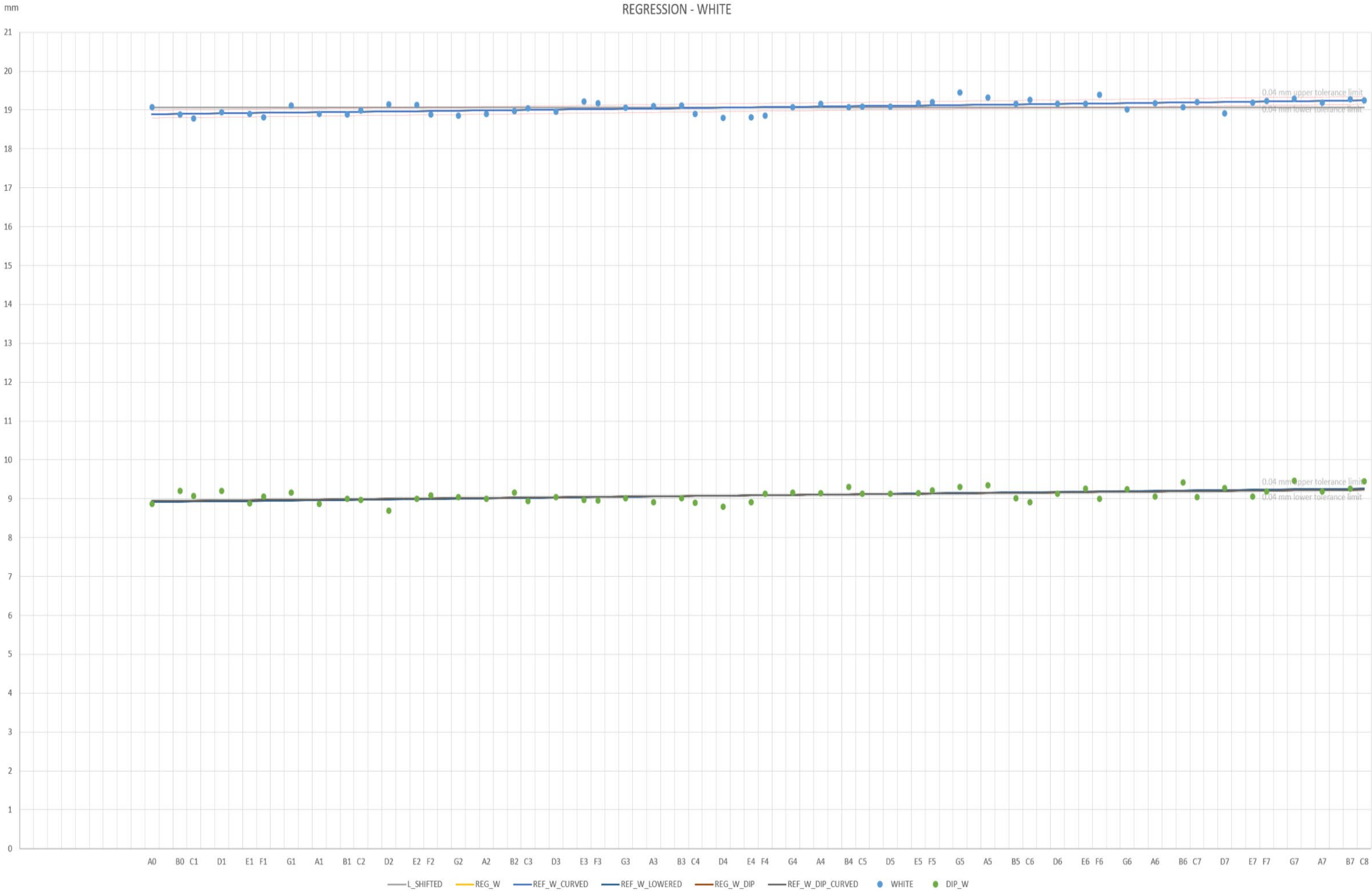

August Förster 275
KEY DIP
HEIGHT
mm
-0,07
0,26
0,12
0,25
-0,08
0,09
0,17
-0,11
-0,30
0,08
0,12
-0,09
-0,08
-0,09
-0,04
-0,15
-0,06
-0,17
-0,29
-0,18
0,05
0,19
0,09
0,17
0,20
-0,14
-0,24
0,09
-0,17
0,06
-0,13
0,23
-0,16
0,08
-0,15
0,24
-0,04
0,22

4.12.5 Worksheet "DIAG_WB"

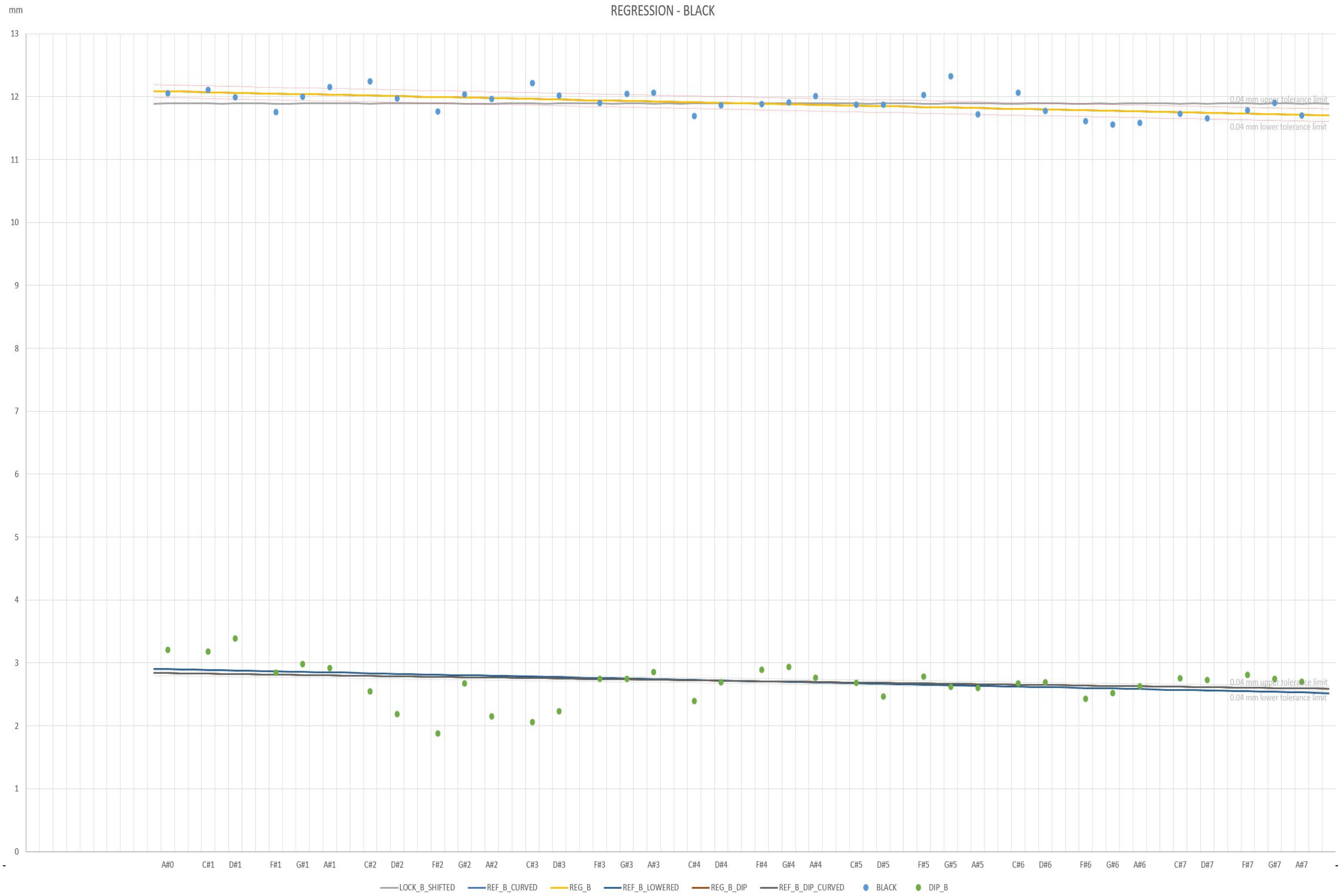
This diagram displays all measurement values and reference curves for the white and black keys. The slightly slanted reference curves (tilt > 0) are clearly visible. These represent the best possible fit to the measured values. As long as the tilt remains within an acceptable range, the workload is minimized. If desired, however, the tilt can be set to zero after the measurement process to produce a perfectly straight reference curve (see chapter "Starting a measurement"). **Important:** The mm scale refers to the key slip, provided that at the start the height of the white keys above the key slip was measured on both the left and right sides. The blue values represent the heights of the white keys, here approximately 19–20 mm. The dark line at around 18 mm, below the reference curve for the white keys (blue), shows the base curve of the white keys for the black keys in the rear section. Because the guide rail was likely not perfectly aligned horizontally with the key surface during measurement, turning the sensor for measuring the black keys resulted in slightly lower readings for the white keys. The black keys are about 12 mm higher than this base curve, i.e. just under 30 mm above the key slip.



4.12.6 Worksheet “DIAG_W”

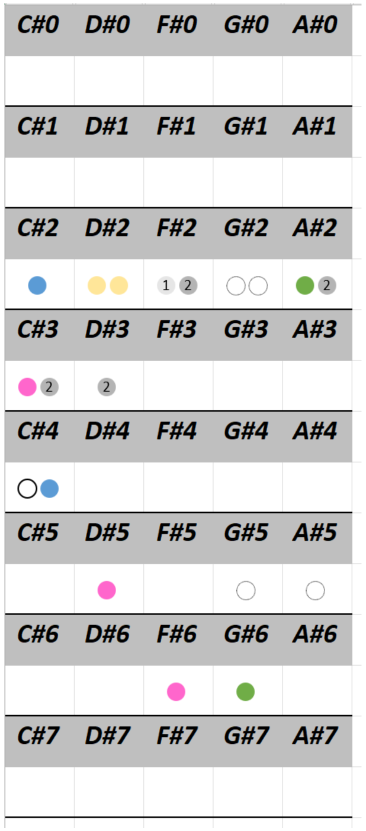


4.12.7 Worksheet “DIAG_B”



4.12.8 Worksheets „LVL_TOO_LOW“ / „DIP_TOO_LOW” / LVL_TOO_HIGH / DIP_TOO_HIGH

After the measurement data has been imported, the “CALC” button on the “DATA” worksheet can be pressed. This automatically generates four overview tables in which the required punchings for each key are displayed in color. The calculations are based on the punching thickness values defined in the “PUNCHINGS” worksheet.



When a dataset is loaded from the device, the punching thickness values valid at the time of recording are also transferred and entered into the worksheet. These values can be modified if necessary, and the color-coded tables can then be recalculated at any time by clicking “CALC” based on the updated values.

With the checkboxes “WHITE” and “BLACK”, the display can be limited to either the white or the black keys, which greatly improves clarity. This allows the technician to focus specifically on the required punchings for a subgroup of keys.

The color-coded tables can easily be transferred to a smartphone or tablet via screenshot. This makes the information directly available at the instrument and simplifies the process of placing the correct punchings under the keys.

There is a special case for the thicker punchings: The last four balance rail punchings and the last seven front rail punchings (from 0.42 mm upwards) are displayed in the tables only with an integer value from 1-7. This ensures clarity, as displaying the exact thicknesses here would make the tables too cluttered. In the device itself, however, the thicker punchings are shown with their actual thickness values.

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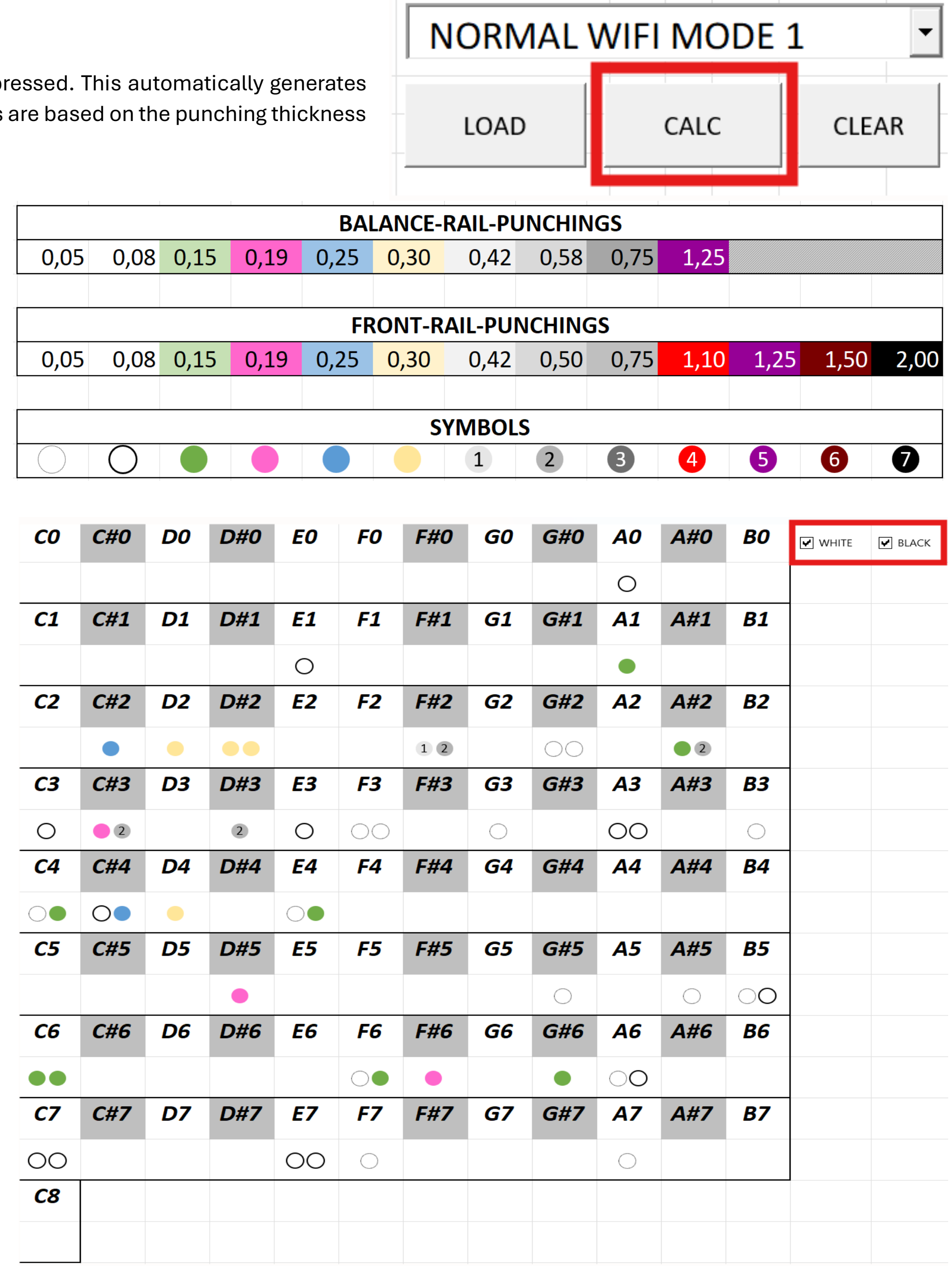
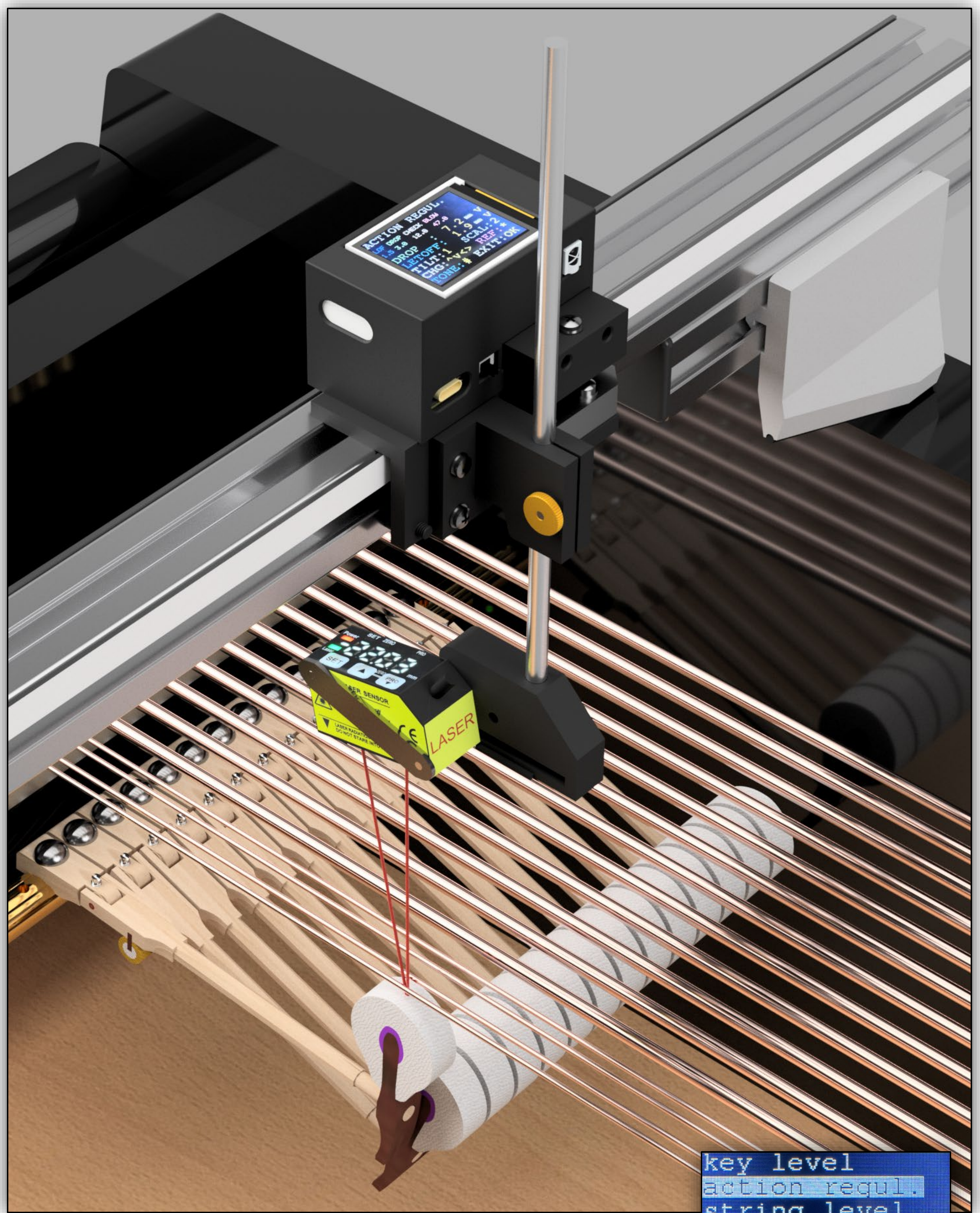


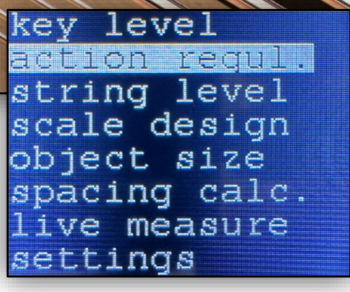
Practical tip:

It is advisable to prepare the required number of punchings of each thickness in advance. Punchings that may have stuck together during the punching process should be separated and then laid out loosely. This provides a good control: if no punchings remain and none are missing at the end, it is ensured that all punchings have been placed correctly under the keys.

