Die Wyler Minilevel A10: precision levels

1 Einleitung

Eigentlich fühle ich mich ja in meinem Herzen doch irgendwie als "Messtechniker". Die Liebe zu elektronischen Messgeräten fing bei mir schon früh als Jugendlicher an und hat seither auch nicht wirklich nachgelassen. Die Präzision meiner Messgeräte durch Umbauten und Finetuning an die Grenzen des (hobbymäßig) Machbaren zu treiben, hat mir dabei schon immer besonders Spaß gemacht. Bei Themen wie "Intermodulation" oder "Phasenrauschen" muss man sich auch schon wirklich tief in die Materie einarbeiten, denn das Rauschen eines Quarzoszillators zu messen, das in ein paar kHz Abstand schon bis zu 170dB* unter dem eigentlich Träger liegen kann, verzeiht nicht den geringsten Fehler- zumal der physikalisch überhaupt mögliche Grenzwert bei Zimmertemperatur eh bei -173dB(m) liegt.

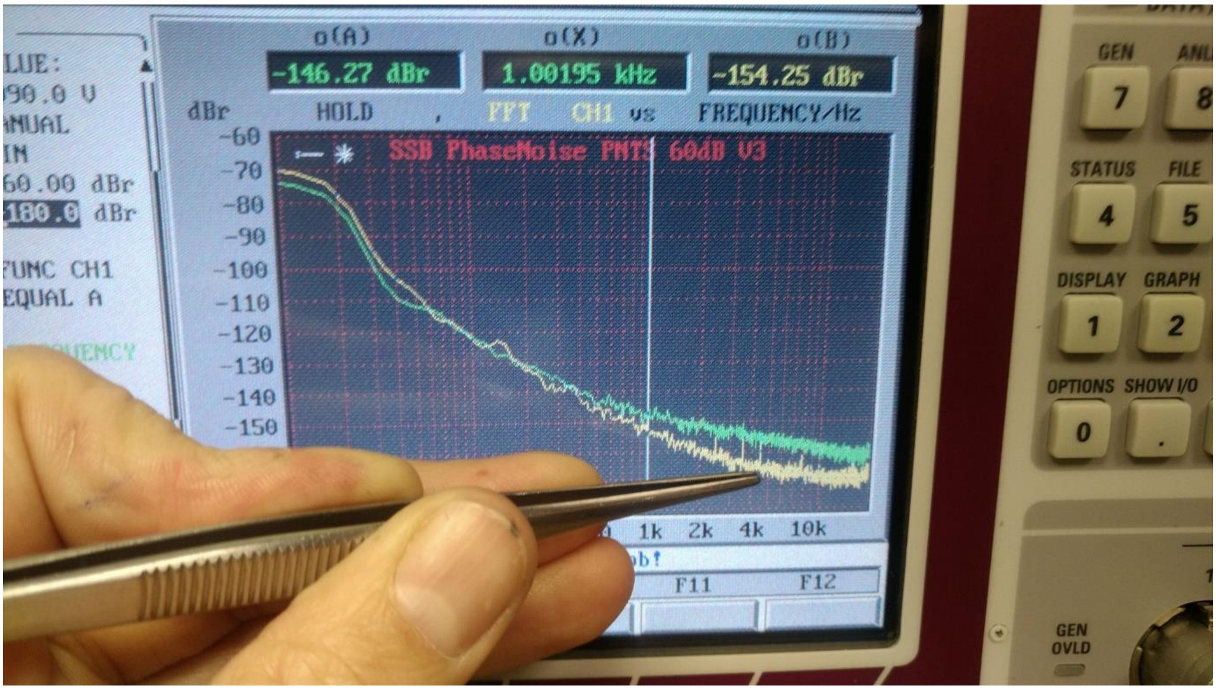


Abbildung 1: besser kann ein Tag nicht verlaufen: mal eben 10dB mehr Dynamik geholt durch Einsatz eines entrauschten Netzteils. Wir befinden uns hier etwa 170dB unterhalb des Signalpegels!

Die Anforderungen sind dabei so hoch, dass hier typischerweise auch kaum noch ein Hobbybastler noch irgendwie mitreden kann. Es gibt nur noch ganz wenige Enthusiasten, denen sowas Spaß macht und ich kann stolz behaupten, dass ich einer von diesen wenigen "Verstrahlten" bin. Achja- kommerzielle Geräte zur Phasenrauschmessung gibt es natürlich, kosten derzeit aber etwa etwa bis zu einer Viertelmillion Euro!

* Übersetzung für Mechaniker: wenn "0dB" mit einem 1m Länge gleichgesetzt würde, so reden wir bei -170dB über eine Strecke von 1*10^-17; also 0,000 000 000 000 000 01 m. Ich weiß gar nicht mehr, wie man sich das vorstellen soll. Es wäre um den Faktor zehn Millionen kleiner als ein Atomdurchmesser; also noch kleiner als der momentan angenommene Durchmessers eines einzelnen Elektrons!

Warum die geschwollene Einleitung?
Nun- um es vielleicht etwas verständlicher zu machen, dass es in meiner Natur zu liegen scheint, sich nie mit irgendwas im "Originalzustand" zufrieden zu geben, sondern immer zu versuchen, das bereits Gute noch irgendwie "besser" zu machen. Dass ich mit dieser Einstellung natürlich nicht nur Messgeräte ans Optimum "heranschraube", sondern ich das auch für mein neu entdecktes Gebiet -die Werkzeugmaschinenmechanik- versuche, dürfe mit dem erklärten Hintergrund nun einleuchten.

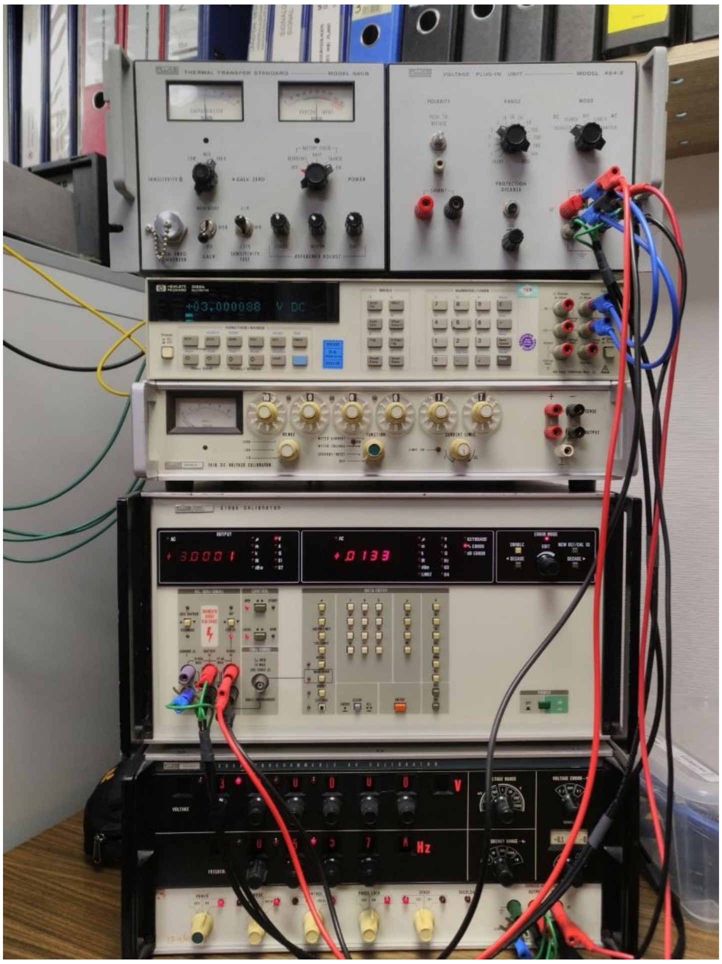


Abbildung 2: mein Kalibrierplatz- hier kann ich mich bis aufs letzte µV austoben- aber alles nur Hobby!

Wie ich inzwischen gelernt habe, ist die Basis für Präzision in der Mechanik eine gute Messplatte. Meistens ist die aus Granit, wurde irgendwann einmal von einer entsprechenden Spezialfirma mit Diamantschleifstaub und Läpp-Platten auf eine bestimmte Oberflächenebenheit hin getrimmt und danach mit Prüfzertifikat und Einordnung in eine bestimmte Genauigkeitsklasse (z.B. nach DIN876) an den Kunden ausgeliefert.

Mit einer solchen Platte kann man dann fröhlich Messungen an Werkstücken machen, denn wir nehmen diese Granitbasis für uns als "ideal" an; also die noch verbleibenden Rest-Unebenheiten nur noch so klein sind, dass sie für uns bedeutungslos werden.

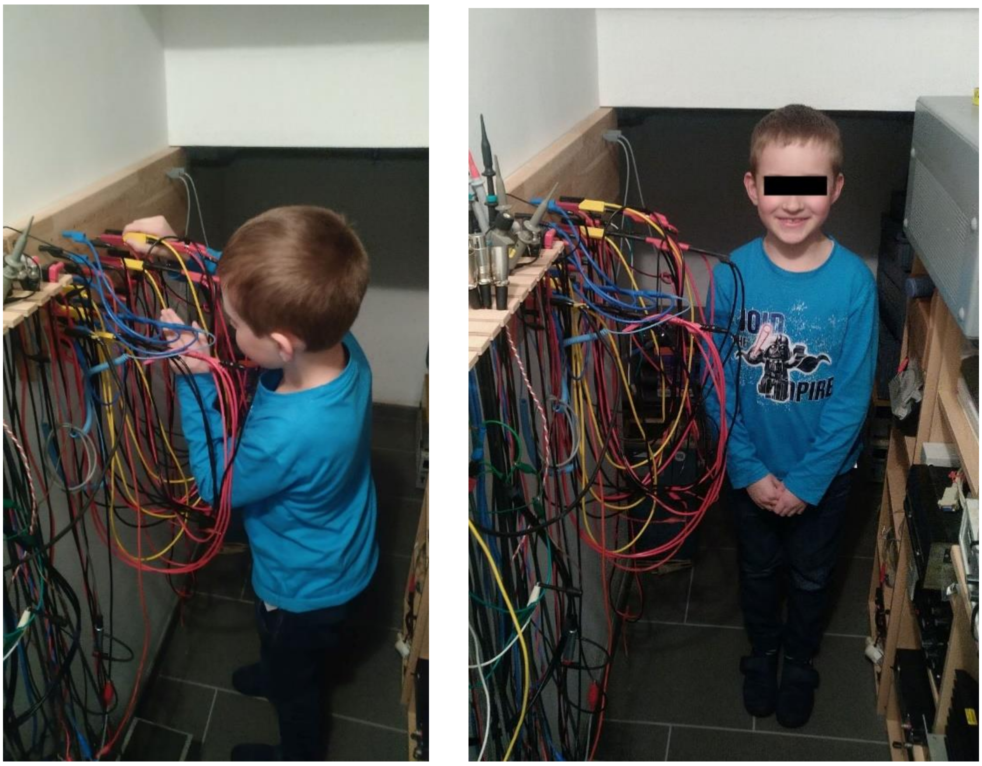


Abbildung 3: oft "hilft" der Jüngste bei meinen Projekten mit- hier z.B. beim Kurzschließen meiner (ehemals) sauber aufgehängten Laborkabel

Diese Annahme ist auch legitim, aber natürlich unterliegt auch ein noch so fester Granitstein irgendwann einer gewissen Form von Abnutzung. Egal, ob der Meister versehentlich eine Kaffeetasse darauf hat fallen lassen, oder der Azubi mit einem nicht entgrateten Werkstück hässliche Kratzer in die kostbare Oberfläche hineinfabriziert hat- eine Messplatte, die "in Benutzung" ist, kann eben auch irgendwann Spuren dieser "Benutzung" zeigen. Und damit diese Spuren früher erkannt werden, als dass ihr Einfluss irgendwann so groß wird, dass sie wirklich unsere Messergebnisse deutlich zu verfälschen beginnen, gibt es das sogenannte "Kalibrierintervall". Bei dieser "Kalibrierung" wird festgestellt, ob das Messmittel (=die Granitplatte) noch immer so genau ist, wie angenommen, oder ob es nun zu seiner ursprünglichen Spezifikation inzwischen signifikant abweicht. Gerade für Firmen, die sich auf ihre Messungen zwingend verlassen können müssen, ist daher die gewissenhafte Einhaltung dieser Kalibrierintervalle unheimlich wichtig!

Wie aber nun "kalibriert" man denn nun so eine Messplatte? Wie kann man diese aller-winzigsten Unebenheiten einer Messplatte überhaupt noch messen? Brauche ich dazu eigentlich nicht noch etwas Genaueres als die Messplatte selbst- die ja aber normalerweise schon das Genaueste der Werkstatt selbst ist?