5 “action regul.” function – Measuring and adjusting grand piano action regulation parameters



The “action regul.” function is selected from the main menu. After activation, the device enters a dedicated measurement mode for capturing and adjusting the main regulation parameters of the grand piano action. Using the laser sensor, the values for letoff, drop, check, and blow distance can be determined and adjusted with high precision.

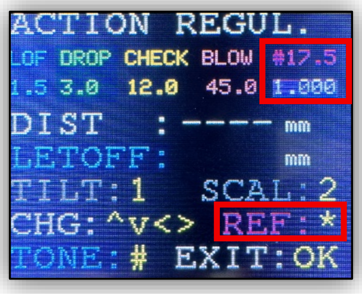


5.1 Reference Modes (STRING / HAMMER-TO-STRING)

The laser measures the distance from the hammer head to the bottom of the string and thus provides the basis for various regulation parameters for example, the distance of the hammer head in rest position to the bottom of the string (the so-called blow distance).

The reference, i.e. the lower edge of the string, can be determined in two different modes:

5.1.1 STRING Mode



The STRING mode is used when the dampers have not yet been installed. In this case, the strings are directly accessible from above in the striking area.

The sensor measures the top edge of the string and corrects the value downward by the entered string diameter. In this way, the exact bottom of the string is obtained as a reference.

This mode is active by default when the action regul. function is first started. It can be recognized by the violet display of the string thickness in the top right corner of the screen:

- the string number (#) on top,
- the exact string diameter in millimeters below.

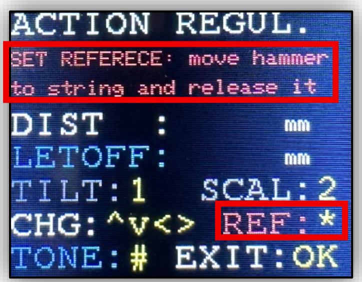
The string diameter can be adjusted at any time with the up/down arrow IR-keys, depending on which note is being measured.

An approximate value is sufficient, as the deviations are very small:

- difference between two string numbers: 0.025 mm (25 µm)
- difference of four string numbers: only 0.1 mm (1/10 mm).

Advantage of STRING mode: When moving the sensor on to the next note, a new reference is automatically measured when crossing the strings. It is sufficient to roughly adjust the string diameter from time to time. An acoustic signal confirms that a new reference has been set.

5.1.2 HAMMER-TO-STRING Mode

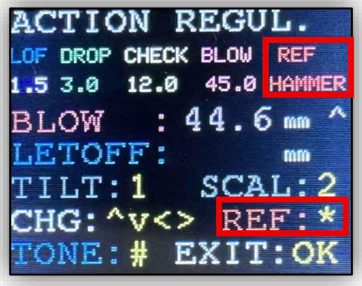


When the dampers are installed, direct measurement of the string is not possible, as it is covered by the dampers.

In this case, the HAMMER-TO-STRING mode is used:

- The sensor measures the hammer head directly beneath the string at its crown.
- This measurement is taken as the reference for the bottom of the string.
- The hammer head is lifted to the string with a hammer shank lifter tool and then released.

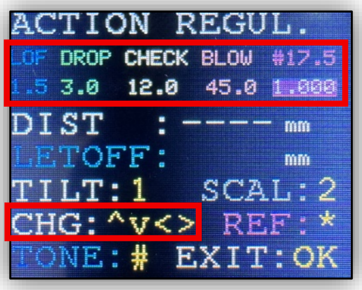
Switching between the two modes is done with the asterisk key (*).



The active mode can be identified on the display:

- STRING mode: “REF:” shown in violet, string diameter displayed.
- HAMMER-TO-STRING mode: “REF:” shown in red, with the display reading “REF HAMMER” (also in red) instead of the string diameter.

5.2 Main Dialog



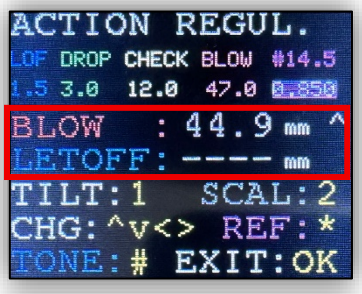
5.2.1 Target values of the regulation parameters

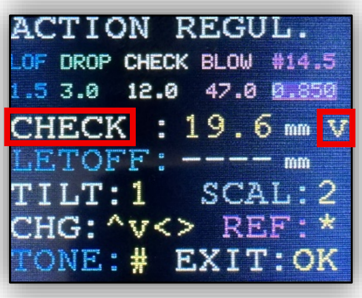
In the main dialog, the target values of the regulation parameters letoff, drop, check, and blow can be set.

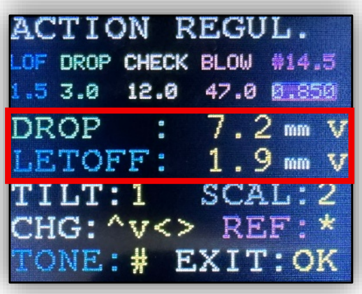
Use the left/right arrow keys to select the desired parameter and the up/down arrow keys to adjust the corresponding target value (CHG: ^v <>). The currently active value is displayed in inverted colors.

In STRING mode, the string thickness can also be adjusted. In this case, the string number (#) is shown in the top right of the display, with the exact string diameter in millimeters displayed below.

5.2.2 Measurement display







Below this, the current measurement values are shown, i.e. the distance from the hammer head to the bottom of the string. The display is divided into two lines:

- **First line**
  - Depending on the distance of the hammer head from the string, the display automatically switches:
  - **BLOW** (blow distance): distance greater than 40 mm → hammer at rest.
  - **DIST**: distance between 40 mm and 25 mm → not a typical regulation range, pure distance display.
  - **CHECK**: distance less than 25 mm but greater than 10 mm → hammer is caught by the backcheck after striking. Typical values: 12–15 mm (depending on manufacturer specifications).
  - **DROP**: distance less than 10 mm → hammer rises close to the string, letoff occurs, and the hammer falls back slightly onto the repetition lever.
- **Second line**
  - Here, **LETOFF** is displayed. Measurement values only appear if the hammer head rises slowly enough for the letoff point to be detected.
- **Deviation display**
  - On the right-hand side, arrows indicate deviations from the target value:
  - Down arrow (orange) → measured value is greater than the target value.
  - Up arrow (magenta) → measured value is smaller than the target value.
  - The measured value itself is also color-coded:
  - orange   target value too high
  - magenta   target value too low
  - white   target value reached, arrow disappears.

5.3 Setup (Guide rail and sensor)

The guide rail is placed on the grand piano rim directly above the hammer strike line. It must rest stable and without wobble (see chapter "Aligning the guide rail").

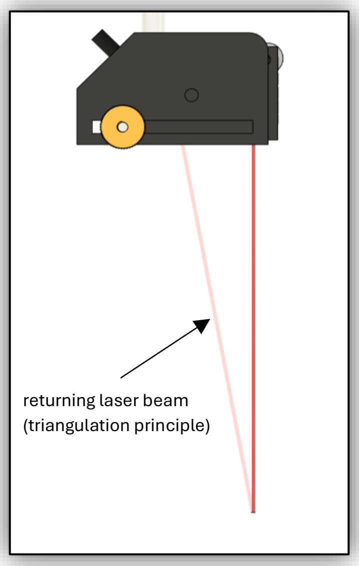
For these measurements, SENSOR 2 with its extended measuring range of 70 mm is used (see chapter "Laser distance sensors"). The measurement values shown on the sensor display range from -35 mm to +35 mm, corresponding to a total range of 70 mm:

- -35 mm = maximum distance (farthest away, still measurable)
- +35 mm = minimum distance (closest, still measurable)

If the measured object lies outside this range, the display shows "---". The same occurs if the returning laser beam (triangulation principle) is blocked by an obstacle.

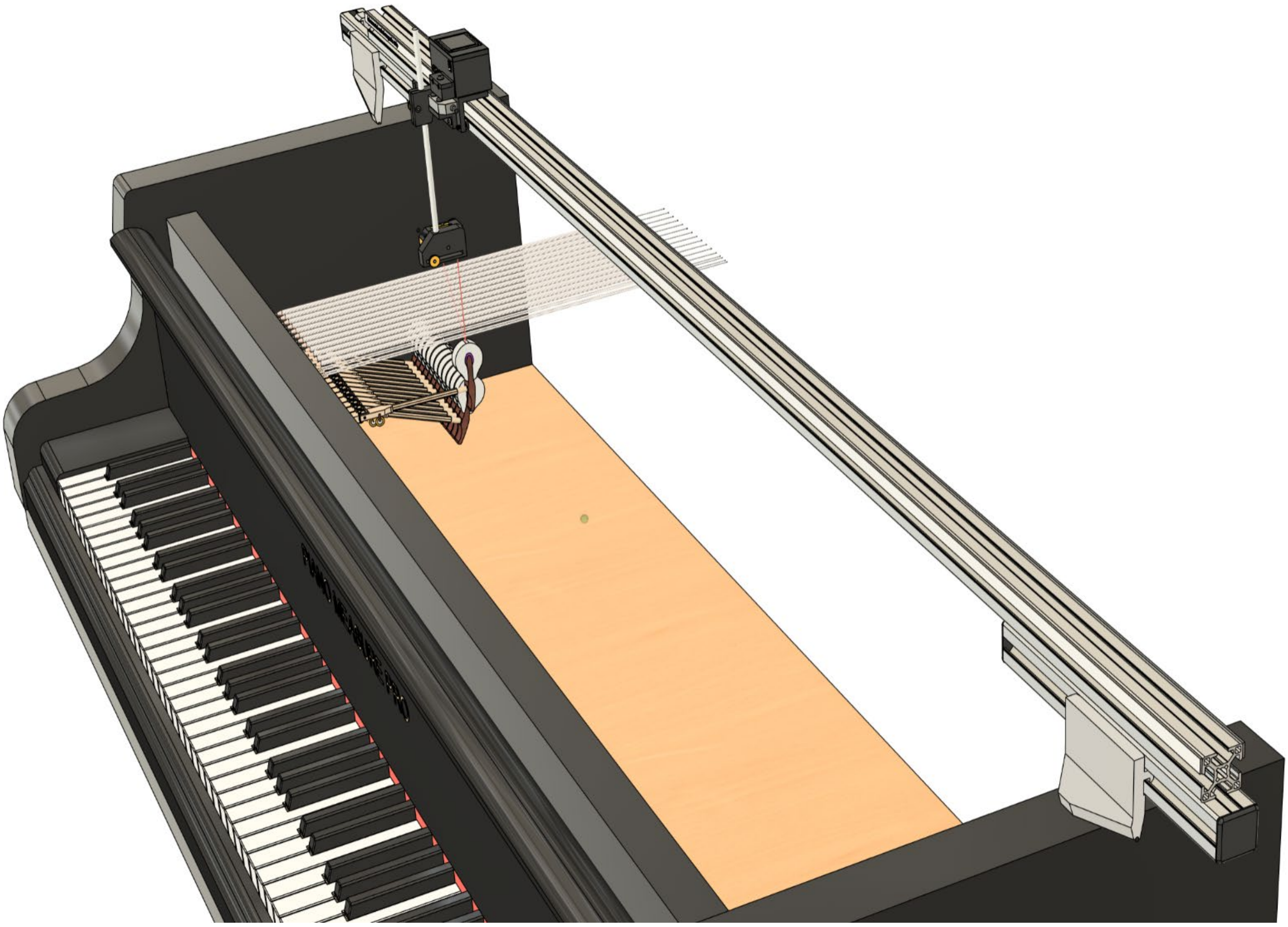
The sensor arm is then lowered in height so that, at the lower end of the measuring range (-35 mm), a reserve of 5-10 mm remains. In practice, this means that when the laser spot is aimed at the crown of a hammer head in rest position in the tenor section, the display should read about -30 to -25 mm.

It must be taken into account that the bass hammers are positioned higher than the others. The setup must ensure that the sensor can measure all hammer heads in the bass, tenor, and treble sections while still maintaining at least 50 mm of upward clearance to the top of the string. The usual blow distance of grand pianos is about 47 mm (depending slightly on the model).

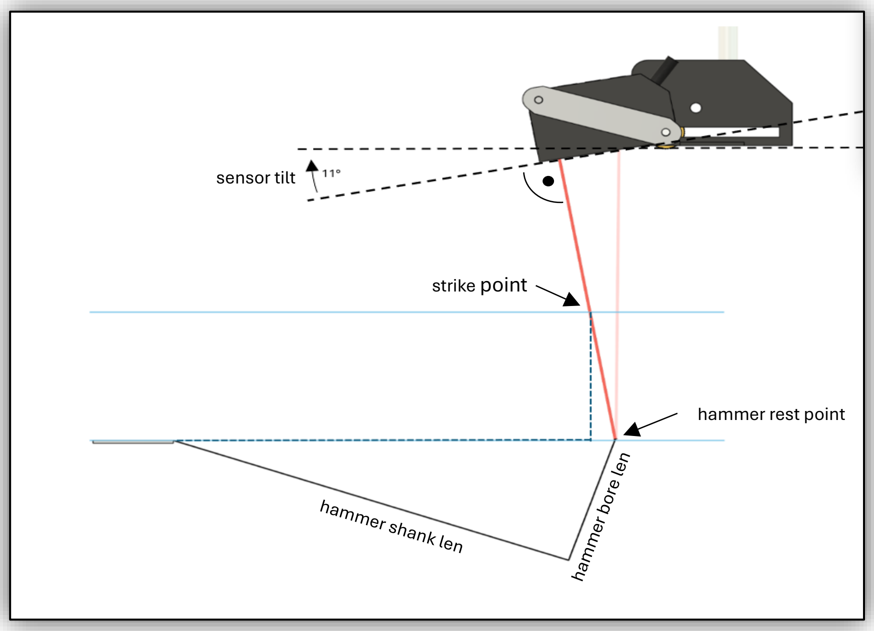


Smaller measurement values including negative ones on the laser distance sensor display always indicate that the measured object is further away from the sensor.

⚠ Note: The display can be rotated by 180° at any time using the IR key 9, depending on whether the device is placed in front of or behind the guide rail.



5.3.1 Sensor tilt (TILT mode)



If the laser sensor is positioned exactly perpendicular to the string plane and aligned with the crown of a hammer head in rest position, it can be observed that the laser spot no longer hits the hammer exactly at the crown when it reaches the string. The reason is that the hammer head moves along an arc when rising, which depends on the length of the hammer shank as well as the bore length of the hammer head.

To ensure that the laser spot hits the hammer crown exactly at the crown point both in rest position and in striking position, the sensor must be tilted.

- If the sensor is **in front** of the guide rail, it is tilted **upward**.
- If it is **behind** the guide rail, it is tilted **downward**.

The tilt must be adjusted until the spot hits the hammer crown at the crown point in both end positions. This adjustment only has to be determined once by trial and can then be maintained. It usually also applies to the bass hammers with sufficient accuracy.

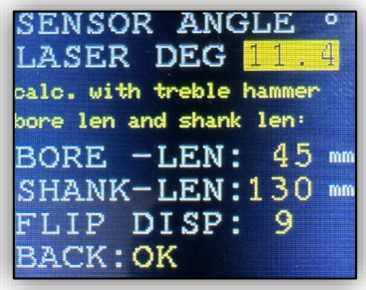
Tilting the sensor is particularly useful when all regulation parameters of a note are to be checked at the same time.

In some cases, however, tilting is not possible, for example when parts of the cast-iron plate (plate struts) or other components of the grand piano’s acoustic assembly obstruct the beam path (often in the upper tenor / treble). In these situations, the sensor is positioned vertically and the parameters are measured one after the other. This is done, for example, as follows:

- First, the blow distance is measured within a group of notes (hammers in rest position).
- Then letoff is checked by moving the guide rail or the sensor slightly forward or backward in the slotted guide until the laser spot hits the hammer crown exactly at the crown point in the upper position.