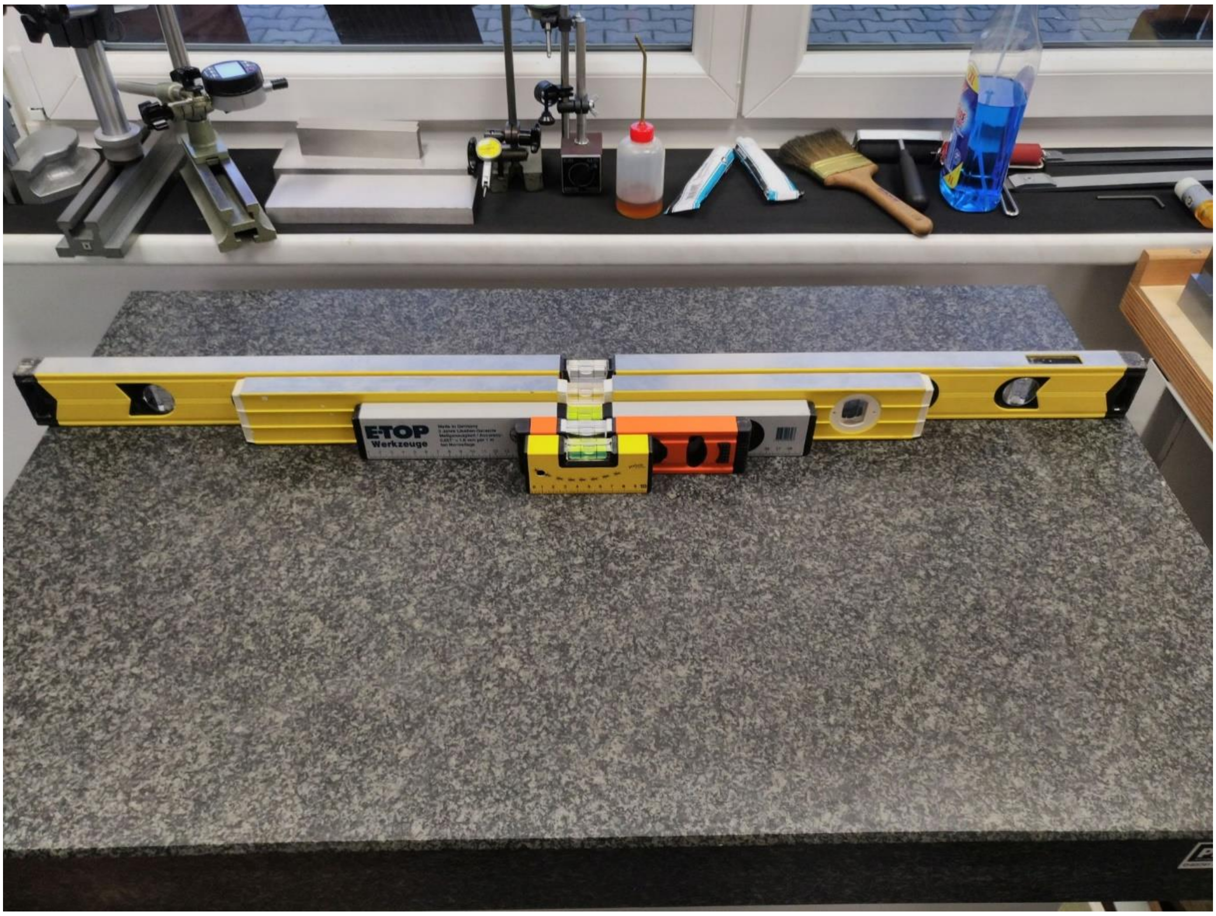


Abbildung 4: mit solchen Waagen werden wir wohl nicht viel weiter kommen bei der Messplattenüberprüfung...;-)

Stimmt. Wir brauchen was: und zwar die Gravitation! Die ist immer ganz sauber und starr auf den Erdmittelpunkt gerichtet, ist immer, jederzeit und kostenlos verfügbar und bildet damit ein als "ideal" anzunehmendes Präzisions-Lot für Jedermann!* Wir müssen dieses Lot nur noch irgendwie "anzapfen" und schon können wir damit messen. Wie zapft man die Schwerkraft an? Mit einer Waage! Und genau das machen die Firmen, die sich mit der Kalibrierung und Ebenheitsmessung von Messplatten beschäftigen, ebenfalls: mit höchstpräzisesten Spezialwaagen fahren sie in einem festgelegten Raster über die zu prüfende Fläche und ermitteln an jedem einzelnen Messpunkt, ob die Fläche -im Vergleich zum vorherigen Messpunkt- ansteigt, gleich bleibt oder abfällt. Aus der Hintereinanderreihung dieser einzelnen gemessenen "Steigungs- und Gefällehäppchen" ergibt sich das Oberflächenprofil (also die Berg- und Tal-Ansicht) der geprüften Fläche. Dabei sind die eingesetzten elektronischen Waagen so empfindlich, dass sie bereits registrieren, wenn man unter einen 1m langen Stab auf einer Seite eine 1µm dicke Folie legen würde (gibt es so dünne Folien überhaupt? Meine dünnste ist 10µm dick....)!

* Erst kürzlich wurden ja die Gravitationswellen nachgewiesen, die z.B. beim Entstehen schwarzer Löcher ausgesendet werden können. Die werden natürlich auch einen wiiiiiiinzigen Einfluss auf unser Lot haben. Aber bestimmt nicht groß genug, um irgendeine Messplattenmessung zu versauen. Versprochen!

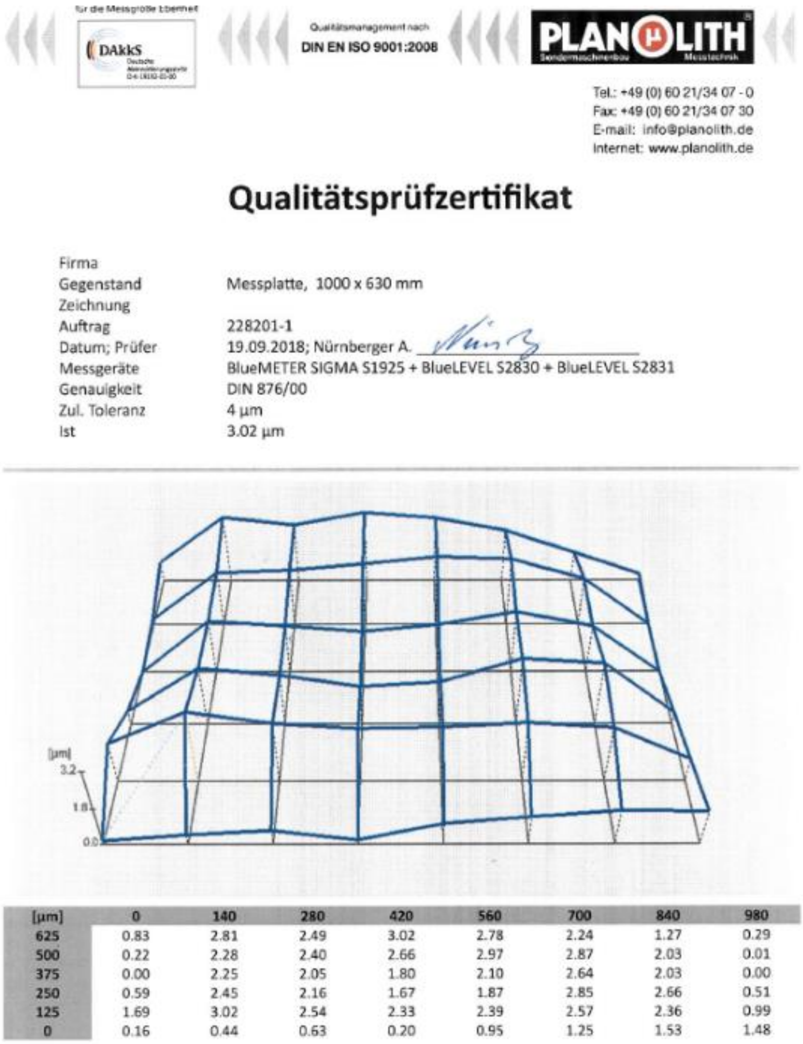
Eine Waage, die 10cm lang ist und über diese Auflösung (1µm/m) verfügt, könnte also eine Veränderung der geprüften Fläche unter ihren Messfüßchen von nur 0,1µm detektieren. Würde ihre Anzeige in der Einheit "0,1µm-Schritte" erfolgen, ergäbe sich beim Unterlegen einer 10µm Hassbergfolie eine Anzeige von "100". Diese hohe Auflösung erreicht sie natürlich nur unter ganz bestimmten Bedingungen, weshalb die geprüfte Fläche vorher bereits schon ziemlich gut "in Waage" ausgerichtet sein muss. Aber wenn man das gemacht hat, kann man so ganz gut prüfen, ob eine solche Waage korrekt einigermaßen korrekt funktioniert oder nicht.

Abbildung 5: so sehen heutige Mess-Systeme aus; hier das "BlueSystem" von Wyler (Quelle: wylerag.com)

Apropos "Waage": eben WEIL diese Instrumente so "speziell" sind, redet man von ihnen auch oft auch nicht mehr als "Wasserwaage" , sondern als "Neigungsmesser". Und ihre Empfindlichkeit wird auch manchmal nicht mehr in "µm/m" angegeben, sondern in Bogensekunden (=Arc sec). Dabei ist eine Bogensekunde der 3600ste Teil eines Grads, also etwa 0,00027°. Auf 1m Länge bezogen, wäre das ein Neigungsmesser mit einer Empfindlichkeit von etwa 5µm/m. Ein Neigungsmesser mit 1µm/m Empfindlichkeit würde dementsprechend mit 0,2 Arcsec bezeichnet werden (exakt: 0,97µm/m). Je nachdem, welche Einheit das Gerät in seiner Anzeige verwendet, muss man das eben umrechnen.

2 von der Theorie zur Waage

So, nun habe ich Euch allen so viel über Präzisions-Winkelmesser erzählt, da wäre es ja nun mehr als enttäuschend, wenn ich es bei der bloßen Theorie beließe. Na klar: das Kalibrierzertifikat meiner eigenen Planolith Granitplatte DIN876/00 stammt aus dem September 2018 und selbst bei geringer Nutzung (=private Nutzung) sollte man sie nach spätestens 2 Jahren erneut überprüfen, also "kalibrieren".


für die Messgröße Ebenheit

DAkkS Deutsche Akkreditierungsstelle

Qualitätsmanagement nach DIN EN ISO 9001:2008

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Qualitätsprüfzertifikat

Firma	
Gegenstand	Messplatte, 1000 x 630 mm
Zeichnung	
Auftrag	228201-1
Datum; Prüfer	19.09.2018; Nürnberger A.
Messgeräte	BlueMETER SIGMA S1925 + BlueLEVEL S2830 + BlueLEVEL S2831
Genauigkeit	DIN 876/00
Zul. Toleranz	4 µm
Ist	3.02 µm

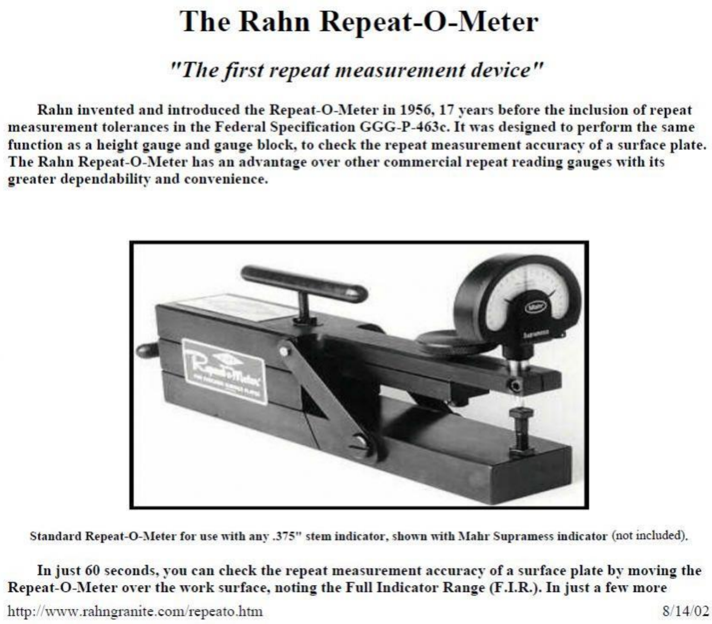
[µm]	0	140	280	420	560	700	840	980
625	0.83	2.81	2.49	3.02	2.78	2.24	1.27	0.29
500	0.22	2.28	2.40	2.66	2.97	2.87	2.03	0.01
375	0.00	2.25	2.05	1.80	2.10	2.64	2.03	0.00
250	0.59	2.45	2.16	1.67	1.87	2.85	2.66	0.51
125	1.69	3.02	2.54	2.33	2.39	2.57	2.36	0.99
0	0.16	0.44	0.63	0.20	0.95	1.25	1.53	1.48

Abbildung 6: Zertifikat meiner Planolith 1000x630mm Granitplatte

Dieser Zeitraum ist jetzt abgelaufen und ich habe mir irgendwie in den Kopf gesetzt, diese Kalibrierung mal mit eigenen Mitteln versuchen zu wollen. Wie auch bei meinem elektrischen Messtechnik-Hobby natürlich alles mit Hausmitteln und mit Hobbycharakter; jedoch möchte ich schon versuchen, dass meine Methoden am Ende einigermaßen sinnhaft und die damit erzeugten Messwerte belastbar sein werden.