The TILT dialog is called up with IR key 1, in which the tilt angle of the sensor is set. If the parameters for hammer shank length and hammer bore length are changed, the correct tilt angle of the sensor is automatically calculated. Alternatively, however, the angle can also be set manually.

The TILT mode is active as soon as the text “TILT:” is shown in white in the main dialog. By pressing key 1 again it is deactivated; the text then appears gray.



The measurement itself is carried out along the laser axis (not vertically). When TILT mode is active, the measurement values are automatically corrected according to the set tilt angle. This is necessary because only the vertical component reflects the actual distance of the hammer head to the string plane. The correction is made according to the cosine formula. This ensures that the laser beam hits the hammer crown exactly at the crown point both in the rest position and in the striking position and that the actual values (vertical) are displayed.

5.3.2 Measurements with dampers installed

Measurements without dampers installed are unproblematic, since in this case the hammer heads are not covered by the dampers. In many cases, however, measurements can also be carried out with dampers installed, provided that the spacing between the dampers allows this.

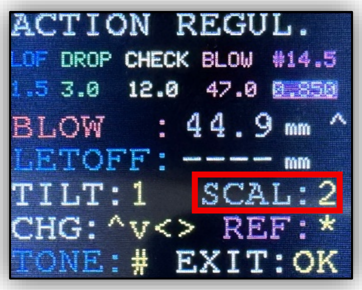
As a rule, the gap is large enough for the laser beam to pass between the dampers and detect the distance of the hammer head to the string. The prerequisite, however, is that the una corda shift of the action is activated. In this way, the hammer heads are shifted to the right and can be detected by the laser.

To avoid having to press the una corda pedal constantly, a wedge can alternatively be inserted between the grand piano action and the stop on the left. If this shift is still not sufficient, the right cheek block can also be removed, as the shift is often limited there by a stop screw. This allows an even greater lateral movement of the hammer heads to be achieved.

In the bass and lower tenor section, the strings and dampers are slanted due to the cross-stringing. Since the sensor arm is a round rod, the sensor can easily be rotated slightly to the right or left to remain aligned parallel to the strings.

⚠ **Important:** The string reference height can only be determined in “Hammer-to-String” mode (see following chapters) when dampers are installed. Direct measurement of the string above the hammer head is not possible in this case, as the damper blocks access.

5.3.3 SCAL mode

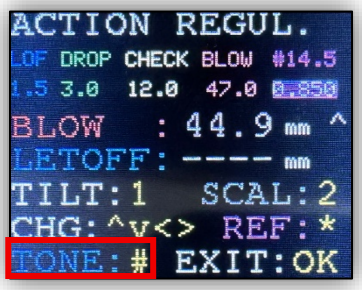


In SCAL mode, not the hammer head itself but the hammer shank is measured. Using a special scaling, the equivalent distance of the hammer head to the string can be calculated.

This mode is particularly useful when the dampers are very close together or the damper felts protrude laterally, making direct measurement at the hammer head impossible with dampers installed.

⚠ Note: This function is currently in the **BETA phase**.

5.3.4 Acoustic feedback (TONE)



When setting letoff or blow, the device can provide acoustic feedback. Two consecutive tones are played:

The first tone is always the same.

The second tone varies in pitch depending on the deviation from the target value:

- If the measured value is greater than the target value, the second tone becomes progressively lower.
- If the measured value is smaller than the target value, the second tone becomes progressively higher.

This is particularly helpful for the technician, since when setting letoff at the letoff button or blow at the capstan, full attention is directed to the action. This eliminates the need to constantly look back and forth between the action and the display.

✅ As soon as both tones sound approximately the same in pitch, the measured value corresponds to the target value.

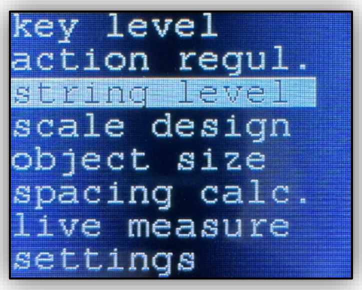
The acoustic feedback is controlled via TONE mode, which is toggled with the hash key (#).

- “TONE:” blue → acoustic feedback for letoff
- “TONE:” light red → acoustic feedback for blow
- “TONE:” gray → acoustic feedback deactivated

The toggle sequence is: blue → light red → gray.

6 “string level” function - Levelling the Strings

After selecting the “String Level” function, the system enters the dedicated measuring mode for determining the string heights.



The objective is that all strings within a unison are positioned at exactly the same height. Only then will the hammer head strike each string with equal force, ensuring a homogeneous tone.

⚠️ Especially after restringing, levelling the string heights is essential. A precise alignment of the hammer crown with the string unison is also the prerequisite for proper hammer voicing.

Advantages of contactless measurement

Traditionally, the check is performed with a small spirit level placed on the string unison. The strings must be plucked repeatedly, the level removed, and the strings corrected individually. This time-consuming back-and-forth continues until all strings touch the level, it no longer rocks, and it sits exactly horizontal.

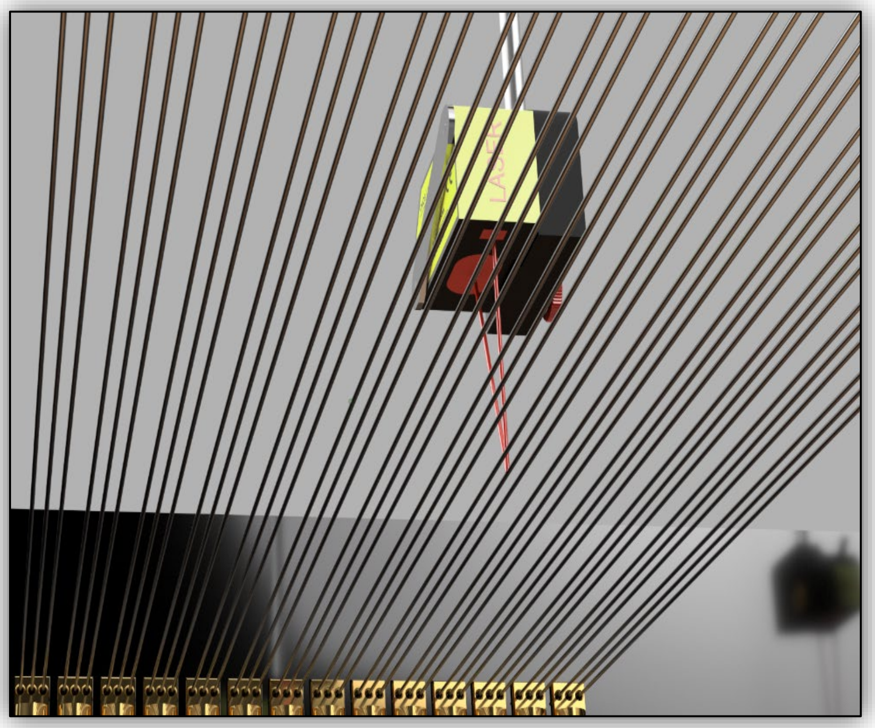
With the contactless measuring system Piano Measure Pro, these steps are eliminated:

After slowly moving the laser across the string unison, the display immediately shows which string is the highest and which are lower.

The highest string is automatically set as the reference, and all other strings are measured relative to it.

Strings that are too low must be corrected upwards.

Live control during correction



By positioning the laser spot exactly on the string that lies too low, a LIVE display appears.

While the technician raises or lowers the string with the regulating tool, the change is shown in real time:

- immediately visible whether the string is still too low,
- whether it has already been raised too much,
- or whether it has reached the correct target height.

This provides the technician with direct graphical feedback, without the need for repeated measuring, correcting, and checking.

It results in significant time savings, since the entire string choir can be levelled precisely in a single working step.

6.1 Setup – Rail / Sensor

The measuring rail is placed on the rim (case) of the piano and positioned so that the sensor can capture the string heights. It must be ensured that both the first treble strings at the bass break and the last unison in the tenor section can be measured correctly.

The rail must always rest without wobble (see chapter “Guide Rail Alignment”).

For measurement, SENSOR 1 should preferably be used, since the accuracy of SENSOR 2 is not sufficient for this application (see chapter “Laser Distance Sensors”). A rough pre-adjustment may be possible with SENSOR 2, but precise fine-levelling should only be performed with SENSOR 1.

The sensor arm is lowered so that the string lies approximately in the laser focus, with SENSOR 1 at a distance of about 50 mm. The sensor display provides orientation.

The measurement values range from -15 mm to +15 mm, corresponding to an absolute measuring range of 30 mm:

- -15 mm = maximum distance (farthest measurable point)
- +15 mm = minimum distance (closest measurable point)

If an object lies outside this range, the display shows “---”. The same applies if the returning laser beam is blocked by an obstacle in the triangulation path. As soon as the value 0 ±1 mm appears and the laser spot is centered on a string, the distance is correctly set. In addition, the rail must be aligned as closely as possible parallel to the string plane. This can be checked with a digital inclinometer (Bevelbox, smartphone app, etc.):

Place a short straight bar (10-15 cm) on the strings to be corrected and zero the inclinometer. Place the bar on the rail and check the angle again. Adjust the tilt using the supports, which each have a slanted edge for precise positioning.

Position both supports on one side so that they rest with the slanted edge against the case rim, this allows the height to be set precisely. Use the rear support to finally ensure stable, wobble-free positioning.

💡 **Note:** In future firmware versions (software updates), automatic compensation of the rail tilt will be integrated. Then it will no longer be necessary to align the rail parallel to the strings before measurement, the rail only needs to be placed in position. This feature is currently in beta stage and not yet available.

⚠️ **Warning:** Smartphones or Bevelboxes with magnets on the underside must never be placed directly on the rail. External magnets of any kind must be kept away, as they may damage the magnetic encoding of the rail’s magnetic strip (see chapter “Linear position encoder (magnetic strip sensor”). A small bar must always be used as an intermediate support, and a minimum clearance of at least 20 mm must be maintained.

6.2 Measuring a Unison

The laser is moved slowly across the entire unison. When the sensor stops, the measurement result is displayed.

If the travel does not fully cover the unison, no result will be shown.

The sensor automatically detects whether the unison consists of two or three strings. After stopping, the last 15 mm of travel are evaluated. The plateaus and their maxima are determined, and each maximum position is stored for later correction.

The results, normally three strings (occasionally two on older instruments), are displayed as vertical white bars side by side on the display:

The highest string is automatically set as the reference, indicated not by a bar but by a thin green line.

Strings lying lower appear as white bars. The greater the downward deviation, the longer the bar. Very large deviations are shown as maximum-length red bars.

Above each bar, the deviation from the reference in µm is displayed numerically.

In this example, the right string is used as the reference, since it is the highest string in the unison. It is indicated by a thin green line.

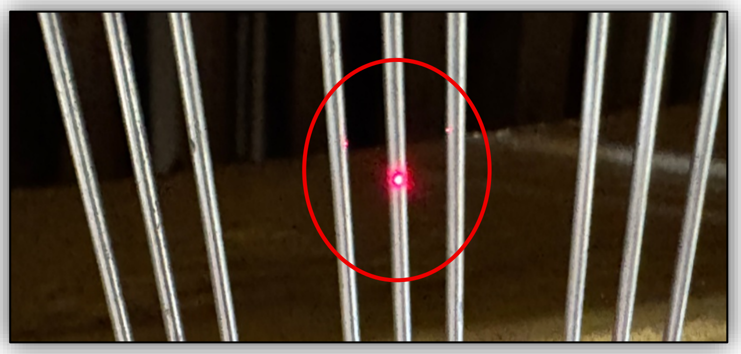
The middle string lies 0.336 mm (336 µm) below the reference. This is represented on the display by a long white bar.

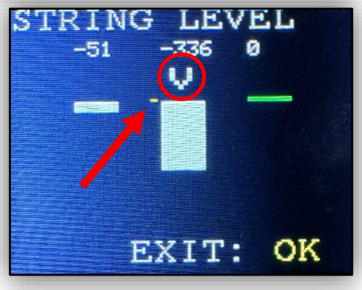
The left string lies only 0.051 mm (51 µm) below the reference. The deviation is minimal and is shown as a very short white bar.

This makes it immediately clear which string is correct, which requires only slight adjustment, and which needs significant correction.

6.3 Correcting / Adjusting the String Height (LIVE Display)

After the measurement results are displayed, the laser spot can be positioned directly on the string that needs correction. The spot must be aimed exactly at the center of the string.





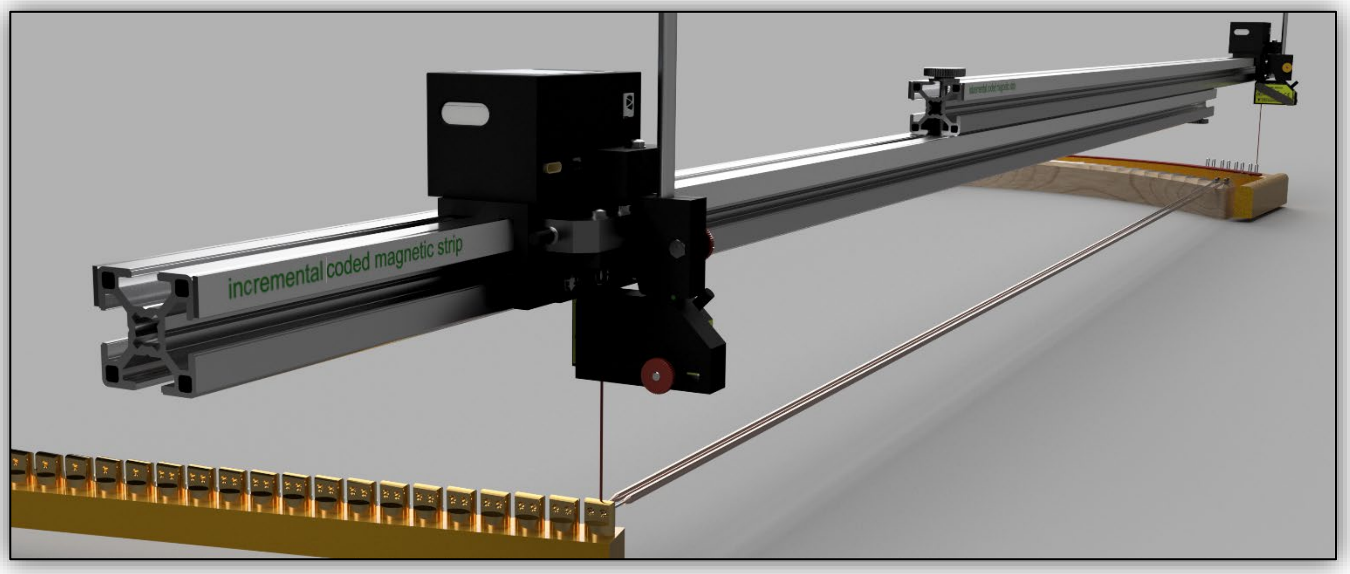
The previously stored positions of the plateaus (maxima) are compared with the current position. As soon as this matches a maximum position, a small downward arrow (v) appears above the corresponding bar. This indicates that LIVE mode for this string is active. The position is then zeroed, and all subsequent changes in string height are measured relative to this reference point.

Each deviation is shown as a thin yellow line to the left of the main bar. This provides the technician with direct graphical feedback on how much the string moves up or down during correction. If the adjustment is too large, the yellow line turns red.

In this example, the middle string should be raised until the yellow line is exactly the same length as the white bar. At this point, the string has reached the correct height. The same procedure is then repeated for the next string that requires correction.

Finally, the entire unison is measured again to verify the result.

7 “scale design” function – Scale Measurement / Downbearing



With the scale design function, the lengths of piano strings can be measured with high precision. For this purpose, two devices are used simultaneously on the guide rail.

Since a single guide rail has only a limited length and is usually sufficient only for upright pianos or smaller grands, two rails can be coupled for larger instruments, such as concert grands with particularly long strings. The rails are joined and extended to the required length so that even very long scales can be measured. In this way, it is possible to capture the full string lengths of a Bösendorfer Imperial concert grand with a total length of 290 cm.

Each guide rail is equipped with a high-precision magnetic strip. Both devices are fitted with their own linear encoder, which continuously records the current position on the rail. The distance between the two devices is therefore determined from the difference between their respective positions.

Communication takes place via a dedicated WiFi connection between the two devices. Through this wireless link, positional data are continuously exchanged.

Both devices are equipped with their own laser distance sensor. In this function, the laser spot is used primarily for the precise positioning of the devices at the desired measurement points. The actual distance measurement of the laser is only required later for the downbearing calculation.

Positioning the devices on the guide rail:

The guide rail is placed directly above the string to be measured. Device 1 is positioned at the front termination point of the string, i.e. at the agraffe or capo bar. If two guide rails are in use, Device 1 is usually placed on the lower rail.

Device 2 is aligned at the rear: either at the bridge pin (end of the speaking length S) or at the hitch pin in the plate (to determine the total length B). When two rails are used, Device 2 is normally positioned on the upper rail.