3 Der Ansatz

Nach dem Genuss vieler Youtube-Videos wird mir klar, dass man die Ebenheit einer Platte mit zwei Dingen prüft:
a) dem Repeat-o-Meter
b) der Vermessung der ganzen Platte; z.B. mittels differentieller Neigungsmesser, Autocollimator oder Laser-Interferenzmessgeräten


The Rahn Repeat-O-Meter

"The first repeat measurement device"

Rahn invented and introduced the Repeat-O-Meter in 1956, 17 years before the inclusion of repeat measurement tolerances in the Federal Specification GGG-P-463c. It was designed to perform the same function as a height gauge and gauge block, to check the repeat measurement accuracy of a surface plate. The Rahn Repeat-O-Meter has an advantage over other commercial repeat reading gauges with its greater dependability and convenience.

Standard Repeat-O-Meter for use with any .375" stem indicator, shown with Mahr Supramess indicator (not included).

In just 60 seconds, you can check the repeat measurement accuracy of a surface plate by moving the Repeat-O-Meter over the work surface, noting the Full Indicator Range (F.I.R.). In just a few more

http://www.rahngranite.com/repeato.htm 8/14/02

Abbildung 7: Rahn Repeat-o-meter; Quelle: www.rahngranite.com

Das **Verfahren a)** dient dazu, eher lokale Dellen oder Hügelchen auf der Plattenoberfläche zu finden. Dieser Parameter wird dafür verantwortlich gemacht, wie gut "wiederholbar" eine Messung auf dieser Messplatte gemacht werden kann. Es darf ja nicht sein, dass eine Messreihe ortsabhängig ist; also z.B. dass die gemessene Höhe eines Werkstücks auf der Messplatte überall gleich ist und nicht davon abhängt, ob ich die Messung an der Kante vorne links mache oder den Messaufbau nach hinten rechts schiebe. Es soll überall dasselbe Ergebnis herauskommen. Das zu beurteilen, dient vorwiegend das Repeat-o-meter.

Abbildung 8: dasselbe Messprinzip, allerdings längst nicht so stabil wie das Original!

Verfahren b) überzieht die gesamte Messplatte mit einem Liniennetz; z.B. im 10cm-Raster. Mit den oben beschriebenen Präzisionswaagen fährt man dann in diesem 10cm-Raster über die Messplatte und nimmt die Messwerte in eine große Tabelle auf. Klar- lokale Dellen, die vielleicht genau ZWISCHEN zwei Rasterpunkten liegen, werden damit nicht entdeckt. Dafür hat man ja aber Verfahren a), das jedoch wiederum auch wirklich nur lokale Dellen finden kann, aber nicht dazu geeignet ist, das "große Ganze" zu erfassen. Wie man sieht, ergänzen sich die beiden Verfahren und man muss wirklich alle beide anwenden, um eine Platte zuverlässig zu prüfen.

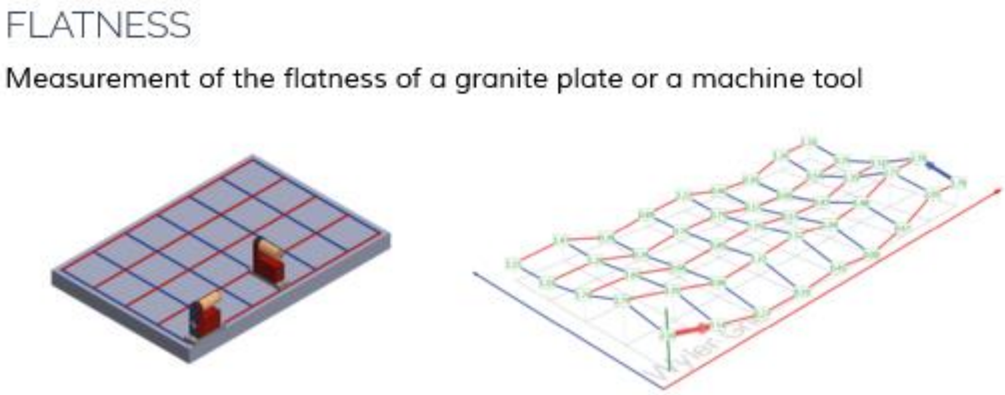


Abbildung 9: so macht man eine Messung der Ebenheit! (Quelle: wylerag.com)

Natürlich gibt es für beide Verfahren die jeweiligen Spezialgeräte und genauso "natürlich" kann man sie auch in geringerer Präzision mit Hausmitteln nachzuahmen versuchen. Die Hausmittelvariante des "Repeat-o-Meters" (original Hersteller: Rahn) ist ein möglichst massiver und stabiler Messuhrhalter (z.B. ein Messbalken) mit in einer gewissen Entfernung eingespannter Messuhr und untergelegtem Metallplättchen, das verhindert, dass der kleine Tastfinger der Messuhr ungewollt in jeden noch so kleinen Kratzer "einrastet" oder der Zeiger zappelt, weil er gerade mal ein Staubkorn gefunden hat. Ein weiteres Problem ist die seitliche Krafteinwirkung auf die Messspitze der Messuhr. Man muss bedenken, dass man hier typischerweise Präzisionsmessuhren mit 1µm oder sogar 0,5µm Auflösung benutzt. Da lässt es sich nicht vermeiden, dass seitliches Ruckeln auf den -im Englischen als "Plunger" bezeichneten- Messfinger leider auch Einfluss auf den Zeiger hat und die Ergebnisse deshalb minimal verfälschen kann.

Solche Probleme hat das originale Repeat-o-meter natürlich nicht, denn es ist so massiv und solide aufgebaut, dass es sich weder durch Staubkörner aus der Ruhe bringen lässt noch können hier prinzipbedingt irgendwelche Querkräfte auf die Messuhr entstehen. Daher ist es auch so beliebt und seit den 1960ern im Design quasi unverändert auf dem Markt im Einsatz. Viele Hobbybastler bauen es sich mit Erfolg nach, denn das Funktionsprinzip ist eigentlich supereinfach. In manchen Beschreibungen im Internet entsteht bei mir allerdings der Eindruck, dass hier manchmal mehr hineininterpretiert wird, als es in Wirklichkeit ist. Ob der Einschnitt zwischen starrem und flexiblem Teil nun eckig ist oder rund, dürfte absolut egal sein. Solange sich das Flex-Teil unter seinem Eigengewicht nach unten biegen kann (und damit der Plattenoberfläche folgen kann), wird es funktionieren. Und auch der seitliche Haltebügel muss meiner Ansicht nach nicht mit übertriebener Präzision gefertigt werden. Er verhindert lediglich, dass der Flex-Teil abbricht, wenn man das Repeat-o-meter nach Beendigung der Messungen wieder von der Platte nimmt und in seine Holzkiste zurücklegt. Gäbe es da diesen Bügel nicht als Dehnungsanschlag, würde das Flex-Teil vermutlich überdehnen und auf Dauer vielleicht sogar Schaden nehmen oder gar abbrechen. Oder umgekehrt könnte eine Verbiegung in die Gegenrichtung auch zum Überlasten der Messuhr führen (ihr Messbereich ist ja nur ganz klein). Um das alles zu gewährleisten, würde eigentlich fast auch ein Stück Klebeband oder ein Tüddeldraht reichen. Oder ein Blechstreifen, den man nach Ende der Messung einfach zwischen Ober- und Unterteil des Repeat-o-meters schraubt und damit beide Elemente gegeneinander festklemmt, so dass sie sich nicht mehr gegeneinander verbiegen können.

Auch hier werden manchmal ganze Doktorarbeiten über so ein simples Ding geschrieben. Nunja- das Repeat-o-meter ist sicherlich eine geniale Erfindung. Aber man muss es auch nicht überbewerten oder mehr "Kunst" hineininterpretieren, als drin ist.

Große Worte von mir, wenig dahinter? Mal sehen. Ich habe soeben ein Stück Flachstahl bestellt: 50mm breit, 25mm dick, 1m lang. Daraus werde ich auch so eine Art "Simple-o-meter" basteln. Aber ohne Feinverstellung und so simpel wie irgend möglich, denn ich habe wenig Zeit und will fertig werden. Dann werden wir sehen, ob auch meine Worte groß waren oder nur mein Mundwerk ;-)

4 German becomes English..

Back to the topic "precision levels". You might wonder why I change to english language now, but at least from now on, we are not "alone" anymore: two norvegian "VIP-Machinists" will cross my way soon and to simplify the readability of my report for them, I switch over to english. I know, every professional editorial office would start crying about my habits, but I don't care. I enjoy the freedom I have with this kind of reports I write, so I just proceed with that I want, and not with that OTHERs want me to :-)

5 Precision levels

I have no clue why I was crawling some internet fleamarkets for the term "Wyler", but already the second day of this search, an item appeared, that immediately arised my curiosity: a bunch of 9pcs Wyler precision levels was offered, but no price given. It was sold "for hobbyists", as the units do not have any kind of guarantee, even might have the need for repair service. First, I hesitaed, because this kind of equipment without a expected price is normally far beyond the capabilities of a private hobbyist. Nevertheless I wrote a message to the seller and asked him about his financial expectations for the levels. The response was astonishing, because indeed it WAS within the range of a hobbyist!

figure 1: this is, how my Wyler A10 levels did arrive to me

In general it is always a risk to buy items on an digital fleamarket. Even if you google the seller's identity and have his mobile number for whattapp communication, finally this is no guarantee that the seller will ship the item after having received your money. I really had this kind of situation once, that finally ended up in a police station. But also that did not bring back my money, because the "seller" moved inbetween from germany to an european neighbour country (to escape the german police) and because of the "low value" of my incident (it was 300€!), the investigation was officially stopped. Despite having the mobile number of this guy and all the evidences (incl. his bank transfer account) on hand- I lost 300€ and the "seller" did not send anything to me.

If you had such a situation once in your life, I have to admit, that I always get this "bad feeling" in my stomach when sending money to an unknown fleamarket seller. But this time there was no reason for being scared- I bought two of those orange cased "Wyler Minilevel A10" units and got them successfully delivered in a blue, original Wyler case! A bit dusty and dirty, and some of the inner black foam has deteriorated, but after a bit cleaning, everything looked nice and the seller told me in advance that he would sell them "as is"- so everything is allright! :-)

figure 2: for sure they will need a bit of cleaning...but hey- not bad at all for fleamarket stuff, right?!

A (very) small drawback is, that only one of the levels is of my favorite´s size (100mm). I had the choice to take 200mm, 150mm and 40mm as second level, so I decided for the smallest one: 40mm! This is really very small, but still better useable for me than the bigger ones. At least for me with my quite small surface plates, a "too small"" level could be better to have than a "too big" one. In the end, the level unit is always the same: the Minilevel A10 can by ordered in any size you want; the factory just adds the base you need. And those bases are also interchangeable, so I can also make my own bases in other sizes anytime.

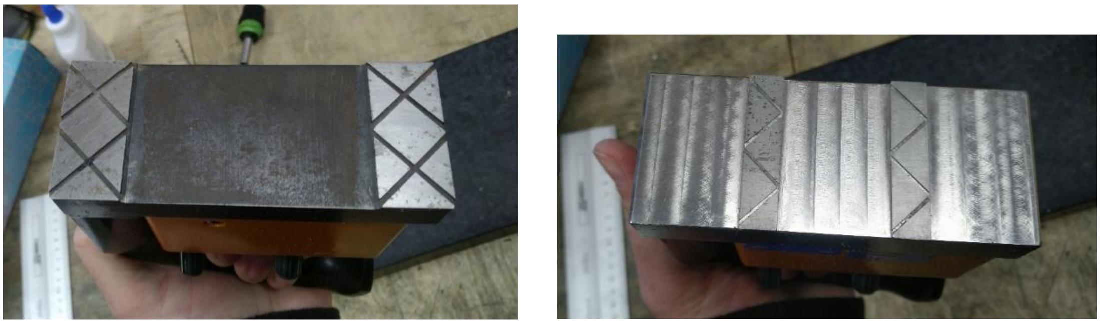


figure 3: I got two different sizes: 100mm and 40mm

The fine thing with those levels is, that they are equipped with the biggest sensitivity the supplier provides: 1µm/m! THAT is really great!!!