In this way, two different lengths relevant to piano making can be determined:

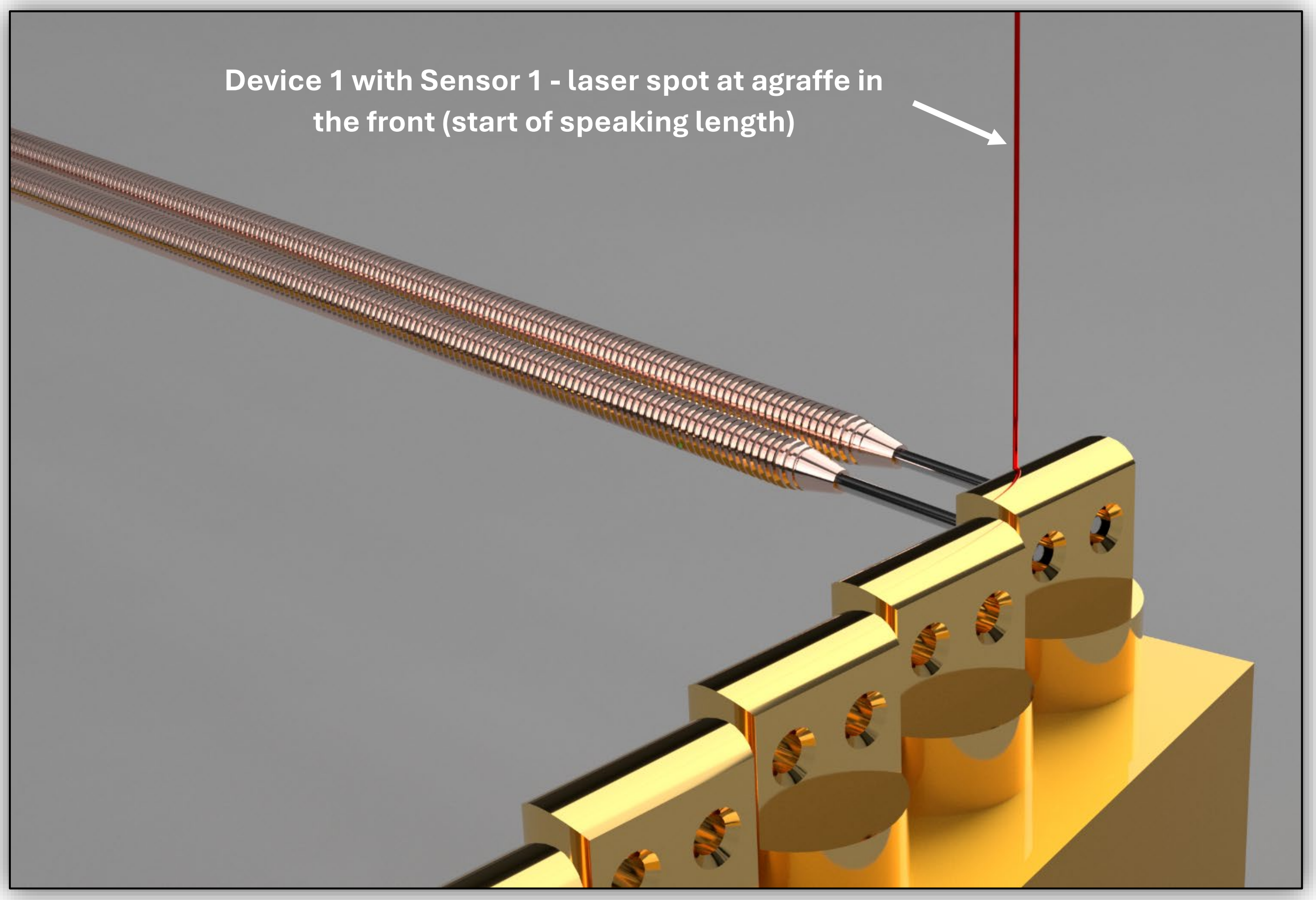
- Speaking length (S): from the front termination point (agraffe/capo bar) to the bridge pin.
- Total length (B): from the front termination point to the hitch pin in the plate.

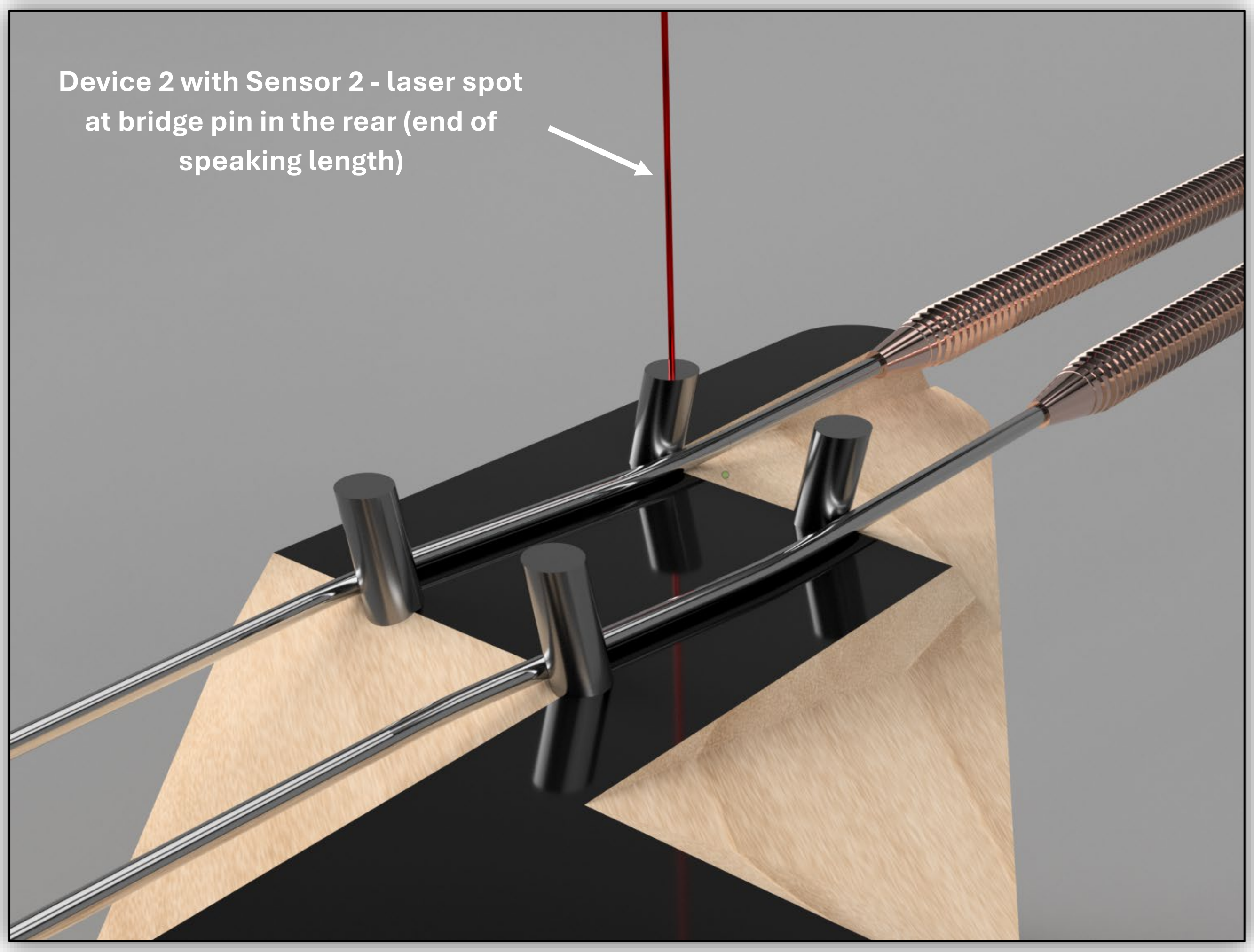
Only in the bass section, or in the lower tenor if transition strings are present, are both values usually required, since wound bass strings are manufactured there. The bass string maker specifically requires the rear length A (the difference between total length B and speaking length S) as well as the total length B itself.

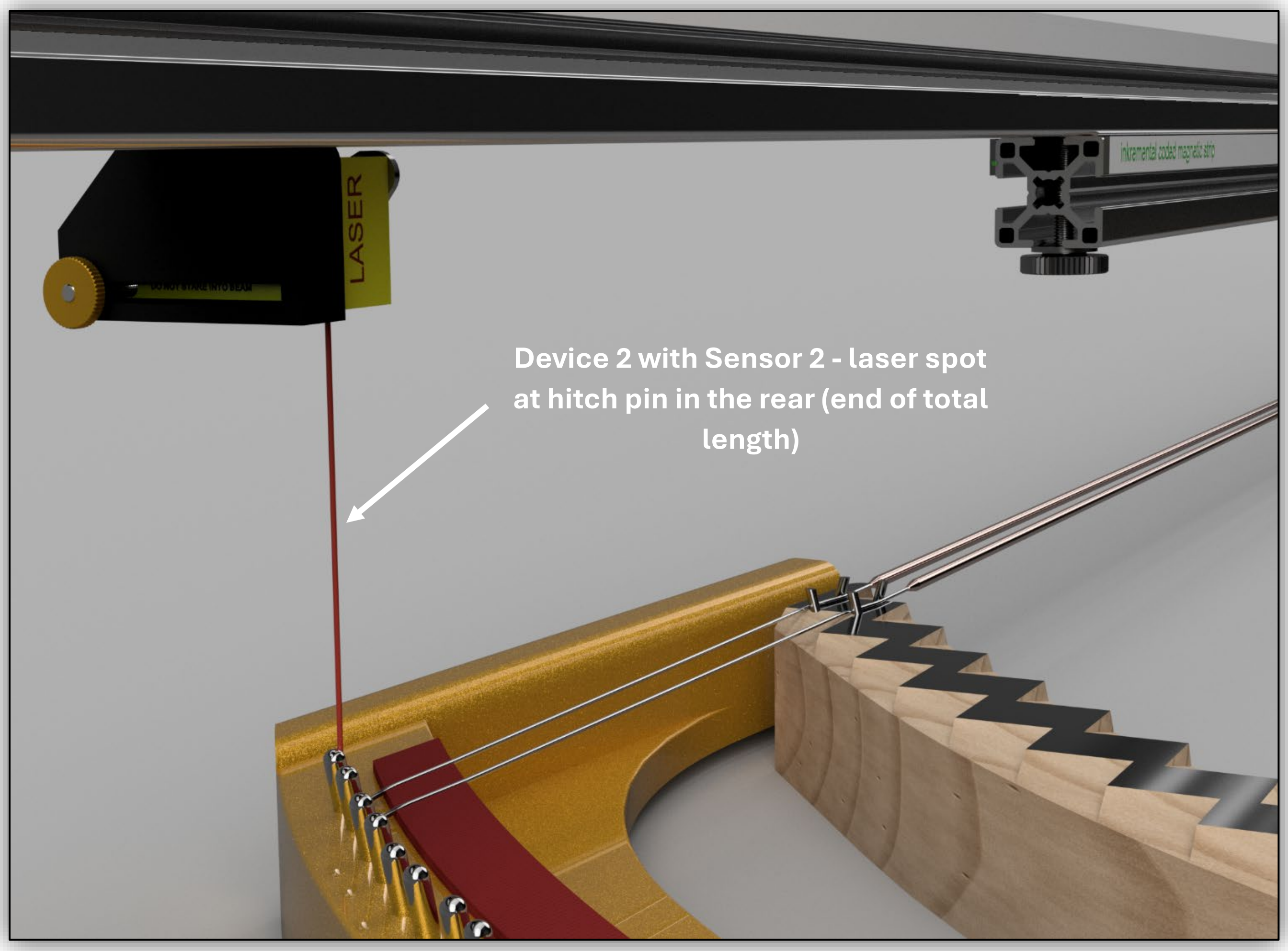
These designations (A, B, S) are used consistently in the following chapters:

- S = speaking length (agraffe/capo bar → bridge pin)
- B = total length (agraffe/capo bar → hitch pin)
- A = rear length (B – S)

In the tenor and treble, it is usually sufficient to measure only the speaking length S, since these sections use plain strings only. Here, S is the decisive parameter for scale analysis and optimization.


Device 1 with Sensor 1 - laser spot at agraffe in the front (start of speaking length)

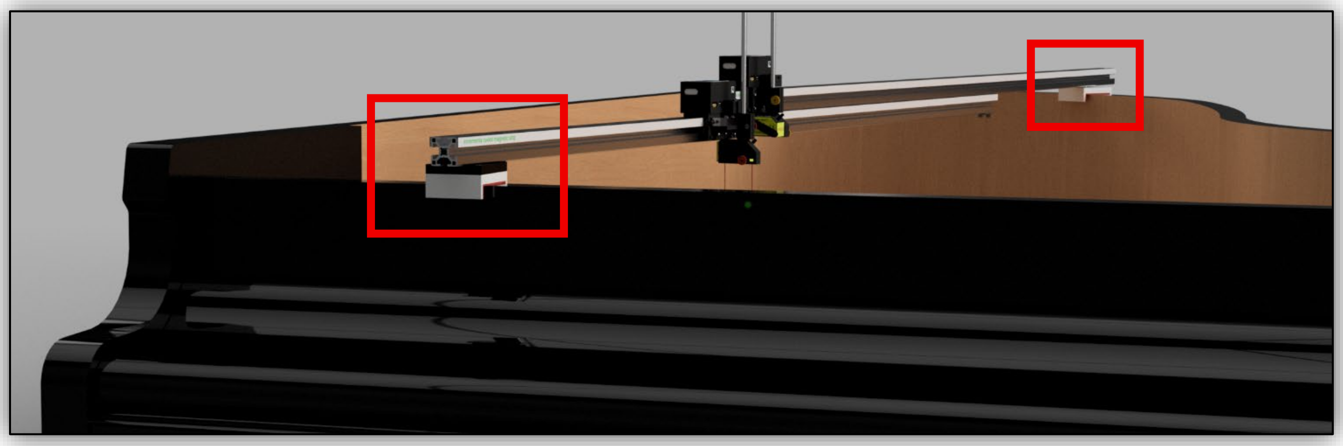

Device 2 with Sensor 2 - laser spot at bridge pin in the rear (end of speaking length)



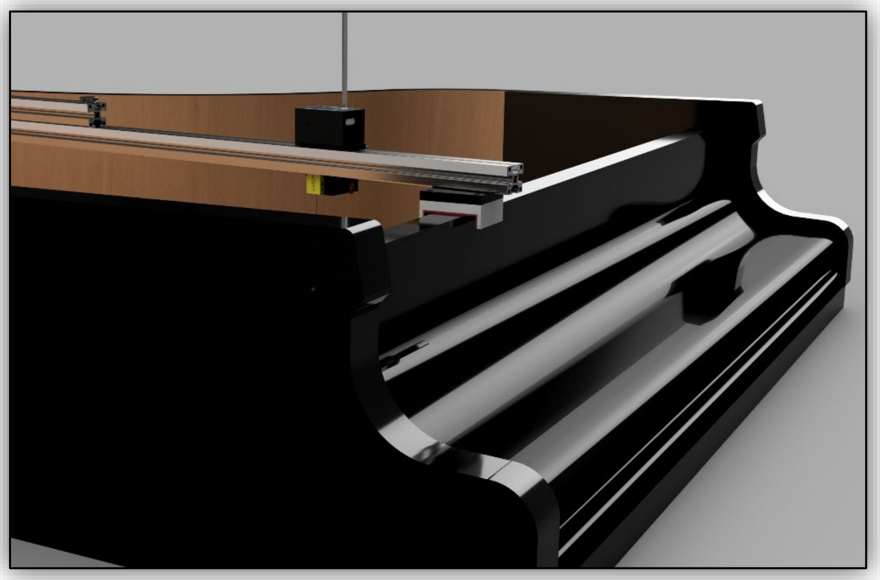
7.1 Placing the Guide Rail above the Strings

The guide rail is placed at the front on the lock rail and at the rear on the rim of the grand piano case. It rests on special sliding pads, the undersides of which are covered with soft felt. This ensures that the rail can glide securely over the polished surface without causing any damage.

The sliding pads are modular in design: spacer plates can be added to adjust the height of the guide rail precisely above the case. On the top of each sliding pad there is a locating pin that engages into a groove on the underside of the guide rail. This provides lateral guidance and allows the rail to be moved smoothly from string to string.



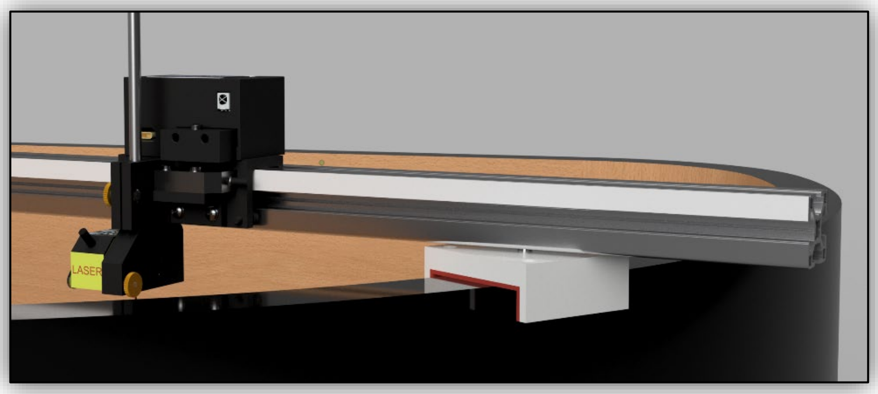
The alignment of the laser spots with the measurement points can be carried out either by moving the devices along the rail or by shifting the entire rail. As a rule, it is not necessary to remove the grand piano lid.



Alternatively, the guide rail can also be placed on a soft cloth that is laid over both the rear rim and the front lock rail.

Measuring ranges of the sensors and areas of application:

For measurements of downbearing it must be ensured that both laser sensors are within the measuring range when they are aligned to the measuring points: in front to the agraffe or string, at the back to the bridge surface or the hitch area of the plate.



The measuring values in the display of SENSOR 1 range from -15 mm to +15 mm, corresponding to an absolute measuring range of 30 mm.

With SENSOR 2 the values extend from -35 mm to +35 mm, which corresponds to an absolute measuring range of 70 mm.