The levels have been quite cheaply sold with the attribute "needs service". So that is the next thing for me to do. I disassemble the levels and have a brief look into them. All looks good, the analog sensing PCB as well as the sensor itself. I am cleaning the unit outside and inside. Then then main question: will the unit power up? Will it work? Will it work even within spec?

figure 4: but what really counts, is the sensitivity: 1µm/m!

Wyler Minilevel A10 units request two TR164 batteries to work. A TR164 battery is something you typically do not get in any supermarket. They are rated 5,6Volt and sometimes used for analog photo cameras. The price of minimum ~18€/piece(!) is not really inviting, if you need 4 pieces for a set of levels that you even do not yet know, if they are technically ok. There are some alternatives available like 4LR44 that are much cheaper, but they need mechanical adapters for its use, and also they are not for free.

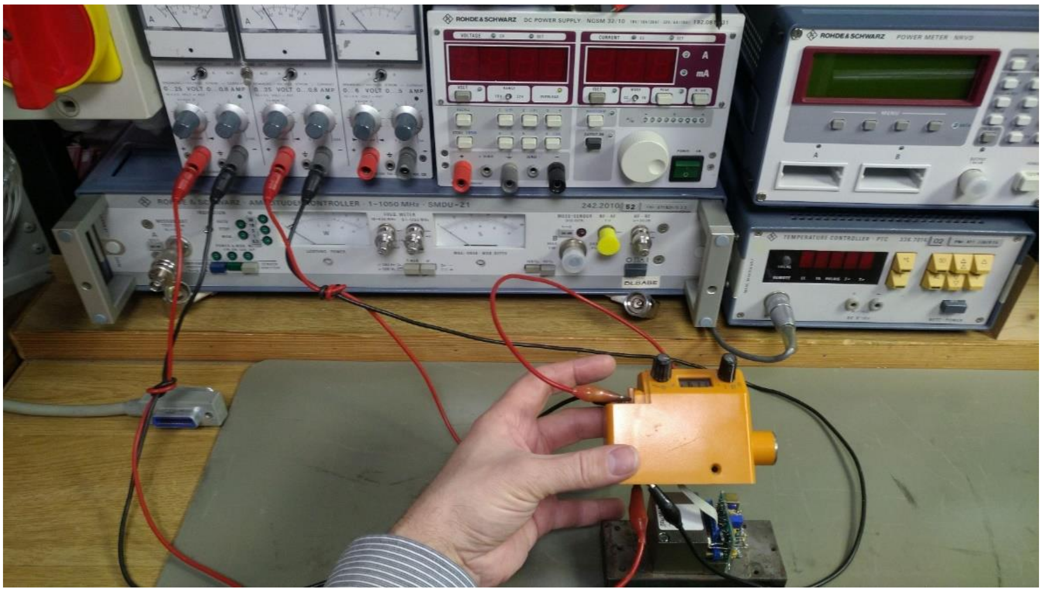


figure 5: fist check with Lab power supply on the test bench

So finally I decided to solder 3 small wires to the contacts of the battery compartment and to use two external lab supplies, adjusted to +5V and -5V DC, and supply the level directly. I connect the leads, then the moment of truth: the level switches on, and the display is showing some values which are changing when lifting the level very gently on both sides. That looks good!

figure 6: the base of the 10cm level is a bit rusty first...

The same procedure for the second level. But this time, I disconnect the base and rework it with the surface grinder, because it has cought a bit rust on its surface that I want to remove because of cosmetic reasons. Easy thing for my small grinder. I take care to grind best possible perpendicularly, although this would have no effect on the precision of the level. I mainly keep the factory-lapped underside as it is, I do only polish with 1000grid wet sandpaper, then do some stoning with the precision flat stones and verify, that the base is not rocking. (It doesn't.)

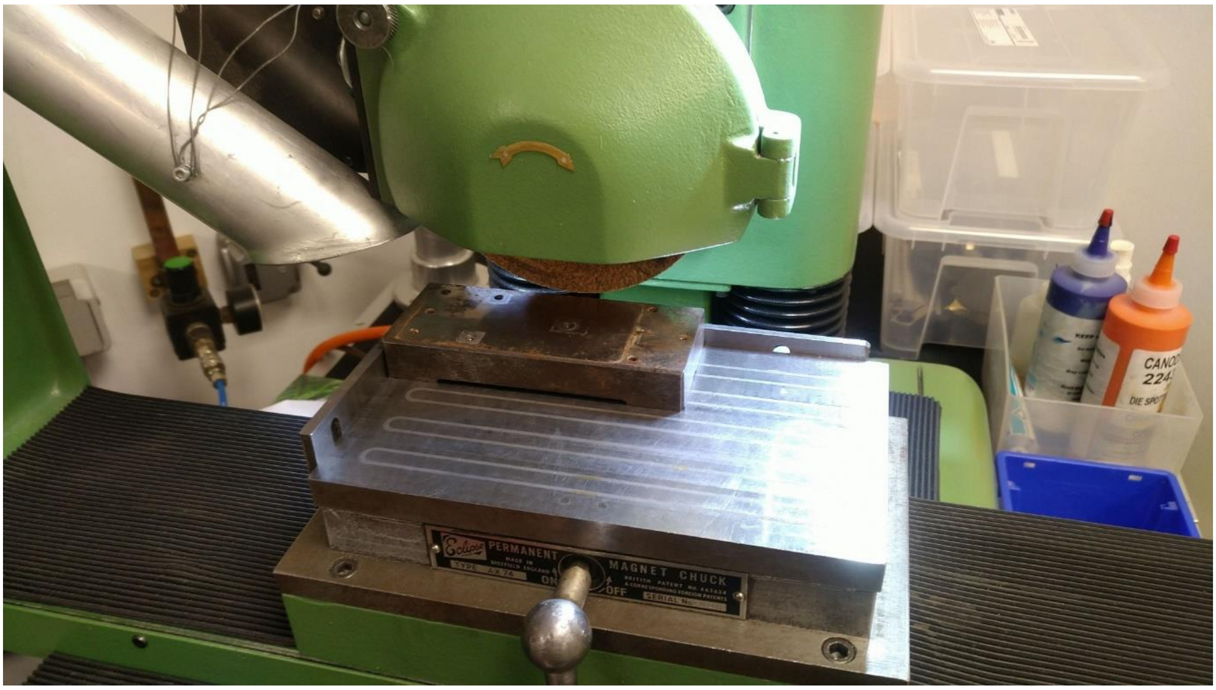


figure 7:...but my small surface grinder "eats" this rust easily for breakfeast ;-)

After the reassembly I do some basic function tests with 10µm feeler gauge under the feet of the level. The resulting displays values are encouraging, although sometimes not always so easy to read, as my electronics hobby workbench is by far not as stable as a precision leveled granite surface plate and introduces a lot of shaking effects into the readings. But still good enough to judge: the levels seem most likely to be absolutely functional! Great!!!!!

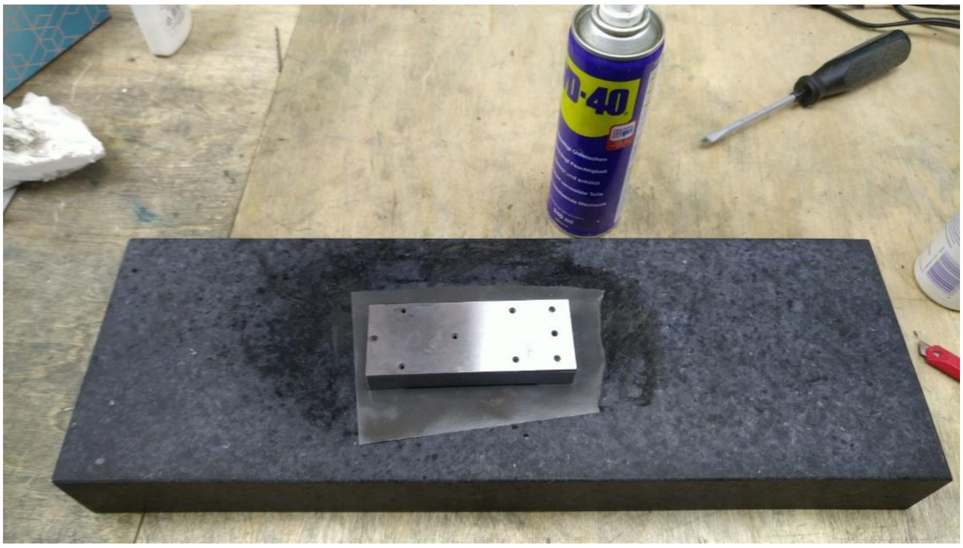


figure 8: "lapping" the downside with 1000grid sandpaper and WD40 on a "cheaper quality" granite plate that I bought for 50€ only (new!)

So what to do next?
I make my first experiences with the levels on my granite surface plate. Still with temporarly soldered cables and lab power supplies standing next to the table. This actually highlights several topics to me that I need to care for! Firstly, I have to replace the temporary cabling somehow by "correct" ones. For its first power-up this may be suitable, but a no-go for a real measurement in the sub µm-Range. Then, I observe that my granite is not as stable as I thought! Or- the granit is, but not my concrete floor on which it is standing!

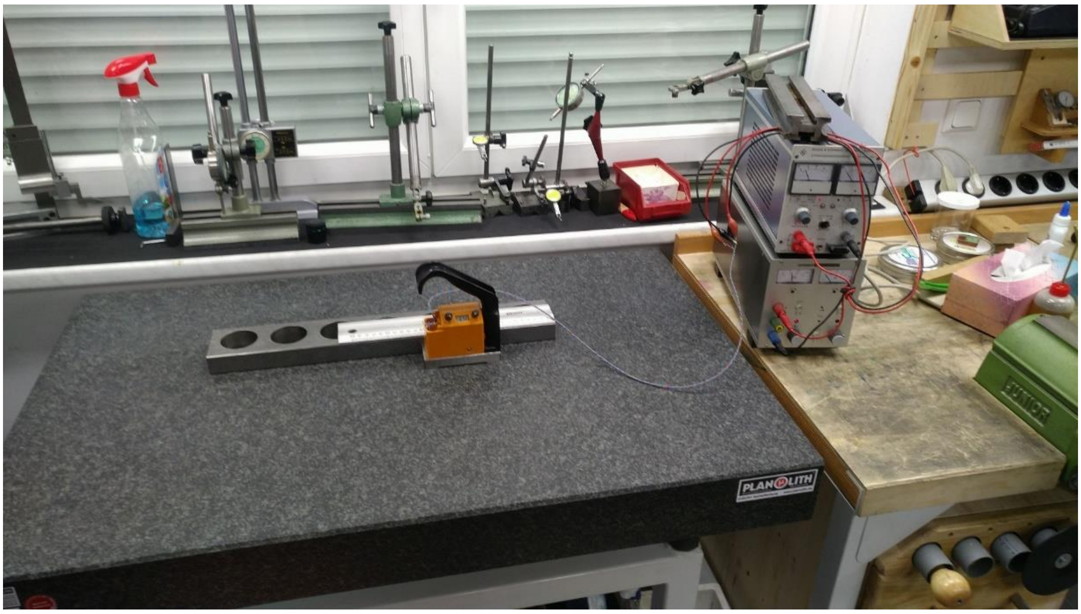


figure 9: first try-out on my "good" granite plate

Being in the basement of a quite modern built house, there is for sure a lot of thermal insulation under the floor to keep the engergy in the house. Although all the floor consisting of hard beton and concrete and having real tiles glued to it, the complete(!) floor of the entire room moves if I am only doing a single step aside! Hard to believe, but 100% reproducible with my new Wyler levels: one step to the left causes ~+20counts on the level; on step to the right about -20counts already! So this represents +/-20µm/m variation just by moving myself in front of the granite. Not visible for a human being, but indeed visible for my new precision levels!