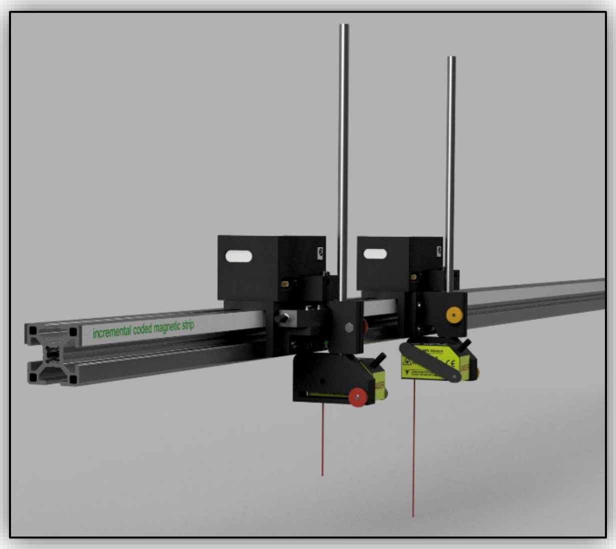
- -15 mm (-35 mm) = maximum distance (farthest away, still measurable)
- +15 mm (+35 mm) = minimum distance (closest, still measurable)

If a measuring object is outside the respective measuring range, the display shows “---”. The same applies if the returning laser beam according to the triangulation principle is blocked by an obstacle.

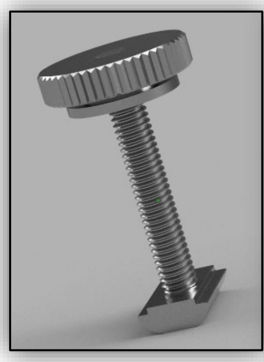
In the application of “scale design” Device 1 with SENSOR 1 is used in the front area of the string termination (agraffes or capo bar), while Device 2 with SENSOR 2 is used in the rear area (bridge or hitch). This assignment results from the typical distances: the agraffes or the capo bar are usually closer to the guide rail, so the shorter measuring range of SENSOR 1 is optimally suitable. The bridge and especially the hitch are considerably further away, which is why the extended measuring range of SENSOR 2 is required here.

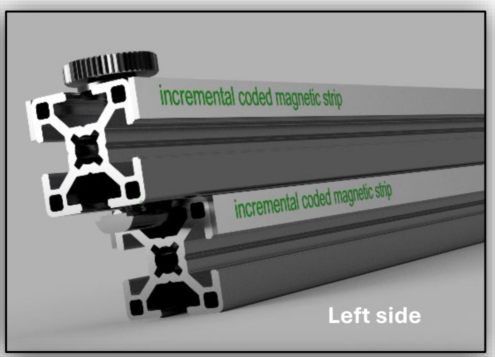
Only one guide rail for uprights and smaller grands:

For uprights or smaller grands normally one single guide rail is sufficient to measure even the longest strings. In this case both devices are placed on the same rail. Only with large concert grands with particularly long bass strings is it necessary to couple two guide rails, so that Device 1 is usually guided on the lower and Device 2 on the upper rail.



Coupling of two guide rails for large concert grands:

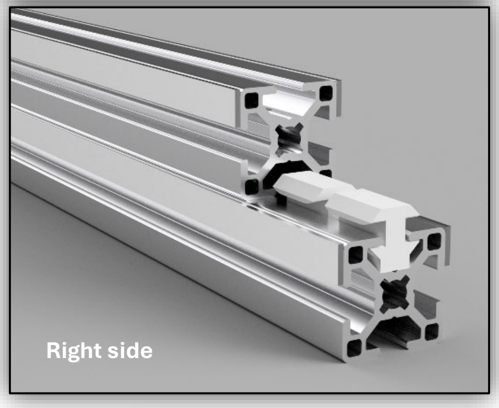




When measuring very long strings in large concert grands, a single guide rail is no longer sufficient. In this case, two rails can be coupled into one unit.

For this purpose, the short rails with the supports, which are required for the other applications (key level, action regul. and string level), are first pulled off from the lower rail. Then a second rail is pushed onto the first one:

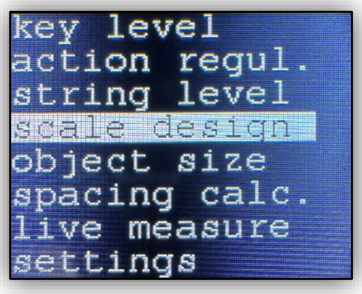
- Left side: A sliding block with a long-knurled screw engages in the groove of the lower rail.
- Right side: Two sliding blocks, which are firmly inserted into the upper groove (press fit), engage in the lower groove of the upper rail.



In this way the two rails can be moved against each other without play and extended to the required total length depending on the size of the grand. Finally, the knurled screw on the left side is tightened, thereby securely fixing both rails together.

7.2 Calling up the Function

The function scale design is started from the main menu on both devices. At the beginning, the devices can be placed next to each other in the start position on the guide rail (see chapter “Connecting the devices (Start position)”). Control is carried out using the IR remote control, which can address both devices simultaneously. If problems occur, for example if only one of the devices responds at times, the entire process can also be carried out sequentially on each device individually



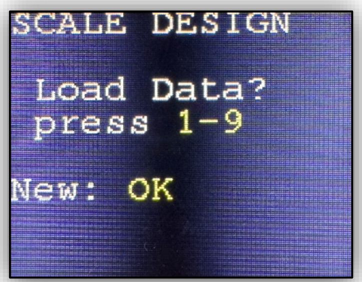
After starting, a query appears asking which device should act as Master and which as Client.

- On the Master device, all setup settings are made. Already recorded measurement values can also be retrieved here by scrolling through the octaves or notes. The technician uses the IR remote control on the Master device to issue the command to save the currently measured distance between the two devices as the string length and then move on to the next parameter or to the next note. Thus, the entire control is carried out exclusively via the Master device.
- The Client has the sole task of supplying the second position or height value. It is aligned to the corresponding measuring point - either by an assistant or by the technician himself - and during this process, while being moved and aligned on the guide rail, it continuously transmits its measurement values (position and height). On the display of the Client device, both the current distance between the two devices (the current string length) and the measurement value of its own laser distance sensor are shown.

Normally, the device configured as “Device 2” (Device 2 with SENSOR 2) in the settings is used in the rear area, i.e. at the bridge or at the hitch, and is selected as the Master. This device is operated directly by the technician. The device configured as “Device 1” (Device 1 with SENSOR 1) serves as the Client and is positioned at the front, at the agraffes or at the capo bar. No settings need to be made on Device 1 during the measurement sequence; it only needs to be precisely aligned to the respective front measuring point (by an assistant or by the technician himself).

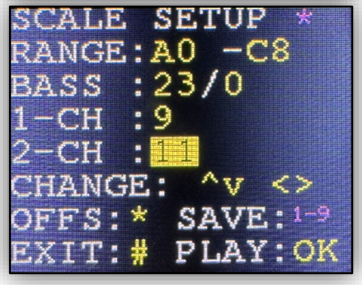
On the display of the Client device, a message appears stating that all setup settings must first be made on the Master device. Once this has been completed, the process can be continued on the Client device with the IR button 0.

7.2.1 Load Dataset (Master Device)



On the display of the device that has been selected as Master, the dialog for loading a dataset first appears. If an instrument has already been partially or completely measured, the existing measurement values can be reloaded here. Nine memory slots are available. With the OK button, a new dataset can alternatively be created.

7.2.2 Setup (Master Device)



In the setup dialog, the basic parameters of the scale are defined.

At the top right, a magenta-colored asterisk indicates that this is a new dataset that has not yet been saved in a memory slot (1–9). If a dataset has been loaded, the number of the occupied memory slot is displayed here instead. The selection and modification of the individual parameters is carried out using the arrow keys on the IR remote control.

First, the tonal range of the instrument is defined (RANGE):

- Standard: A0 to C8
- Older instruments: often only up to A4
- Bösendorfer Imperial: C0 to C8

In the field BASS, the total number of bass notes is entered, i.e. all notes with wound bass strings. After the slash, the number of bass notes that no longer belong to the bass bridge but already to the long bridge (treble bridge) and thus to the transition section is indicated.

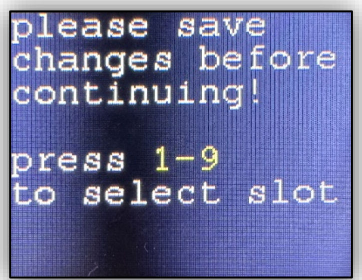
In the example: BASS: 23/0

- total of 23 bass notes,
- of which 0 in the transition section, i.e. all over the bass bridge.

Each bass note can be unichord, bichord, or trichord:

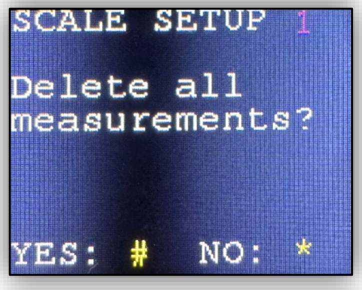
- The number of unichords is set in the field 1-CH.
- The number of bichords in the field 2-CH.
- The number of trichords is calculated automatically as the difference between the total number of bass notes and the sum of 1-CH and 2-CH.

In the example:



- 23 bass notes in total,
- 9 unichords,
- 11bichords,
- 3 trichords (calculated as the difference).

With the star key (*), the submenu Offsets is accessed (see next chapter “Setup - Offsets (Master Device)”). With the number keys 1-9, the current dataset can be saved in a memory slot. All future measurement results are then automatically stored in this slot.



⚠️ If the measurement is interrupted due to an empty battery, all values saved up to that point remain secured in the selected slot and can be reloaded after restarting. The measurement process can then be resumed at the last saved position.

- With the # key, the setup dialog is canceled and the device returns to the main menu.
- With the OK button, all settings are confirmed, the setup dialog is closed, and the play dialog is opened (see chapter “Play Dialog - retrieving existing measurement values (Master Device)”).

If no memory slot has yet been assigned, a corresponding message appears. In this dialog, there is also the option to completely delete already existing data in the selected slot. After successful saving, the message “Data saved” appears.

7.2.3 Setup – Offsets (Master Device)

While in the setup dialog, the offset dialog can be called up with the star key (*). Here, correction values (offsets) can be defined, which are added to specific measurement values.

Operation is carried out via the IR remote control:

With the up / down arrow keys, the currently selected value is changed in whole steps.

With the left / right arrow keys, the value is adjusted in fine steps of 0.1 mm.

With the star key (*), the next parameter is selected.

With OK, one returns to the main setup dialog.

The following parameters can be set:

AGRA-H: This parameter is important for the downbearing calculation. If the downbearing is measured at the front termination of the string directly at the agraffe - for example, when no strings are yet installed in the instrument - the measuring point does not exactly correspond to the later string height. Therefore, the height difference between the string hole and the top edge of the agraffe, where the measurement is to be taken, is entered here. The height value determined by Device 1 is then automatically corrected by this offset so that the result corresponds to the actual string height, even if measured at the agraffe.

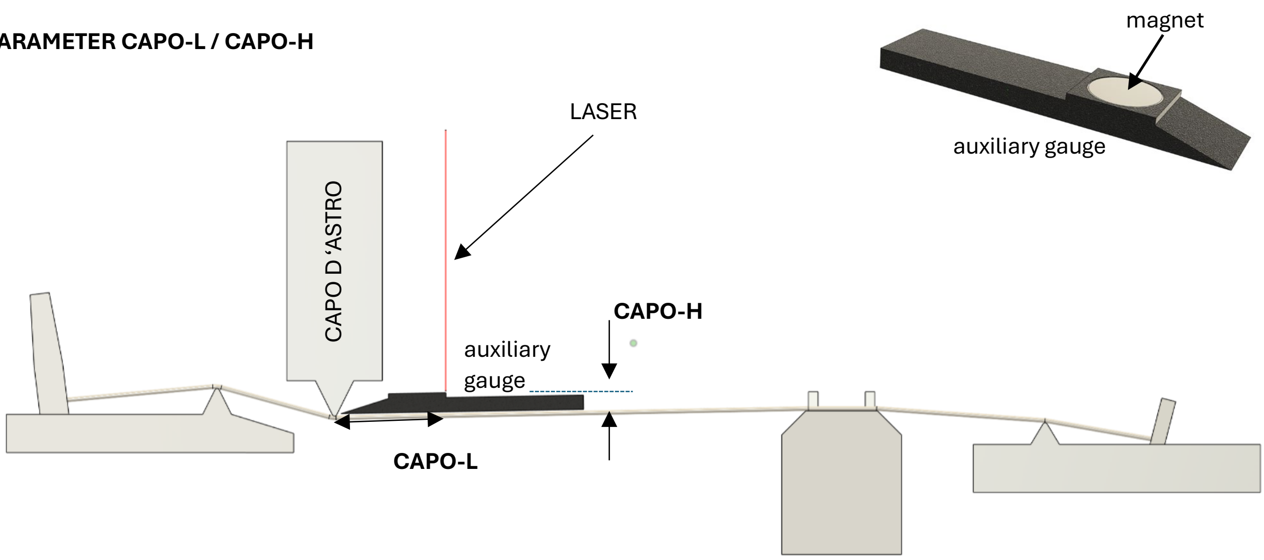
CAPO-L: This parameter is important for the length calculation. In areas where the strings are not terminated by agraffes (or, in uprights, by the bearing bar) but by a capo bar, a direct measurement with the laser is not possible, as the capo bar blocks the laser beam coming from above. In this case, an auxiliary gauge is used, placed on the strings in front of the capo bar and pushed directly against the bearing point (bearing bar) of the string to be measured. The laser then measures not on the string itself but on a marked point on the gauge. The distance from the front edge of the gauge (which lies against the bearing point) to the measuring mark is entered here as the offset under CAPO-L.

⚠ Important: This offset is only taken into account for notes that are actually terminated by a capo bar. From which note this applies is defined with the parameter CAPO-1ST.

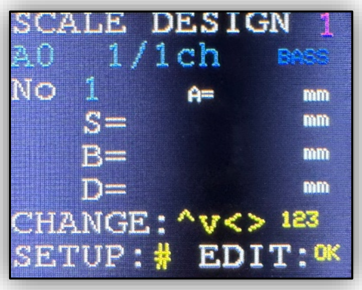
CAPO-H: This parameter is important for the downbearing calculation. If the string height cannot be measured directly at the string but only via an auxiliary gauge, the thickness of the gauge is entered here as a height correction.

CAPO-1ST: With this parameter, the first note terminated by a capo bar (grand piano) is defined. From this note onward, the offsets CAPO-L and CAPO-H apply.

PARAMETER CAPO-L / CAPO-H



7.2.4 Play Dialog – Retrieving Existing Measurement Values (Master Device)



After leaving the setup, the Play Dialog opens. Here, already recorded measurement values can be retrieved and checked.

For each note, the values of the currently selected string are displayed if available. These include:

- S = speaking length
- B = total length
- D = downbearing
- A = afterlength (calculated automatically as the difference between B and S, provided both values are available)

In the first example screen, no values are displayed (empty fields), since no measurement values have yet been stored. In the following example screens, the existing measurement values are shown in green.

Navigation

- With the arrow keys left / right, the display moves to the previous or next note.
- With the arrow keys up /down, the display jumps one octave at a time (e.g. from C1 to C2).
- With the number keys 1-3, the desired string can be selected. This selection remains active when moving to another note, as long as that note has the corresponding number of strings.

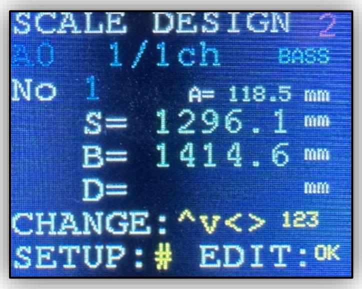
In the unichord range, only one string is displayed.

In the bichord range, the first or second string can be selected.

In the trichord range, strings 1-3 are available for selection.

👉 In practice, in the bass section all strings of a note are usually measured (important for bass string making). In the treble section, it is generally sufficient to measure only one string per note, since for scale analysis and optimization the speaking length S is the decisive parameter.

Display Layout



- First line: On the right, the number of the current memory slot is shown in magenta.
- Second line: On the left, the note designation is displayed (e.g. A0, C4). Directly next to it is the string information: the first number indicates the currently selected string, the second number the total number of strings for that note. Example: 2/3ch means that the second string of a trichord note is selected. On the right side of this line, the section designation BASS or TREBLE is displayed; if in the capo bar section, the additional note TREBLE (CAPO) is shown.
- Third line: Number of the currently selected string (starting with 1 for the first string of the lowest note, e.g. A0). Next to it, the value for the afterlength A (if S and B have been measured).
- Further lines: Measurement values for S, B and D of the currently selected string, each in millimeters.

Operation

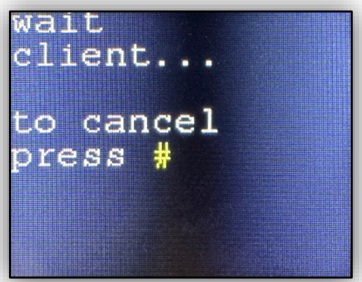
With the # key, the Setup menu is opened again, for example to adjust offsets. Pressing # again in the Setup dialog ends the entire scale design function and returns to the main menu.

With the OK button, the Play Dialog is exited and the system switches to measurement mode (EDIT).

If the two devices have not yet been connected (calibrated), the Calibration Dialog opens automatically.

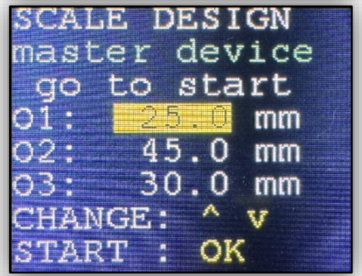
7.2.5 Connecting the Devices (Start Position)

Master Device



If the devices have not yet been connected (calibrated) when the function is first called up, pressing OK (EDIT) to leave the Play Dialog automatically opens the pairing dialog.

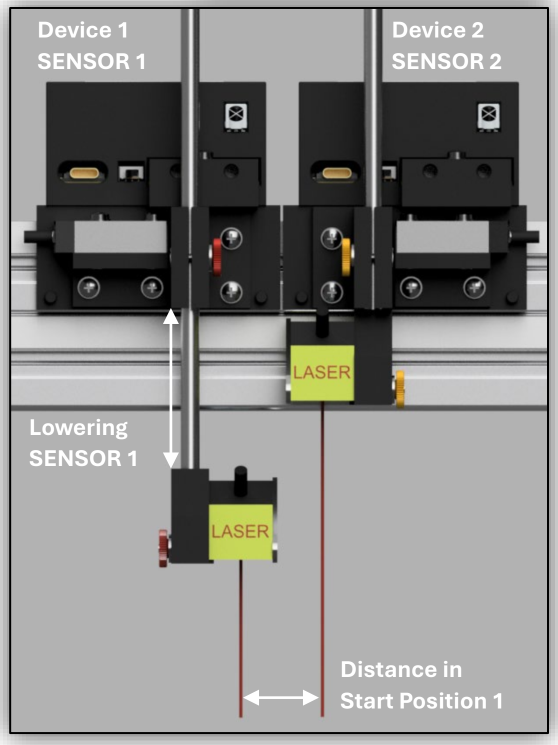
If the message “wait client...” appears, this means that the Client is not yet ready for pairing. The Master remains in this state until the Client device is set to pairing mode (see below “Client Device”). This waiting screen can be exited at any time with the # key.



As soon as the Client connects, it automatically establishes a link to the Master’s WiFi access point. No external network is required. After successful connection, a menu appears on the Master for selecting the offsets for the start position.

Three typical start positions are available:

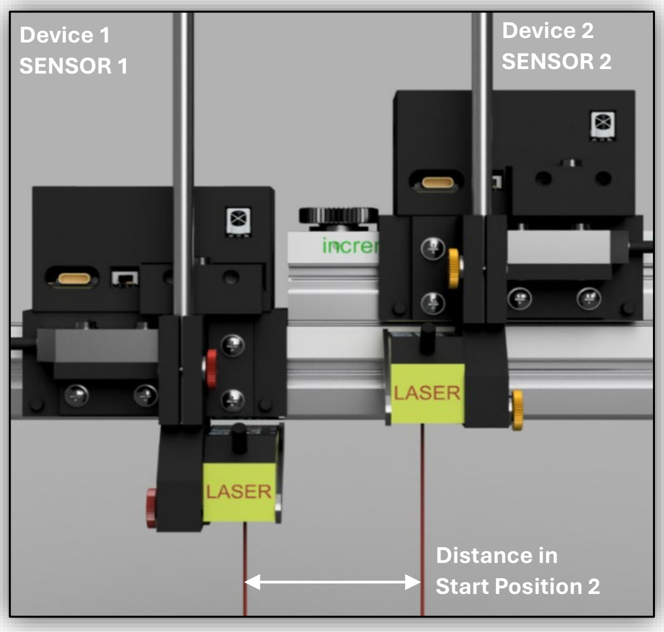
1. Both devices next to each other on the same guide rail (for uprights or smaller grands, or generally in the treble). The sensor arm of Device 1 is lowered (OFFSET H1 must be defined on the Master device, see below).
2. Device 1 on the lower rail and Device 2 on the upper rail (with coupled rails for very long strings in the bass / tenor).
3. Same as Start Position 1 but without lowering the sensor arm (only for length measurements where no values from the laser distance sensors are required → no downbearing calculation).

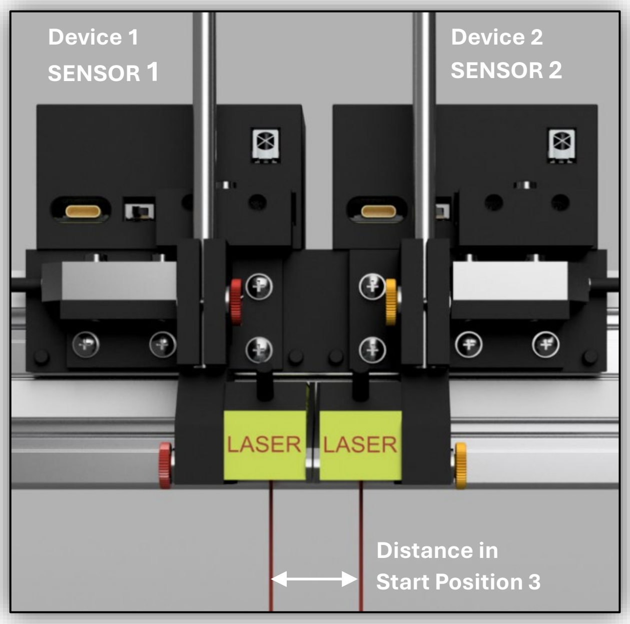


The stored offsets correspond to the distances between the laser spots in the respective start position and are automatically taken into account in the later calculation of the string lengths. The required offset can be selected with the up / down arrow keys.

For the downbearing calculation, the height values from the laser distance sensors are also required. If both devices are on the same guide rail, SENSOR 1 must be lowered so that the measuring range is reached.

⚠️ During the measuring process, it is always possible to return to this calibration menu and select another offset. This is useful, for example, after measuring the long strings in the bass / tenor, when the devices are repositioned for the treble next to each other on the same rail.





Client Device

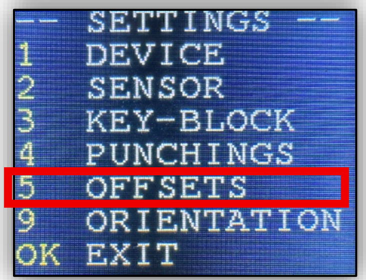
On the Client, the 0 key is pressed as soon as the message “wait client...” appears on the Master display (after setup has been completed and the Play mode exited with OK). A message then prompts the Client device to be moved into the start position, if this has not already been done.

Once both devices are correctly positioned, OK is pressed on both devices to confirm that they are in the start position. The offset selected on the Master is then adopted, and both devices switch to measurement mode.

Note on connection issues

If no connection can be established, or if it becomes apparent that the measurement values are not being transmitted smoothly in real time, a different WiFi channel can be selected on the Master for the Soft AP (Access Point). For this, both devices must be restarted. Directly on the Master’s start screen, an alternative channel can be selected with the 1 key, if the current channel is heavily used by other networks (see chapter Powering on the device).

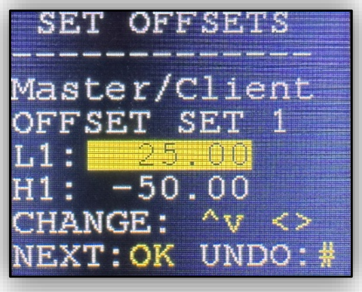
7.3 Offsets for Start Positions



The Settings menu is accessed from the main menu. With the corresponding key, the submenu “OFFSETS” opens, in which the offsets for the different start positions can be adjusted (all values in mm).

⚠ **Important:** The offsets are always defined and applied on the Master device. Offsets entered on the Client device are not taken into account!

Start Position 1 – both devices on the same guide rail (SENSOR 1 lowered)

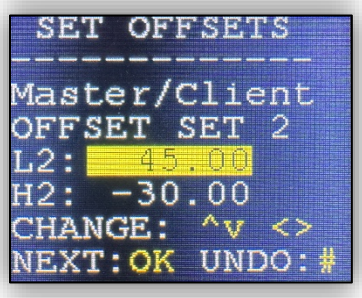


On the first screen, the length and height offsets for Start Position 1 are defined.

The length offset L1 is the distance between the two laser spots. This value is determined once with a measuring tape and stored in the device. From the factory, it is already calibrated to the existing geometry. If a different sensor is installed or a component is replaced later, it may be necessary to readjust the value.

The height offset H1 is -50 mm, since both laser distance sensors measure downward from the same reference point, but SENSOR 1 is lowered by exactly 50 mm in order to reach the measuring range for downbearing calculation. Therefore, 50 mm must be subtracted from the value of SENSOR 2 (-50 mm is added), so that both sensors return the same distance for the same measuring point. For details, see below “Lowering of the sensor arm (Start Position 1)”.

Start Position 2 – devices on two coupled rails

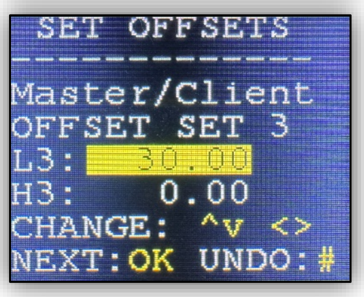


Pressing OK leads to the next screen for Start Position 2.

The length offset L2 is larger than L1 in this case, because the sensors are mounted on different rails and the distance increases accordingly.

The height offset H2 corresponds to the thickness of the guide rail (usually 30 mm). This value is subtracted from the height measurements of SENSOR 2, since it is positioned 30 mm higher than SENSOR 1 due to its location on the upper rail. Both sensors must be normalized to the same reference plane.

Start Position 3 – both devices on the same guide rail (without lowering)



Pressing OK leads to the final screen for Start Position 3.

This start position can be used if no downbearing calculations are required. The laser spots serve exclusively for positioning during length measurement. No values from the laser distance sensors are needed. For H3, the typical entry is 0 mm.

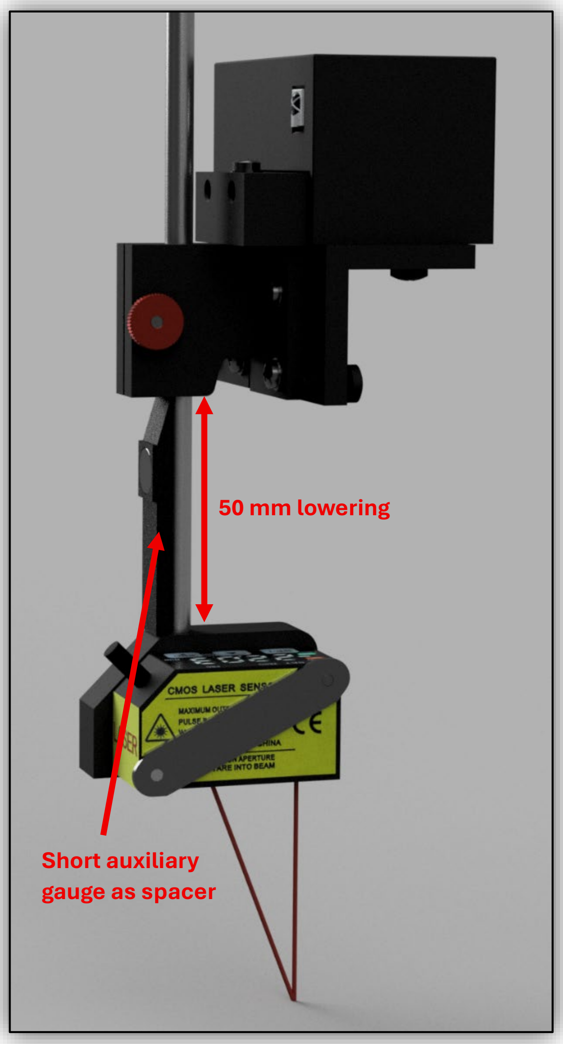
With the # key, changes can be undone.

With the OK button, the dialog is exited, the values are permanently saved, and the device returns to the menu.

Lowering of the Sensor Arm (Start Position 1)

In Start Position 1, the sensor arm of SENSOR 1 is lowered by 50 mm so that the measuring range is reached. Without this lowering, the laser distance sensor would sit too high and in many cases would be outside the valid measuring range.

For downbearing measurement, however, the height values of both sensors at the respective measuring points are required. To set the offset precisely to 50 mm, the short auxiliary gauge can be used. This gauge has an exact length of 50 mm. As shown in the figure on the right, it is clamped between the components and then fixed in place with the knurled screw.



Auxiliary Gauges for Measuring Strings in the Capo Bar Section

The offsets CAPO-L and CAPO-H are defined depending on the structural conditions of the instrument.

If the capo bar is very wide and the gauge must be pushed in deeply, the larger offset (e.g. 22 mm) should be selected and used.

In all other cases, the smaller offset (e.g. 10 mm) is sufficient.

Positioning the short 50 mm gauge is difficult in the damper section if the dampers are installed. In this case, the long 120 mm auxiliary gauge is used. It is simply pushed under the lifted damper up to the bearing bar (front termination of the string). The laser spot is then aligned with one of the two measuring marks on the gauge.

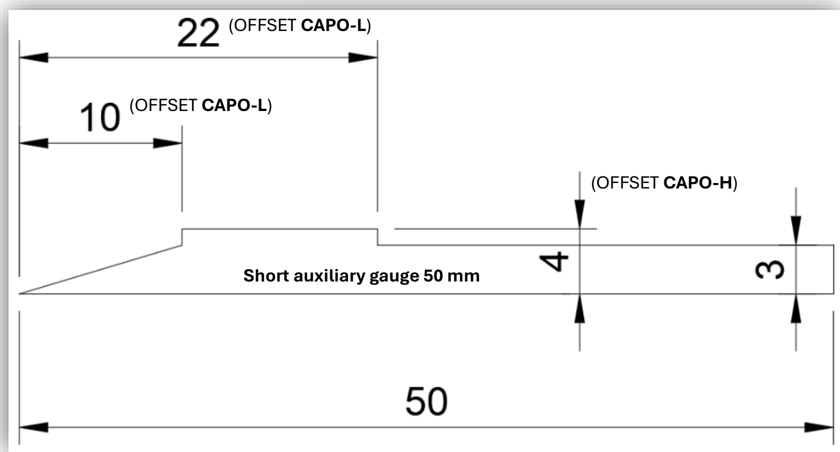
The stored offset corrects the measurement so that the resulting length is displayed accurately.

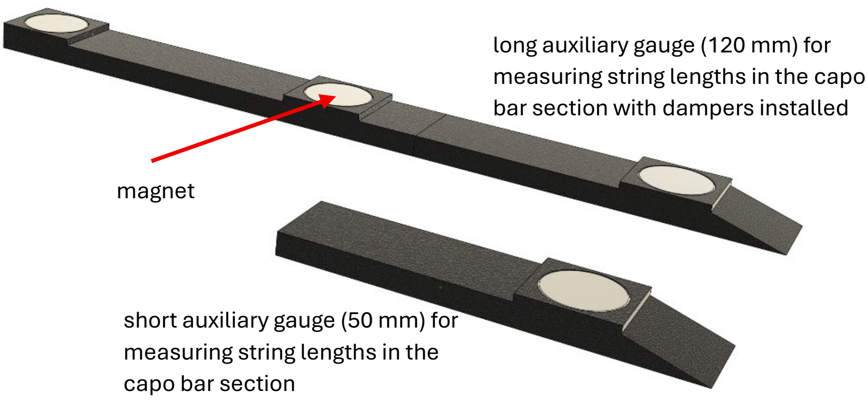
Note on Aligning the Laser Spot on the Auxiliary Gauge

The laser spot must be aligned exactly on the respective edge (either at 10 mm or at 22 mm). The exact transition is recognized by the fact that the height measurement value suddenly jumps by one millimeter, as there is a step at that point.

For downbearing measurement, however, the laser spot should be aimed exactly at the center of the magnet during both measurements. In this case, an offset CAPO-H = 4 mm is stored.

⚠️ For downbearing measurement, it is not necessary to align the laser spot exactly to the edges as is required when measuring string lengths.



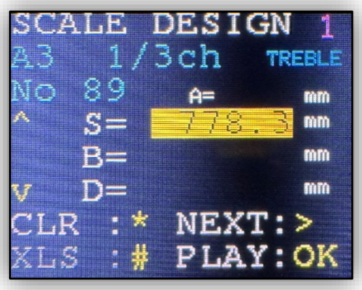


7.4 Measurement Mode (Recording Measurement Values)

After confirming the start position with OK on both devices, Master and Client switch to measurement mode. This is indicated by the measurement values on the display now appearing in orange (as opposed to green in Play mode).

When the devices are moved along the guide rail, the distance between them is displayed live on both screens. For measurement, the two laser spots are aligned exactly with the start and end points of the string to be measured. The technician then confirms on the Master device the acceptance of the currently set value. This value is stored permanently in the dataset of the currently selected memory slot.

7.4.1 Master Device



The layout of the display is very similar to Play mode (see chapter “Play Dialog – Retrieving Existing Measurement Values (Master Device)”), except that in measurement mode the values are displayed in orange (green in Play mode). The Master device takes over complete control of the measurement process.