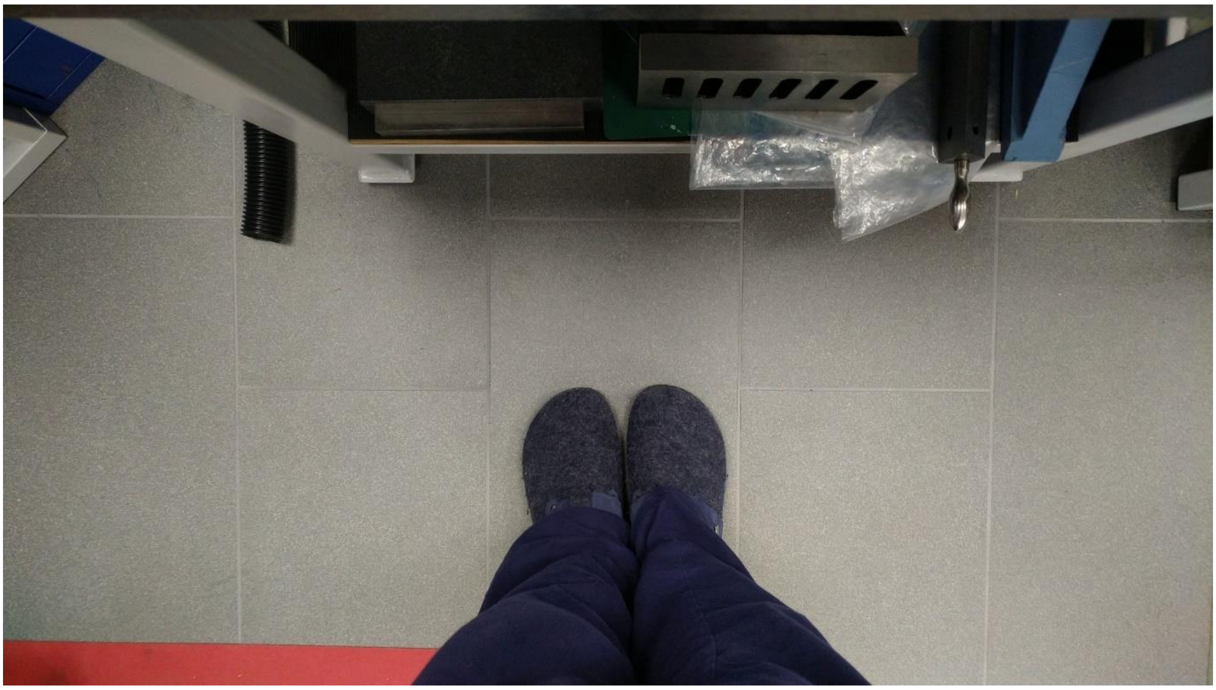


figure 10: it actually has impact on the reading, if I make a step to the left or the right!

As summary, I learn two things:
1. I need to solder a good connecting cable with an external power supply.
2. I need to compentsate for my "shaky" concrete floor somehow. Most likely I need to go for **differential measurement!**

I guess, I can combine the two topics and solve them together.

To make it short: I bought a couple of "Lumberg SV60" connectors. They do exellently match to the sockets in the Minilevels. It's a DIN-like, but 6pin plug with a faxiting ring, that you can screw onto the connector of the level so that it cannot accidently slip out and fall off. I use shielded cable with 3 inner wires (+5V, -5V, analog out, GND on shield) for connection. The more flexible your cable is, the better the handling afterwards. Then I grabbed a homemade 2x 15V powersupply that I happened to have on hand and modified it to the needed 2x 5V DC. The analog outputs of the two levels were lead to two yellow banana jacks so that you can attach a multimeter to it. Ready!

So easy? Actually yes! You do not need any fancy stuff to get that working. Having access to the analog outputs of the levels is the key for the differential measurement. A good quality, battery driven (at least it needs to be floating to ground!) Multimeter does the job very easily. My Fluke 87 hand multimeter delivers 4,5digits of resolution, so resolving the delivered signal to a sensitiviy of very cool 0,1µm/m- transferred to a 10cm base of the level this results in increadible sounding 0,01µm! That is 10nm, folks! Unbelieveable!

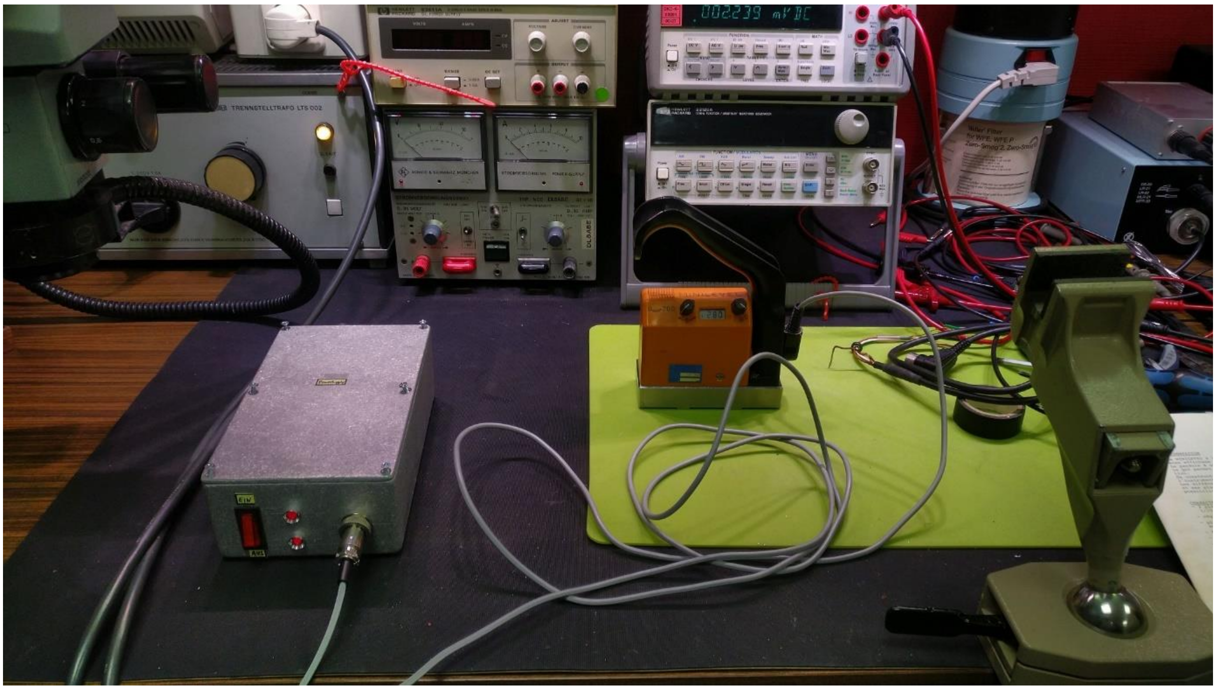


figure 11: first approach with external power supply- still single measurement

For sure in this range I have a lot of (electrical and probably mechanical/thermal) drift, because the level is not designed for this level of 10x more resolution than specified, but it does absolutely not hurt to have an equipment that is perhaps 20 times more sensitive than I actually need. :-)

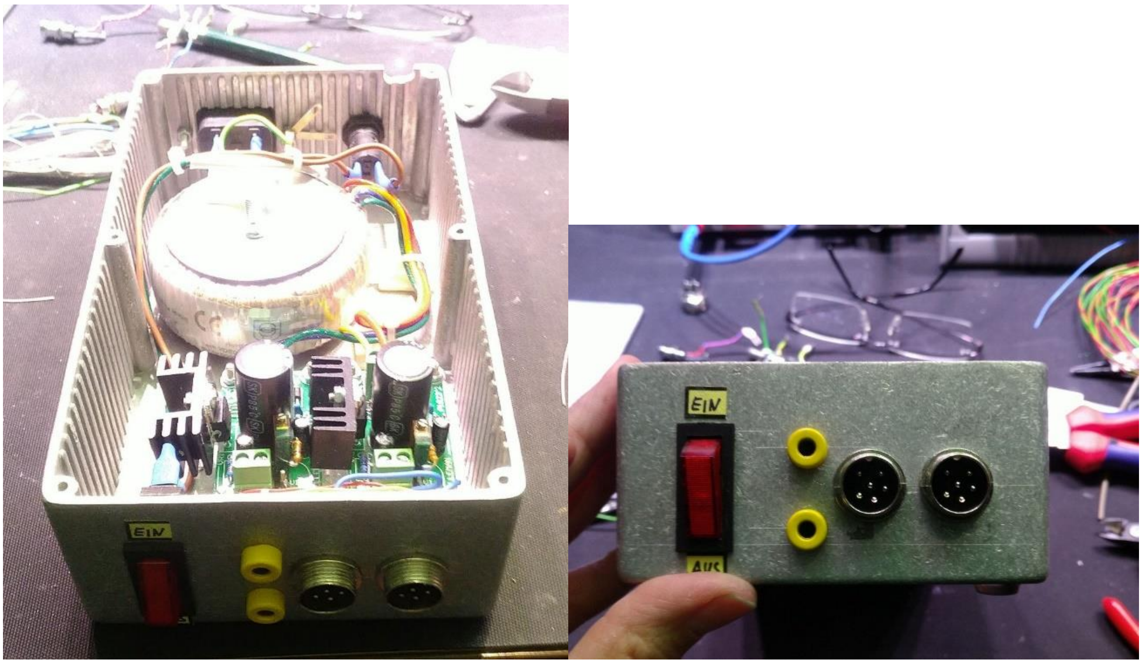


figure 12: my homebrew +5V/-5V power supply

The procedure of the differential measurement with the levels is quite simple.

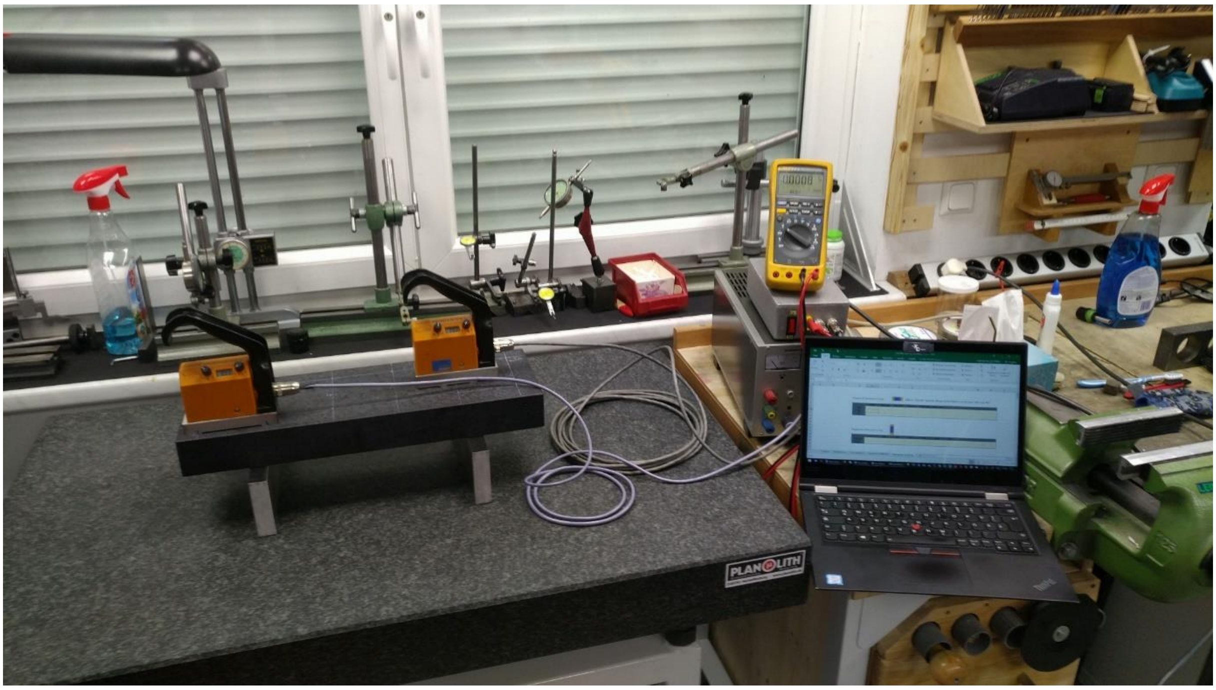


figure 13: with two levels- wich compensate each other for external effects- we can make a differential measurement now!

We have two levels: one as "REFERENCE", standing still in one defined place of the granite surface. The second level is the "MEASURING" level, so it is moved step by step across the surface and records the change of inclination of the surface. Both signals will be subtraced from each other by the multimeter and only the DIFFERENCE of both is shown. So if I walk around the plate and cause a movement of the concrete floor, so that the granite surface plate drops to one side, this has impact on BOTH levels! The good thing: because of the differential measurement, any influence, that impacts BOTH output signals, will be compensated automatically against each other. Only differences of the signals will be measured, not common changes. So the value on the multimeter stays (almost) the same now!

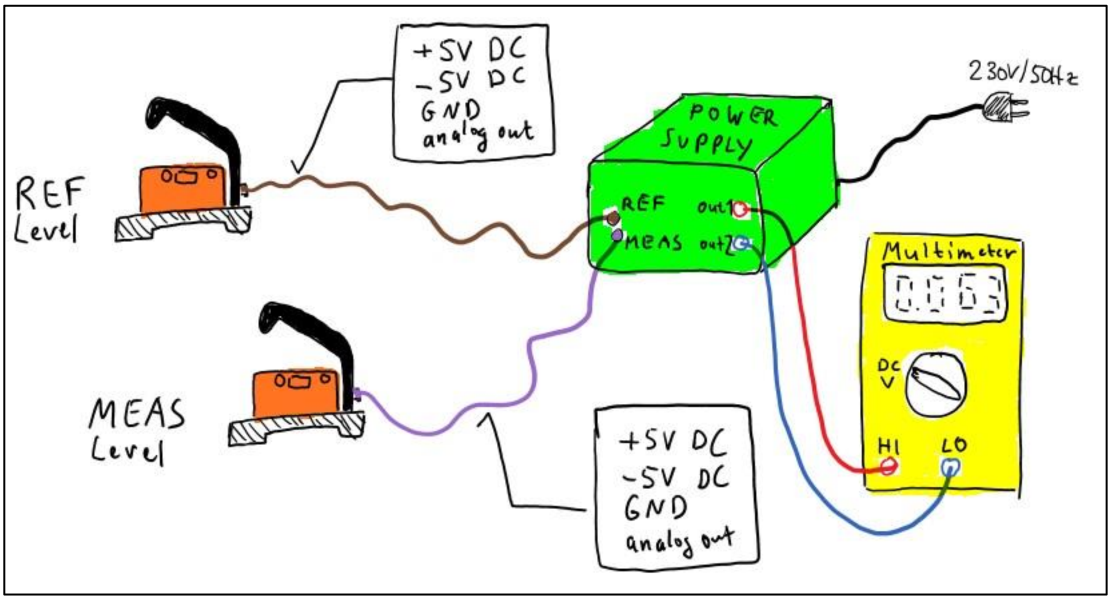


figure 14: differential setup

This works extremely well; especially if you are leveling and off-setting the levels according their manual first und then additionally use the "RELATIVE" button on the multimeter to zero it out automatically to kill even just the last few digits in the nm-range. The result is a precision leveling system in differential mode with a resolution of 0,1µm/m - and all this with the capabilities of a hobbyist! Great! This is, what I like!!!

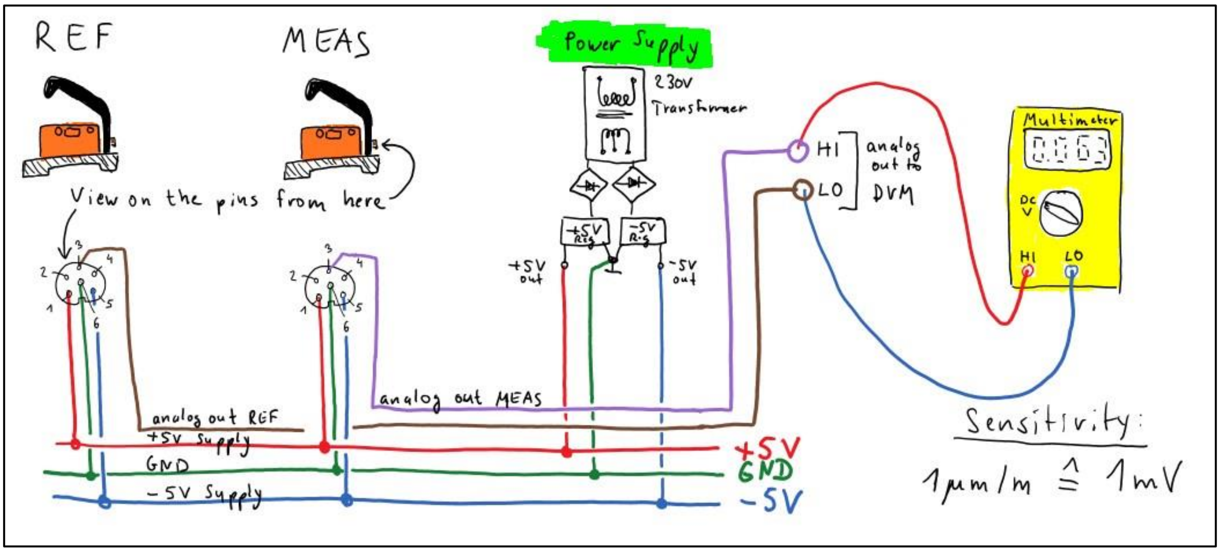


figure 15: this is the connecting diagram

This methods works as better as the tracking between both levels is as equal as possible. In this moment, the smaller level ist still be bit de-adjusted, but we will solve this later!

6 Jan-Sverre Haugjord and Henrik Andren

During my level-soldering, it happens, that Jan-Sverre Haugjord, a very well known Norvegian machinist and a personal friend of Richard King, writes me a mail asking me something about one of my restoration reports. Triggered this way, we also spoke a little bit about other machining stuff and current projects and so J-S became aware of my current "leveling-project". It ended up like it always does: J-S and Henrik became so interested to this topic, that they spontaneously decided to buy-off all of the remaining levels of the seller in one shot! Luckily, there were still 4pcs available -in different sizes, however, but so Jan-Sverre as well as Henrik will get the chance to buy in general the same equipment like I have to make a differential setup as well.

At least because I present the seller an economic situation to sell all of his items comfortably in one "single shot", I also got in closer communication with him. It turned out, that on his business side he "owns" a company that is specialized of exactly what we try to do on hobby level: measurement, qualification and certification of granites surface plates! Winner, winner, chicken dinner! :-)*

* I learnt this wording by EEVblog owner Dave Jones. He is a proud aussie engineer, so perhaps this sentence is only regionally understandable?

Knowing people and receiving parts of their knowledge given by them "good-will" is often the (one and only) key for hobbyists like me to make progress! It is not money or equipment, that you will receive by such contacts. It is actually <u>much more</u>: it is sometimes part of their know-how or feedback to your questions that is normally really really helpful! Remember: the best machines and measurement stuff is useless, if you have no clue how to operate them. So gaining "knowledge" is the best thing you can get!

So with the seller. I learn, that even in their best certified lab they have similar "shaking" effects- even with a special concrete floor, decoupled to the rest of the building. For sure they have this effect on an much smaller level like I have- but the topic itself is the same they have to cope with. Interesting!

7 Flatness measurement

A couple of days later I start learning to make flatness measurement with my levels. Folks, this is harder than you might think! First, you have to find the correct size of the measuring grid that you use for your plate. My MEAS-level has a base with two precision lapped flats on the underside. The minimum distance between is 70mm, the maximum 110mm. The main requirement for this grid is, that you still have an overlap of the measurement spots; so in my case it could be any size between ~80 and 100mm (1cm overlap). I choose 90mm as standard for my granite plate.

Next, the level is 45mm wide. So the first line of the measuring grid needs to be not closer than 22,5mm to the outer border of the granite plate- to assure that the level's base is still 100% located on the plate and does not overhang at the ends. I choose 30mm as general outside limits.

figure 16: measuring grid example

But shortly after having tried to start my measurement, I already can stop it, because I realize, that I am not yet ready for this step! The differential compensation does not yet work as good as expected, so I need to find the reasons for first.

All in all, it looks like that I will need to verify the accuracy of the level first before I really can use them. The check of the levels will even end up in a new adjustment of the smaller level, so be curious for the next chapters :-)

8 Level adjustment

You cannot believe, that it is possible to adjust a level that has a resolution of 1µm/m with hobbyist tooling only? No?

Ha! Yes indeed, you can!

At least the way for checking is easier than you might think.

First, I check that my granit plate is in level. The requirement here is to be better than 50µm/m, as I saw once in a presentation of Wyler. For me, I get it at least to ~10µm/m. Good.

Abbildung 10: verify, that my plate is in level (Level: Röckle, 20µm/n)

Then, I take my straight edge. I verify that it is quite exactly 500mm long (measurement with linear scale is sufficent).

I place both levels on this straight edge and give them a bit time for settling down (at least min. 5 minutes). Time by time I adjust the offset-knob for a reading as close as possible to "000".

Ok. Without changing my standing position on the floor(!), I take a feeler gauge with 100µm thickness and place it under the right side of the straight edge- just a tiny bit under the corner (not to reduce the 500mm measuring distance).

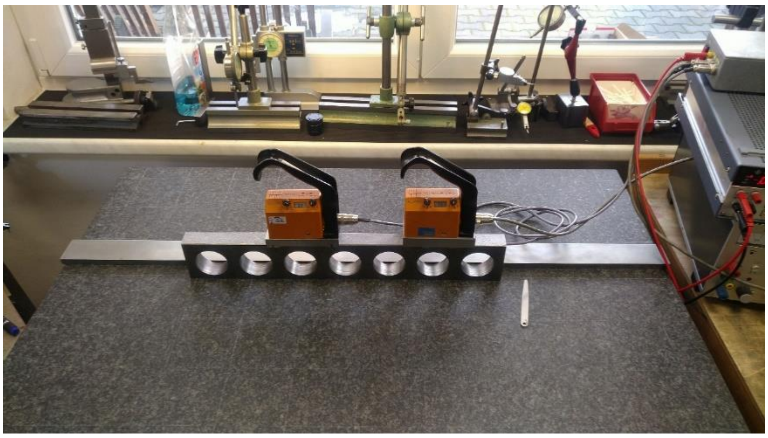


Abbildung 11: test setup for level calibration

With a resolution of 1digit=1µm/m we should read now exactly 200 digits on the levels.

As the complete test setup is such sensitive, I placed a 1m long precision flat bar behind to avoid any rotation error that can easily be introduced by an accidently slightly slanted level. Don't underestimate this effect! It can easily mess up your complete calibration!

Abbildung 12: left: Zeroing the level; right: put a feeler gauge under the straight edge

The 100mm level gives me a reading of about "203" which represents a value of 101,5µm and does match very good to my 100µm feeler gauge (I checked its actual thickness with a micrometer first).

Unfortunately, the 40mm level is giving me a reading of "211" which would stand for 105,5µm. Ok, not a drama, but we can get it better.

Abbildung 13: for hobby usage probably ok, but we can get this even better!

After a couple of checks I trust the 100mm level very much and despite of the Wyler sticker dated 1997(!) I believe, that the 40mm is a bit de-adjusted. Maybe because of hard handling, or accidently mechanical shocks, or just aging effects- I cannot say why. But I believe, if Wyler is doing a calibration and finally even put their sticker to the level, they have done a 100% perfect job!

Let's have a look into the schematics of the level and check out, how we can re-align it.

9 Re-alignment of the analog board

To understand what to do, we need to understand the system concept first. I made a small sketch to better understand the electronics:

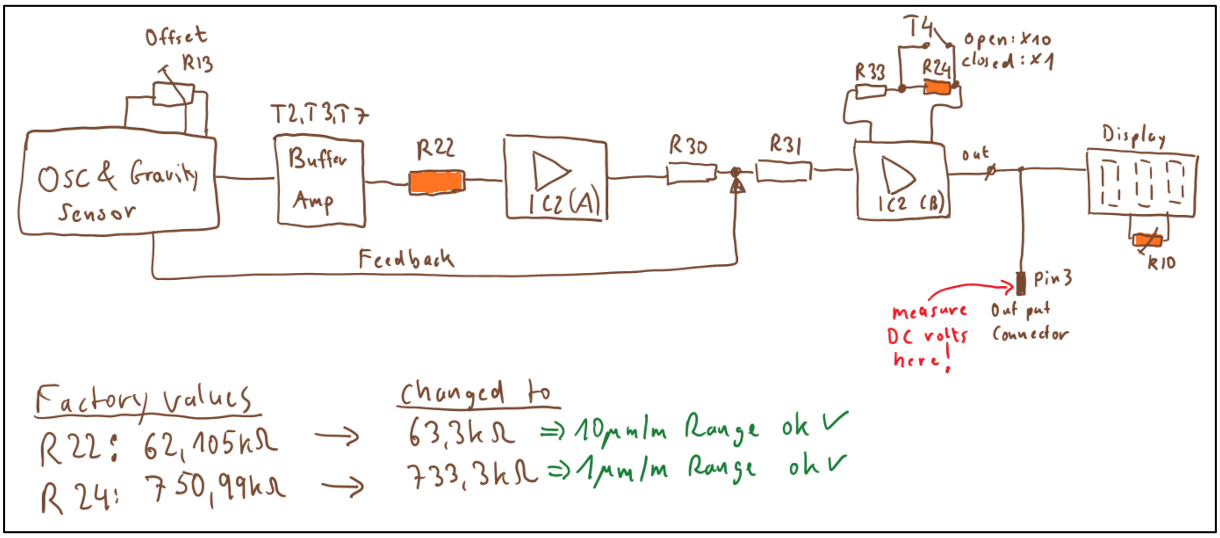


Figure 17: System diagram of the Minilevel A10 (trimmed components in orange)

An oscillator with a feedback loop is feeding the gravity sensing element which delivers an angle-dependent analog output signal to a buffer amp (T2,T3,T7). This buffered signal then goes into IC2 (A)- an operation amplifier who is making an amplification of ~10. Then, after having passed R30 and R31, the signal will enter the IC2 (B) amp. This amplifier has a special feature: with a switching transistor T4 you can change its gain. This is needed to provide the two different sensitivity ranges of the instrument (10µm/m in Range I or 1µm/m in Range II). I did the math and calculated a gain of approx 2,43 in range I and ~24,49 in range II.

After having left IC2 (B), the signal is given to Pin3 of the Lumberg 6pol connector (where you excellently can measure it with a digital multimeter!) and also to the level's display.