Display Layout

- First line (right): Number of the current memory slot (magenta).
- Second line: Note designation, followed by the selected string and the total number of strings (e.g. 1/3ch = first string of three), as well as the section designation BASS or TREBLE. If in the capo bar section, the additional note TREBLE (CAPO) is shown.
- Third line: Number of the currently selected string and the calculated afterlength A. This value is only displayed if both S and B have been measured.
- Further lines: Measurement values of the currently selected string:
  - S = speaking length (agraffe to bridge pin)
  - B = total length (agraffe to hitch pin)
  - D = downbearing (see chapter Measuring Downbearing)

Commands and Navigation

- With the right / left arrow keys, move to the previous or next string or note.
- With the up / down arrow keys, switch between the parameters S, B, and D.
- With the number keys 1-3, select the string of the current note.
- With the 9 key, the display can be rotated by 180°.
- With the star key (*), the currently selected parameter is deleted.
- With the # key, the Excel Live Mode is activated or deactivated. If active, “XLS” appears in white; otherwise, in gray. In this mode, all values are transmitted live via WiFi to an Excel sheet and displayed there immediately in both table and diagram form (see chapter “Live Transmission of Measurement Values to Excel”).
- With OK, a dialog opens with two options:
  - Return to Play mode with OK: In measurement mode, navigation is only possible note by note. In Play mode, by contrast, the up / down arrows allow octave steps. If you want to skip several notes quickly, it is recommended to switch briefly into Play mode, select the desired note, and then return to measurement mode.
  - Enter Calibration Dialog (Start Position) with star key (*): Required, for example, when after measuring the long bass strings and the tenor section, the devices are repositioned in the treble next to each other on the same rail, making a new calibration necessary.

Note on Working in the Bass and Treble Sections

In the bass section, there is a special procedure for capturing parameters:

After measuring the speaking length S of the first string of a note, press the down arrow to switch to parameter B. This is measured and confirmed with the right arrow key. For the second or third string of the same note, the speaking length S is automatically taken from the first string. The device jumps directly to parameter B, since the speaking lengths within a unison are usually identical. If necessary, however, you can always return to parameter S with the up arrow key and measure it again.

This speeds up measurement in the bass: The laser spot is first positioned on the bridge pin (parameter S, first string), then on the hitch pin (parameter B). With NEXT (right arrow), you move to the next string of the note and position again at the hitch pin. In a trichord, the third string is treated the same way; in a bichord, pressing NEXT moves directly to the next note, where the first string is measured again at the bridge pin.

In the treble section, measurement proceeds differently:

After recording S and confirming with NEXT (right arrow), the system immediately switches to the next note. Thus, only the first string of each note is measured for the speaking length S, since this is usually sufficient for scale optimization and analysis. The total length B is normally not required in the treble, and the speaking lengths S of all strings of a note are generally identical.

7.4.2 Client Device

The Client device is used exclusively to capture the second position and height. Its operation is limited to a few functions, since all control is handled entirely by the Master.

Display Layout

- POS: Current position of the device on the guide rail (start position is zero).
- LEN: Current distance between both devices (laser spots). This value is also shown simultaneously on the Master.
- DIS: Current measurement value from its own laser distance sensor.

Operation

- With the 9 key, the display can be rotated by 180°.
- With the 0 key, the device returns to the main menu.

7.4.3 Measuring Downbearing

Downbearing is defined as follows:

An imaginary line is drawn from the top of the string at the front measuring point (agraffe or bearing bar) to the top of the string at the 2nd bridge pin on the sound side. This line is extended backwards into the hitch area. The vertical distance between this extended line and the actual support point of the string at the hitch (usually a felt strip, a brass bar, or a duplex scale) corresponds to the downbearing.

Traditionally, this has been measured using a long thread stretched tightly from the front termination point and lowered until it just touches the bridge surface. The remaining distance from the thread to the support at the hitch is called the downbearing.

With Piano Measure Pro, this measurement can be obtained directly and precisely.

The parameter D (Downbearing) is selected on the Master device using the arrow keys. If a value already exists, it can be deleted with the star key (*) before performing a new measurement. To determine downbearing, two measurements are required, taken in sequence.

When in parameter D (inverted display), the OK button has a special function:

- On the first press of OK, the message “1st press OK” appears. The devices are then aligned with their respective measuring points and confirmed with OK.
- The message “2nd press OK” then appears. The devices are moved to the second measuring points and again confirmed with OK.

The calculated downbearing is then displayed under parameter D. Negative values mean that the downbearing is negative.

⚠️ Note: As long as parameter D is active, the field “PLAY: OK” is grayed out. This means that in this special case the OK button does not function as usual (to access the Play dialog) but is used exclusively for recording measurement values.

Case 1: Strings installed in the instrument

- First measurement:
  - front: Height of the string, either directly on the string or on the agraffe (in which case the stored offset AGRA-H is added, see “Setup – Offsets (Master Device)”),
  - rear: Directly on the string in the area of the 2nd bridge pin.
- Second measurement:
  - front: Same as the first measurement,
  - rear: Directly on the string in the hitch area, where it rests.

Case 2: No strings installed in the instrument

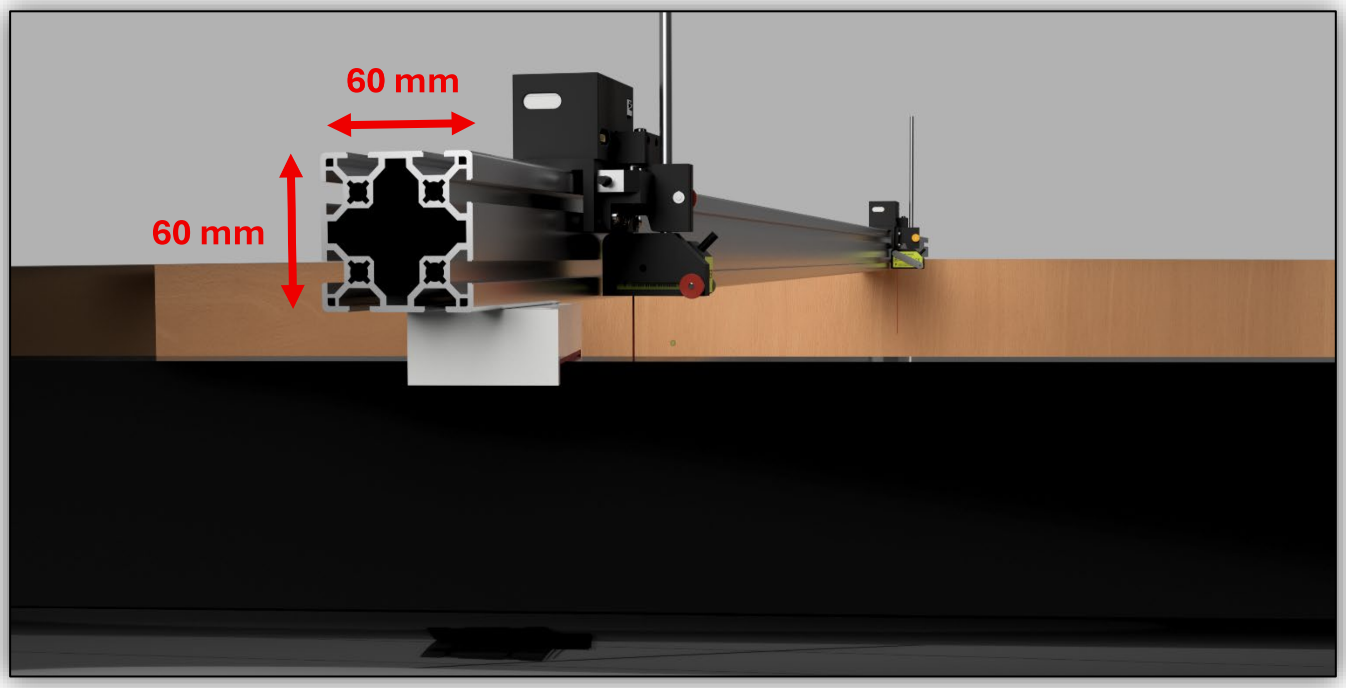
- First measurement:
  - front: Height must be measured on the agraffe (offset AGRA-H is added, see “Setup – Offsets (Master Device)”),
  - rear: On the bridge surface in the area of the 2nd bridge pin.
- Second measurement:
  - front: Same as the first measurement,
  - rear: At the support in the hitch area, i.e. where the string will later rest.

In the capo bar section, the string height at the front is measured directly in front of the capo bar (ideally on the auxiliary gauge, centered on the magnet, with CAPO-H offset preset). The calculation formula takes into account the distance between the two devices, so the downbearing calculation remains correct here as well.

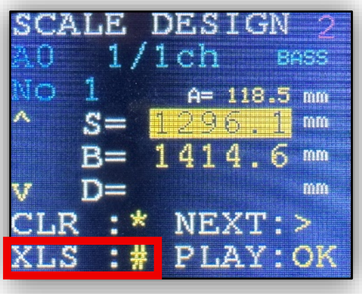
⚠️ **Important Note**

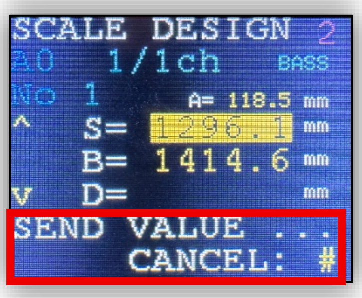
If the guide rail is extended to measure very long strings, it should be supported in the middle. Otherwise, it may sag slightly due to its own weight, which can impair measurement accuracy. However, this only affects downbearing measurements. Length measurements remain sufficiently accurate even with slight sagging.

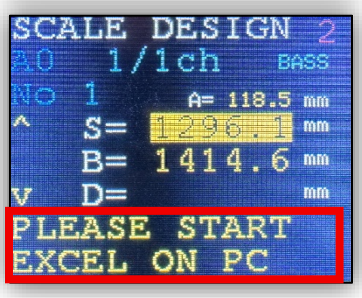
As an alternative for large grands, **a massive system profile of three meters in length (e.g. 60×60 mm or 90×90 mm)** can be used. In this case, sagging is negligible. The Piano Measure Pro devices fit on any standard system profile with a 30 mm grid. In this setup, it may be necessary to lower both sensor arms by the same amount - for example, 30 mm - to bring the laser distance sensors back into the required measuring range.



7.5 Live Transmission of Measurement Values to Excel







The measurement values can be transmitted wirelessly via WiFi in real time to a PC or laptop, where they are processed in an active Excel workbook and displayed graphically. In this way, for example, the speaking lengths S of an instrument can be conveniently imported into Excel and further analyzed and optimized with a scale program.

For bass string production, the manufacturer requires a specification sheet with the values A (afterlength) and B (total length). These values can be measured directly with Piano Measure Pro and automatically entered into the specification sheet, which then only needs to be sent by e-mail.

7.5.1 Activating Excel Mode

Excel mode is activated with the # key. When the mode is active, XLS appears in white; otherwise, in gray. Whenever the note is changed, the values of all parameters of the current note are automatically transmitted to Excel.

During transmission, the message “SEND VALUE…” appears. If no connection is possible, the message “PLEASE START EXCEL ON PC” is shown. If the connection still cannot be established, the process can be aborted with the # key. In that case, the XLS mode is automatically deactivated.

7.5.2 Setup in Excel

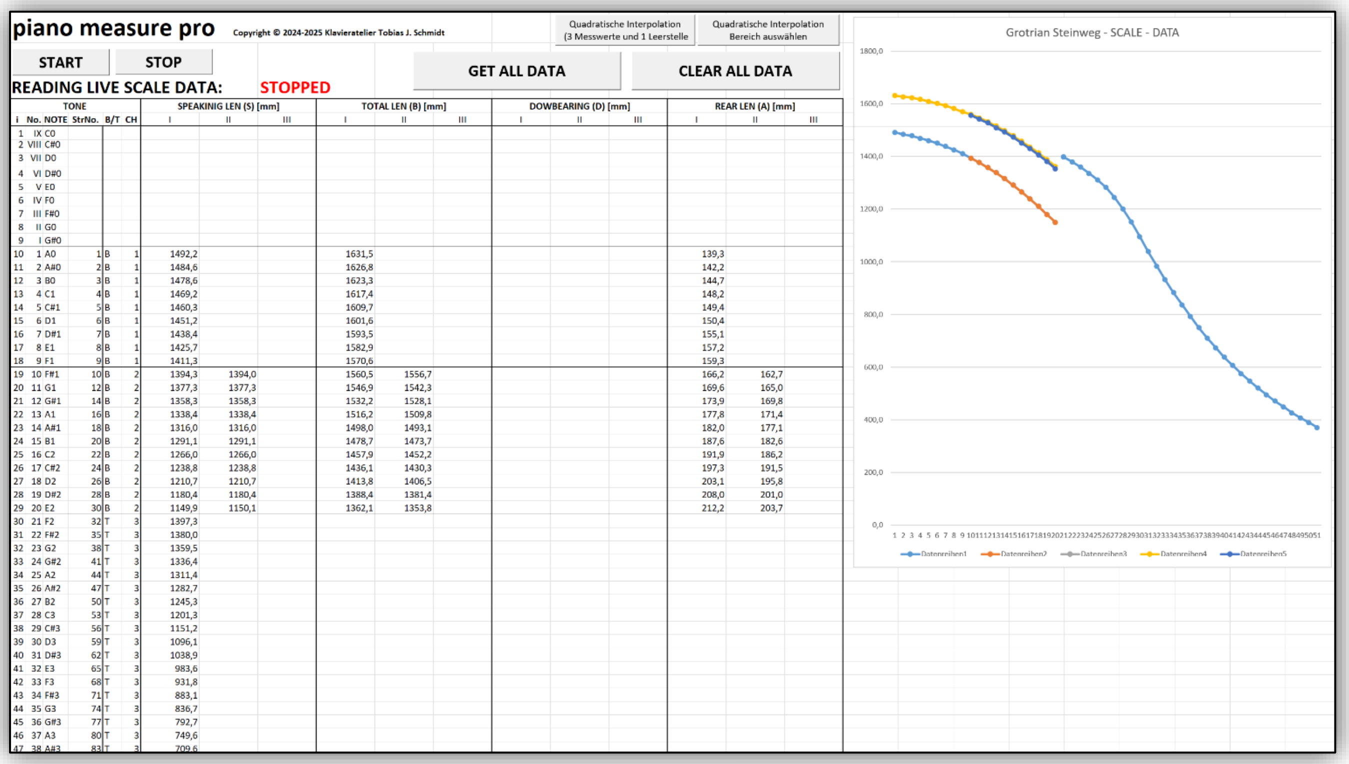
The Excel workbook is opened and prepared to receive measurement values from the Master device.

In the worksheet “DATA”, the option “NORMAL WIFI MODE 2” is selected, since Device 2 is normally configured as the Master.

If no external WiFi network is available, the PC or laptop can also connect directly to the Master device. For this, the network provided by Device 2 is selected (SSID = “piano-measure-pro-2”). In the selection box, “DIRECT (SOFT AP)” must then be chosen (see chapter Analyzing a dataset in Excel, section Key Level).

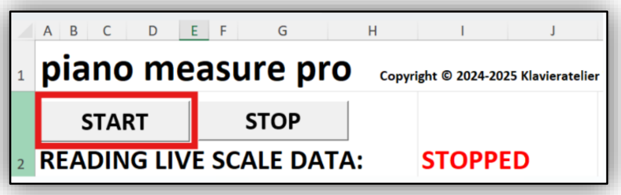
⚠ **Important:** For the measurement values to be received, the **macro functionality in Excel must be enabled** (see Excel security settings in the Trust Center).

7.5.3 Excel worksheet “SCALE_DATA”



TONE						SPEAKINIG LEN (S) [mm]			TOTAL LEN (B) [mm]			DOWBEARING (D) [mm]			REAR LEN (A) [mm]		
i	No.	NOTE	StrNo.	B/T	CH	I	II	III	I	II	III	I	II	III	I	II	III
1	IX	C0															
2	VIII	C#0															
3	VII	D0															
4	VI	D#0															
5	V	E0															
6	IV	F0															
7	III	F#0															
8	II	G0															
9	I	G#0															
10	1	A0	1	B	1	1492,2			1631,5						139,3		
11	2	A#0	2	B	1	1484,6			1626,8						142,2		
12	3	B0	3	B	1	1478,6			1623,3						144,7		
13	4	C1	4	B	1	1469,2			1617,4						148,2		
14	5	C#1	5	B	1	1460,3			1609,7						149,4		
15	6	D1	6	B	1	1451,2			1601,6						150,4		
16	7	D#1	7	B	1	1438,4			1593,5						155,1		
17	8	E1	8	B	1	1425,7			1582,9						157,2		
18	9	F1	9	B	1	1411,3			1570,6						159,3		
19	10	F#1	10	B	2	1394,3	1394,0		1560,5	1556,7					166,2	162,7	
20	11	G1	12	B	2	1377,3	1377,3		1546,9	1542,3					169,6	165,0	
21	12	G#1	14	B	2	1358,3	1358,3		1532,2	1528,1					173,9	169,8	
22	13	A1	16	B	2	1338,4	1338,4		1516,2	1509,8					177,8	171,4	
23	14	A#1	18	B	2	1316,0	1316,0		1498,0	1493,1					182,0	177,1	
24	15	B1	20	B	2	1291,1	1291,1		1478,7	1473,7					187,6	182,6	
25	16	C2	22	B	2	1266,0	1266,0		1457,9	1452,2					191,9	186,2	
26	17	C#2	24	B	2	1238,8	1238,8		1436,1	1430,3					197,3	191,5	
27	18	D2	26	B	2	1210,7	1210,7		1413,8	1406,5					203,1	195,8	
28	19	D#2	28	B	2	1180,4	1180,4		1388,4	1381,4					208,0	201,0	
29	20	E2	30	B	2	1149,9	1150,1		1362,1	1353,8					212,2	203,7	
30	21	F2	32	T	3	1397,3											
31	22	F#2	35	T	3	1380,0											
32	23	G2	38	T	3	1359,5											
33	24	G#2	41	T	3	1336,4											
34	25	A2	44	T	3	1311,4											
35	26	A#2	47	T	3	1282,7											
36	27	B2	50	T	3	1245,3											
37	28	C3	53	T	3	1201,3											
38	29	C#3	56	T	3	1151,2											
39	30	D3	59	T	3	1096,1											
40	31	D#3	62	T	3	1038,9											
41	32	E3	65	T	3	983,6											
42	33	F3	68	T	3	931,8											
43	34	F#3	71	T	3	883,1											
44	35	G3	74	T	3	836,7											
45	36	G#3	77	T	3	792,7											
46	37	A3	80	T	3	749,6											
47	38	A#3	83	T	3	709,6											

After switching to the worksheet “SCALE_DATA”, you enter the area for the scale design function.