Without coming too much into detail, the alignment has to be done in three steps:

1. Adjust R22 for correct output voltage on Pin 3 (range I)
2. Adjust R24 for correct output voltage on Pin 3 (range II)
3. Adjust R10 on the Display unit for a correct reading on the LCD display

During the alignment, I observe, that all those three elements have been a tiny bit de-adjusted.

R22 and R24 are realized as a combination of fixed value resistors (so no trimpots!). I de-soldered them, put in a variable trimpot instead, turned it to the correct position, then de-soldered it again and measured its value. Then I tried to achieve exactly the same resistance value as combination of two standard resistors. This was not easy; and took a bit of time to identify the correct value combination to at least reach the desired value.

But let me explain better with a few pictures.

10 Step1: align R22

I pull out a good quality Voltmeter that I know its calibration and precision is verified (in my case a Rohde&Schwarz UDS5). It attach it between Pin6 (=ground) and Pin3 (=analog out) of the output connector- measuring the analog out voltage.

After having provided a certain settling down time and briefly zero-ing the levels afterwards, I measure its analog output voltage. In range I, 1mV represents 10µ/m. I use the same 500m straight edge and feeler gauge as before, to produce the defined inclination of 2mm/m.

The analog output should read exactly 200mV then.

The 100mm level is really quite spot-on, but my 40mm level does not. It shows "211" in the display and it requires re-adjustment by modifying resistor R22.

figure 18: neither the reading nor the analog voltage is hitting the expected "200"

To find the correct value for R22, I replaced it temporarily with a trimpot, varying it until I finally get the desired "200mV" at the analog output. Take note: it does not matter what the display of the level itself does show now! It is all about the analog voltage to be seen at pin3 of the output connector!

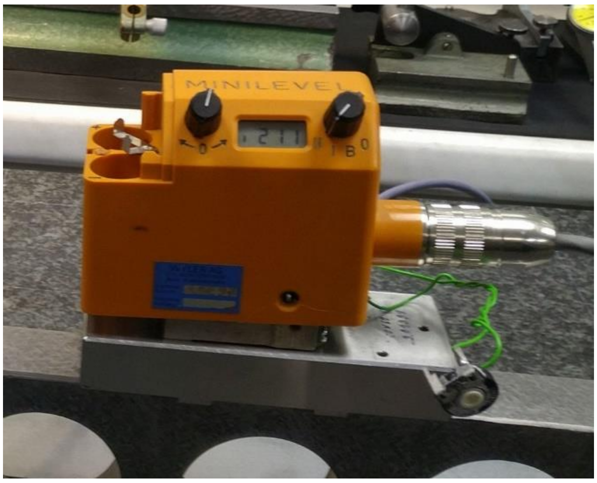


figure 19: temporarily attached trimpot for adjustments

The analog board with the trimming resistors looks like this:

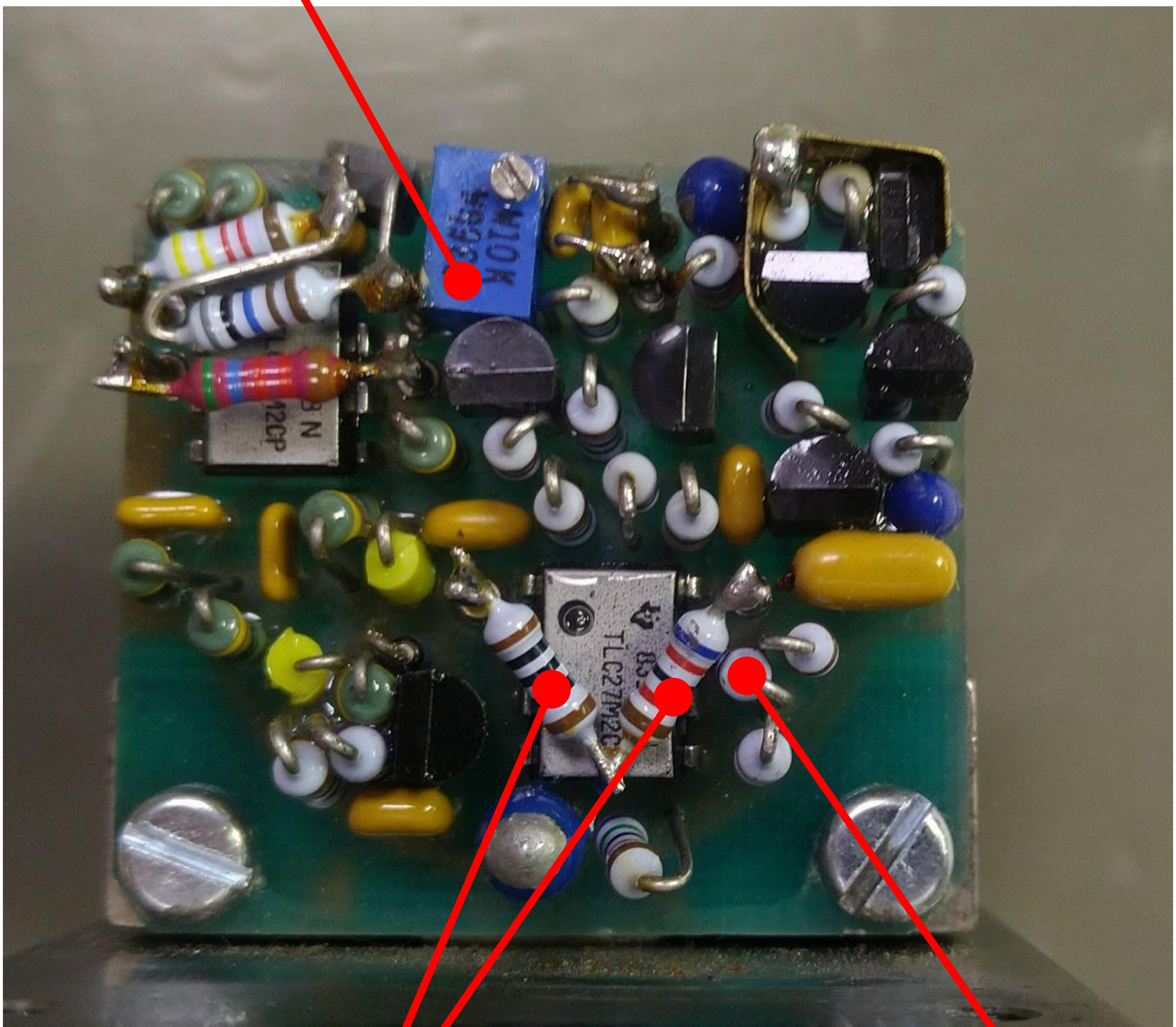


figure 20: analog board of the Minilevel A10- in the original condition when I got it

I replace R22 with a new series value of 63,3kOhms. With that, the analog output in the range I is fine!

11 Step2: align R24

The same procedure for the more sensitive range: range II!

As it is 10x so sensitive, I only need 1/10 of the feeler gauge to achive the same reading of 200mV. I proceed exactly like with R22: I desolder the original value, introduce a temporarily trimpot, make the adjustment, measure the trimpot value and try to establish the same resistance with a combination of discrete parts.

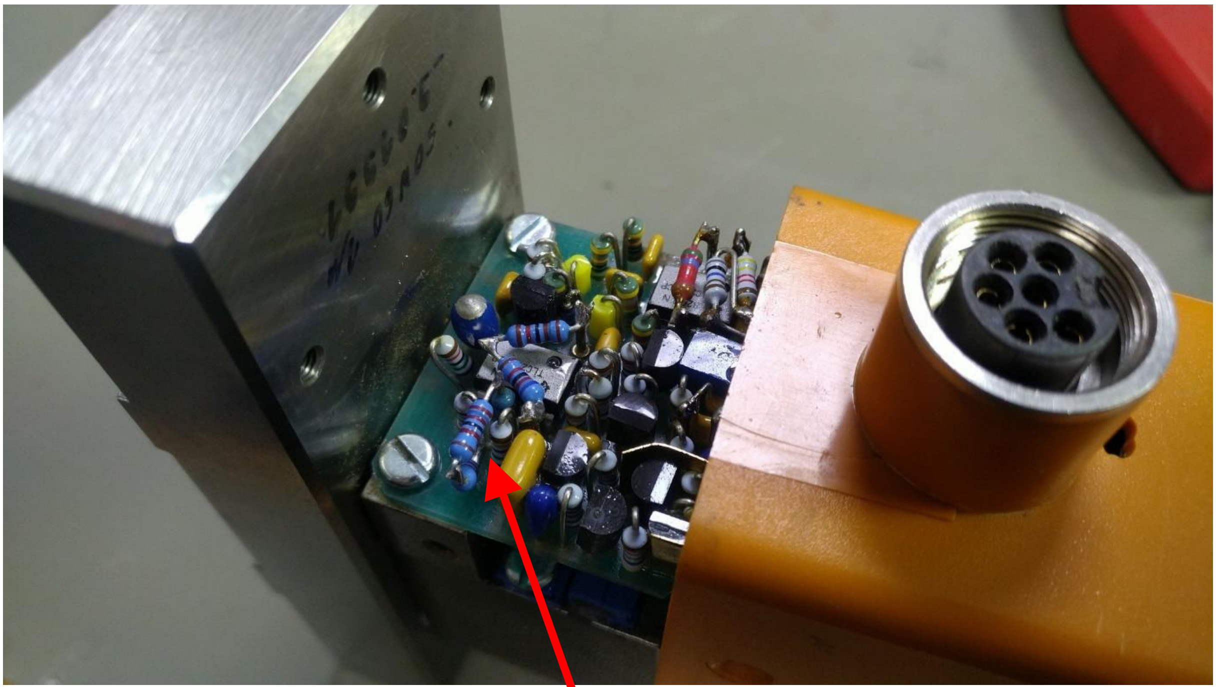


figure 21: new resistors as R22 and R24

The only difference is, that R24 is obviously not expected to be trimmed or serviced, so its location is a bit hard to reach. I disassembled the PCB for desoldering the old R24 and needed to make a combination of 3(!) resistors in series to get the needed value.

But the result convinced me, that all the spent effort was right! The output of this level is now very very close to the output of the second one. :-)

12 Trim R10 for correct display reading

Now, as both ranges I and II do deliver the correct analog output voltages, we also need the display's own display to show the correct values. As it is at least "only" a 2,5 digit DVM circuit, there are not secrets with it.

In contrary to the analog circuit, the DVM module has a trimpot installed for adjustment. In the schematics it is named R10. In real life, I turned the only component on the display PCB that looked "somehow" like a trimport (not being able to identify by part's name). As there was only one single trimpot in reach, I was right. I turned it a couple of turns and - voilà- it shows now the same value like my R&S UDS5 multimeter connected to Pin3.

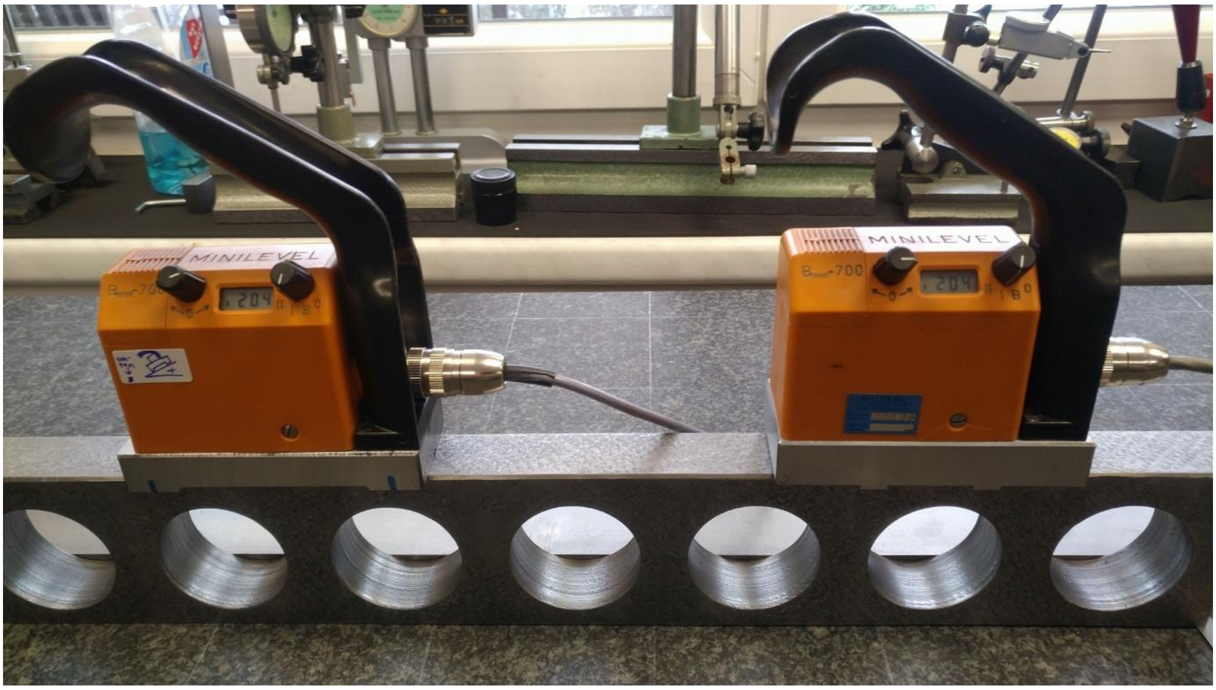


figure 22: final result: "204" on both levels

The result of this adjustment activity is great: as you can see in figure 22, the levels now do most often agree up to their last digit!

figure 23: ...and the UDS5 agrees as well! (also "204" on the external Voltmeter)

And if you check the analog output, it will also match with the displayed value in the LCD of the level. That is, how I like it! All agrees and matches together. And if we want to measure surface plates with it, we need this correct alignment to have!