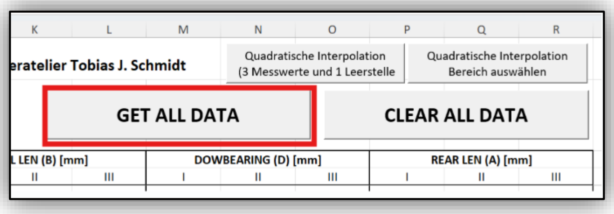


With the buttons “START” / “STOP”, the LIVE transmission mode is activated or deactivated.

The current status is shown in the field “READING LIVE SCALE DATA:”

- “STOPPED” (red): Mode not active
- “STARTED” (green): Mode active, measurement values are transmitted continuously if activated on the master device.

As soon as LIVE mode is active, the measurement values are transmitted to Excel immediately after recording a string, entered into the table, and additionally displayed graphically in the diagram on the right.



After calling up the scale design function, an already existing dataset can be loaded on the Master device (see chapter “Load Dataset (Master Device)”). In this case, a short message appears indicating that the data are available via WiFi.

The buttons in the worksheet can be used for additional functions:

- “GET ALL DATA”: All measurement values stored in the dataset are transferred to Excel at once.
- “CLEAR ALL DATA”: All measurement values from scale design are deleted from the Excel table.

⚠️ **Important:** Deletion affects only the data in the Excel table. The measurement values in the device itself remain stored in the assigned memory slot. Already existing measurement values from other functions (e.g. key level in the worksheet “DATA”) also remain unaffected.

7.5.4 Explanation of the Table

TONE						SPEAKINIG LEN (S) [mm]			TOTAL LEN (B) [mm]			DOWBEARING (D) [mm]			REAR LEN (A) [mm]		
i	No.	NOTE	StrNo.	B/T	CH	I	II	III	I	II	III	I	II	III	I	II	III
1	IX	C0															
2	VIII	C#0															
3	VII	D0															
4	VI	D#0															
5	V	E0															
6	IV	F0															
7	III	F#0															
8	II	G0															
9	I	G#0															
10	1	A0	1	B	1	1492,2			1631,5						139,3		
11	2	A#0	2	B	1	1484,6			1626,8						142,2		

The table provides a clear overview of all measurement values from the scale design function.

Header Columns (“TONE”)

- Column (running number): Sequential numbering of the entries.
- Column “No.”: Running number of the notes. Normally, the numbering starts with 1 at A0. However, if there are additional keys to the left of A0 (e.g. on the Bösendorfer Imperial), the numbering counts downwards from A0 to the left. These tones are numbered with Roman numerals (I, II, III ...) up to the outermost left key.
- Column “NOTE”: Note designation (e.g. A0, C4).
- Column “StrNo.”: String number (strings are numbered beginning with the first string of the first note, counting upwards).
- Column “B/T”: Indicates whether it is a bass note (B = bass with wound bass strings) or a note in the tenor or treble (T).
- Column “CH”: Number of strings belonging to the respective note (unichord, bichord, or trichord).

Measurement Columns

Following this are four main columns with the measured parameters:

- SPEAKING LEN (S) [mm]: Speaking length
- TOTAL LEN (B) [mm]: Total length
- DOWNBEARING (D) [mm]: Downbearing
- REAR LEN (A) [mm]: Afterlength

Each of these main columns is further divided into the sub-columns I, II, III, representing the first, second, and third string of the respective note. Thus, each row contains the measurement values for all strings of the corresponding note side by side.

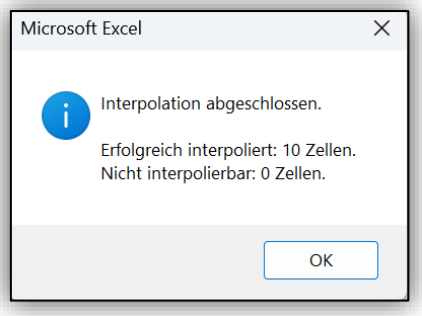
7.5.5 Interpolation of missing values

7	III	F#0					
8	II	G0					
9	I	G#0					
10	1	A0	1	B	1	1492,2	1631,5
11	2	A#0	2	B	1		
12	3	B0	3	B	1	1478,6	1623,3
13	4	C1	4	B	1		
14	5	C#1	5	B	1	1460,3	1609,7
15	6	D1	6	B	1		
16	7	D#1	7	B	1	1438,4	1593,5
17	8	E1	8	B	1		
18	9	F1	9	B	1	1411,3	1570,6
19	10	F#1	10	B	2		
20	11	G1	12	B	2	1377,3	1546,9
21	12	G#1	14	B	2		
22	13	A1	16	B	2	1338,4	1516,2
23	14	A#1	18	B	2		
24	15	B1	20	B	2	1291,1	1478,7
25	16	C2	22	B	2		
26	17	C#2	24	B	2	1238,8	1436,1
27	18	D2	26	B	2		
28	19	D#2	28	B	2	1180,4	1388,4
29	20	E2	30	B	2		
30	21	F2	32	T	3	1397,3	
31	22	F#2	35	T	3	1380,0	
32	23	G2	38	T	3	1359,5	
33	24	G#2	41	T	3	1336,4	
34	25	A2	44	T	3	1311,4	
35	26	A#2	47	T	3	1282,7	
36	27	B2	50	T	3	1245,3	

Missing values

To speed up the measuring process, certain strings can be skipped following a fixed pattern. This reduces the number of individual measurements and **saves time**.

Often the rows of hitch pins or bridge pins are arranged in a nearly straight curve. In such cases, it is sufficient to record the measurement values on the left and right of a skipped string and calculate the missing value by interpolation. In this way, surprisingly accurate results can be achieved, which in practice are often entirely sufficient. The technician decides in each case what level of accuracy is required.



During recording, one hitch pin or one bridge pin is regularly skipped. This creates gaps in the table, which can later be filled by interpolation.

In the upper table, the missing measurement values are marked as gray cells.

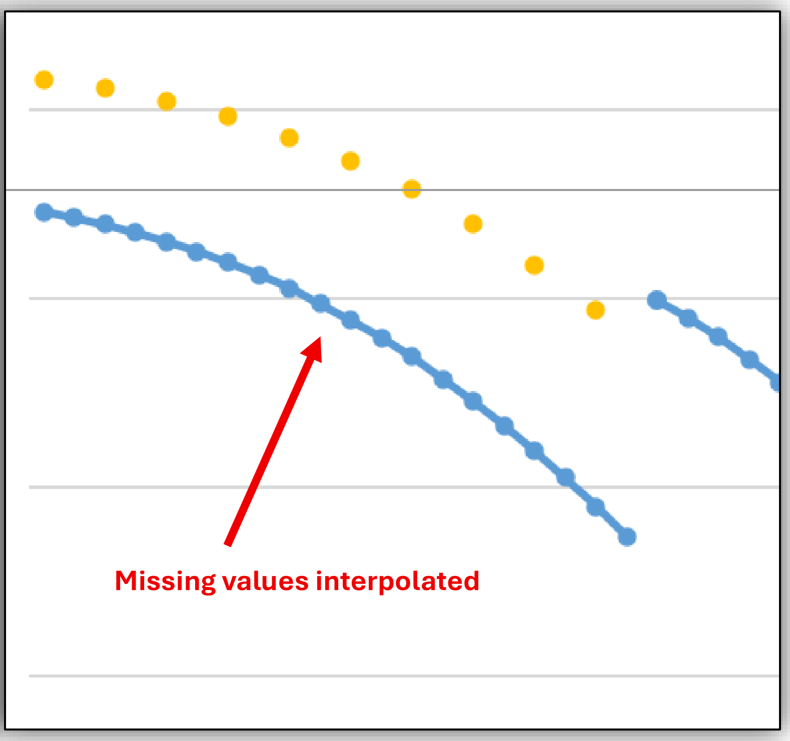
The cell range is selected and, after clicking “Select Quadratic Interpolation Range”, these gaps are automatically filled with interpolated values.

The interpolated values are highlighted in yellow in the table.

In the diagram, it is clearly visible how the missing points supplement the existing line and smooth the curve.

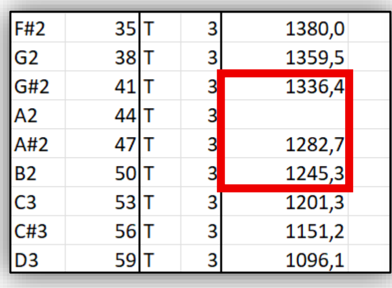
⚠️ **Important:** Interpolation does not replace an actual measurement at critical points (e.g. in transition areas or structural irregularities). It is only a tool to save measuring time in sections with a uniform layout.

1492,2
1486,0
1478,6
1469,9
1460,3
1450,0
1438,4
1425,7
1411,3
1394,9
1377,3
1358,9
1338,4
1315,4
1291,1
1265,7
1238,8
1210,4
1180,4
1148,9

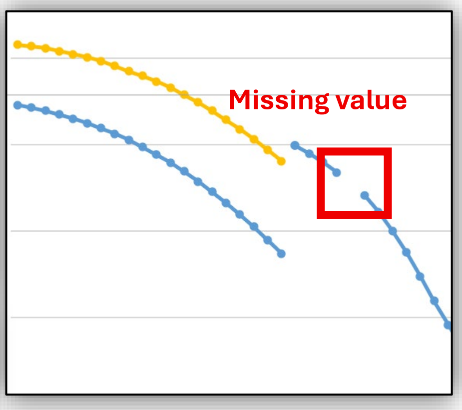


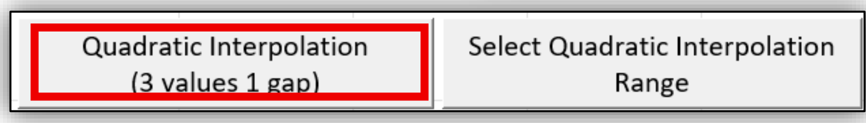
Quadratic Interpolation (3 measured values, one gap)

It can happen that individual strings cannot be measured because they are blocked by components of the acoustic assembly and the laser beam cannot reach the measuring point. If such isolated measurement values are missing, they can be supplemented with a second interpolation method.

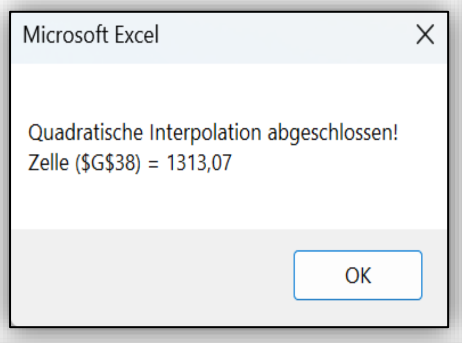


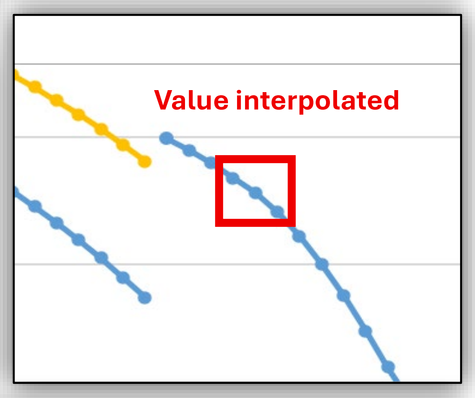
F#2	35	T	3	1380,0
G2	38	T	3	1359,5
G#2	41	T	3	1336,4
A2	44	T	3	
A#2	47	T	3	1282,7
B2	50	T	3	1245,3
C3	53	T	3	1201,3
C#3	56	T	3	1151,2
D3	59	T	3	1096,1

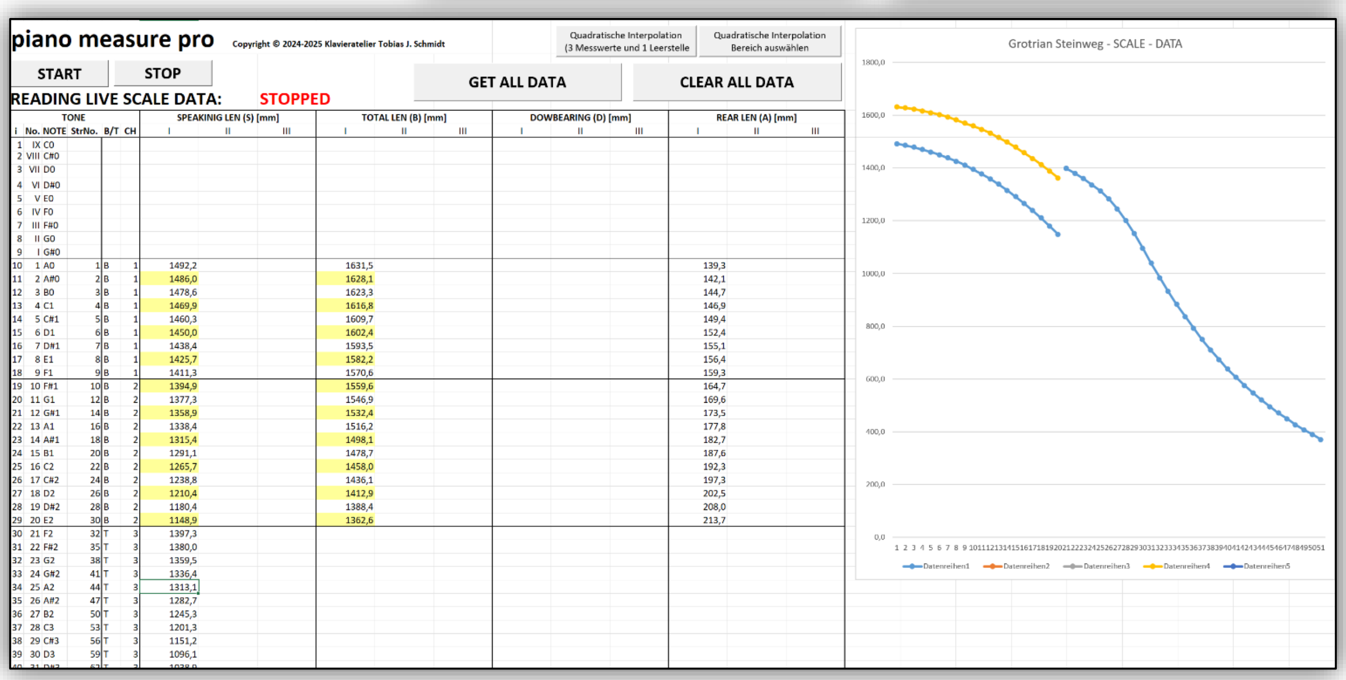




For this, three existing adjacent measurement values and the empty cell between them are selected, and the corresponding button is clicked. The missing value is then automatically interpolated, entered into the table, and the gap in the curve is closed.







7.5.6 Specification Sheet for Bass String Production

In addition, the worksheet “SCALE_BASS” is available. In this table, the measurement values of the wound bass strings are automatically entered. The layout follows a special format tailored to the requirements of bass string manufacturers.

For the production of the strings, the manufacturer requires the following length values:

- Afterlength A
- Total length B

These values are assigned a consecutive string number, starting with the lowest and longest string. Other data such as speaking length or downbearing are not relevant for the manufacturer and would only be confusing. The table can therefore be transmitted to the supplier 1:1 without modification.

In the worksheet “SCALE_BASS”, the structure differs from that of the worksheet “SCALE_DATA”:

The measurement values of the individual strings of a note are displayed one below the other instead of side by side. For unichords or bichords, this results in empty rows, since no measurement values exist for all three strings.

For better clarity, the following functions are available:

- With the button “Hide empty”, all empty rows are hidden.
- With the button “Show all”, all rows are displayed again.

	A	B	C	E	F	G	H	I	J
1	No.	Note	StrNo.	A [mm]	B [mm]	Hide empty		Show all	
29	1	A0	1	139,3	1631,5				
32	2	A#0	2	142,2	1626,8				
35	3	B0	3	144,7	1623,3				
38	4	C1	4	148,2	1617,4				
41	5	C#1	5	149,4	1609,7				
44	6	D1	6	150,4	1601,6				
47	7	D#1	7	155,1	1593,5				
50	8	E1	8	157,2	1582,9				
53	9	F1	9	159,3	1570,6				
56	10	F#1	10	166,2	1560,5				
57	10	F#1	11	162,7	1556,7				
59	11	G1	12	169,6	1546,9				
60	11	G1	13	165,0	1542,3				
62	12	G#1	14	173,9	1532,2				
63	12	G#1	15	169,8	1528,1				
65	13	A1	16	177,8	1516,2				
66	13	A1	17	171,4	1509,8				
68	14	A#1	18	182,0	1498,0				
69	14	A#1	19	177,1	1493,1				
71	15	B1	20	187,6	1478,7				
72	15	B1	21	182,6	1473,7				
74	16	C2	22	191,9	1457,9				
75	16	C2	23	186,2	1452,2				
77	17	C#2	24	197,3	1436,1				
78	17	C#2	25	191,5	1430,3				
80	18	D2	26	203,1	1413,8				
81	18	D2	27	195,8	1406,5				
83	19	D#2	28	208,0	1388,4				
84	19	D#2	29	201,0	1381,4				
86	20	E2	30	212,2	1362,1				
87	20	E2	31	203,7	1353,8				
293									