13 Drift?

The manual of the Wyler minilevel tells you, that the drift of the levels should be not greater than 24 digits within 24hrs.

So I made a check and kept the levels about 3 days nonstop in the workshop- mainly untouched. I observed its behaviour twice a day (morning and night) and never detected bigger drifts than max. 10 counts during that time. After having stabilized 2 days, I made the final 24hrs-check.

Result: it could not be better! Both levels drifted only 1 digit over 24hrs (range II!).

figure 24: excellent drift result after 24 hrs

Nevertheless I need so say, that this was also a "lucky" measurement. In repetition of this test I observed bigger drifts (but all in spec!)- espsecially for the smaller (=adjusted) level. Whereas the 100mm level drifted for -say- 2 or 3 digits; the 40mm one drifted maybe 5 oder 6 digits.

I cannot say the reasons for that. I do not necessarily think, that my trimming and adjustment is the reason for the slightly lower drift performance. I expect more likely the missing temperature sensor in the 40mm level to be the reason:

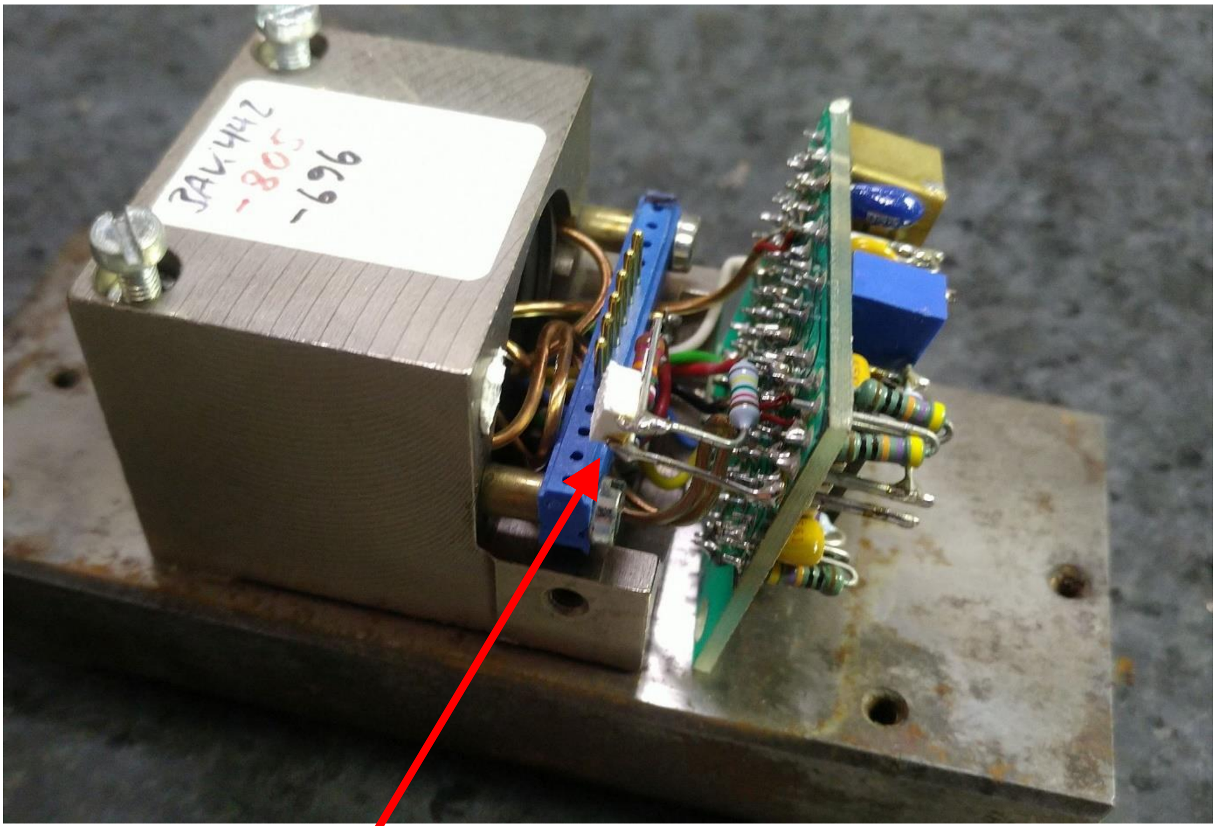


figure 25: this one has a temp sensor!

What? A difference between the levels??

Yes!

Whereas the 100mm type actually has a temperature sensor built in, the electronis of the 40mm type <u>does</u> not have one! I assume, that this sensor was given to improve the temperature stability and compensates some temperature effects.

As the 40mm level does not have this sensor, it can be explained, that she has a bit less performance regarding this point.

Don't ask me, why there is this small difference between the two levels. Maybe a modification?

I wondered to also fit the second level with this modification, but finally I decided against that. The reason: now, was she is perfectly aligned, I do not have any problems with her. So there is no need to change anything. And even if I would like to, I do not know neither the part's name not its value and characteristics, so I abstain from this idea and keep it, as she is!

14 Clone-O-Meter

For all those guys who know me, it is probably not a surprise: FOR SURE I went to build my own Repeat-O-Meter!!! :-)

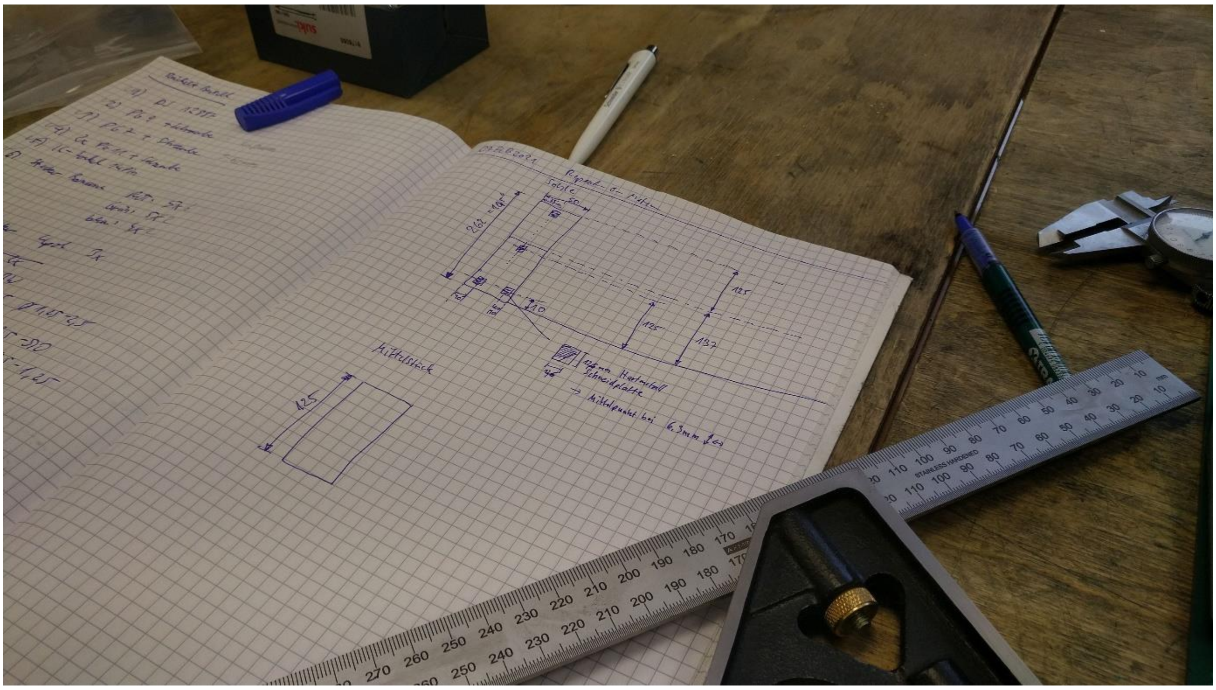


figure 26: raw drawings for my own Clone-O-Meter

All started with the purchase of one meter iron bar (50mm wide, 25mm thick). I cut it in three pieces: two pieces of 262mm length; and another with 125mm length.

But before I start this "quickie project", I have a brief look into the internet. Plenty of pictures are available that present the original Rahn design as well as individual variants. Even an old military norm about flatness measurement of granite tables provides information about a Repeat-O-Meter. I collect all the details, have a brief look at it and finally decide, to at least copy the original! As the best thing I have is a picture of the Rahn Repeat-O-Meter with a imperial scale next to it, I need sometimes es estimate some dimensions. But as far as I understood the design, most of the dimensioning is completely uncritical. Nevertheless I try to keep most of the dimensions close to the original.

But I make a few modifications; at least due to my machining capabilites and the fact, that I still do not own a functioning mill. So my own Repeat-O-Meter needs to be producible with a drillpress, bandsaw and a set of files!

15 My modifications

The changes compared to the original are as follows:

1. As feet, I do not use round shapes, but flat rectangular carbide inserts for lathe tooling. I found a couple of them (used) in my lathe's toolbox and they are quite perfect for my use. They are about 12,6 x 12,6mm (so probably 1/2 inch) and at least only a tiny bit smaller as the original round ones (I suspect they are 3/8" or ~10mm in diameter?).

2. I omit the slotted fine adjust mechanism in the measuring arm. My Mahr Millimess 1µm test indicator has its own internal fine adjust of about 100µm range, so with a good hand and a bit patience, you are easily able to tap the indicator into the correct position before closing its fastener.

3. Apropos- the Mahr Millimess! When I see some original Repeat-O-Meters, some of them come with a 0,00002" resolution indicator. That is the finest resoluation that I know for analog indicators (0,5µm/div). They have a range of +/-25µm only and a new one (Mahr Supramess) costs about close to 500€, a used one on eBay close to 200€. I am not sure, if I should spend this money, because I already have a Mahr Millimess. Its resolution is 1µm "only", but I will give it an honest try first before I spend money for a Supramess. (And we will see: for my application my 1µm-clock will work just fine for me!)

4. The flex cut. Here, I chose another design- on purpose! The original cut is done with a bandsaw to meet the correct degree of stiffness/flexibility of the sensoring arm. As I have no clue, how many material under the end of this cut is required, I change the design: I make a combination of a bandsaw cut and a drilled hole at its end. It start with a small hole only that I definately expect to be too stiff my the application (=not enough flex, so that the sensor arm does not follow the surface of the granite by its own gravity).

Then I will check it, try it out and if more flex is needed, I just drill this hole a tiny bit bigger- reducing the web between hole and the underside. With weakening this web, the stiffness will be reduced, allowing the sensoring arm to better "wabble" around and thus follow the measured surface. In the end, it will tuen out to be fine with a 6,5mm hole, leaving 0,85mm if material at its thinnest point.

The method with the combined hole/sawcut was introduced by NYC CNC obviously. I like this idea, because the smoothness and round shape of the drilled hole should ideally follow the internal stress lines in the material, avoiding steps and inconsistencies in the forces flow. The bandsaw cut -instead- will definately cause crisp edges at the end of the cut, which are prone to break or crack under bending load. The "hole design" will definately be surperior to the "bandsaw cut design", so I gonna use it. And as I said: it simplifies the adjustmest of the desired stiffness. You cannot accidently saw away material that you do not want. You only have to care to grab the correct drill out of your toolbox if you want to open up the hole by a defined size.

The rest of the design is fine for me, so I will keep it.

16 Let's do the constrution!

I start to cut the bar into the three pieces.

I start with the base. I remove the black surface with an angle grinder. Then I use my files set to flatten its surfaces and break the edges. Normally a job for a mill and a flycutter. But with patience, sweat and files you come to a quite good result as well.

figure 27: raw blocks put together for tests

Then I drill and tap my holes. My drillpress is a Flott M3 which is definately not a Guillardon or a Alzmetall, bit is already close in terms of quality and performance. With the aid of a 4kW three phase inverter, I also can cut all the M8 threads with my half-automatic threading tool. The Flott M3 still has enough power to push the threading tool easily into the 25mm thick material- even with usage of an inverter to reduce her speed!

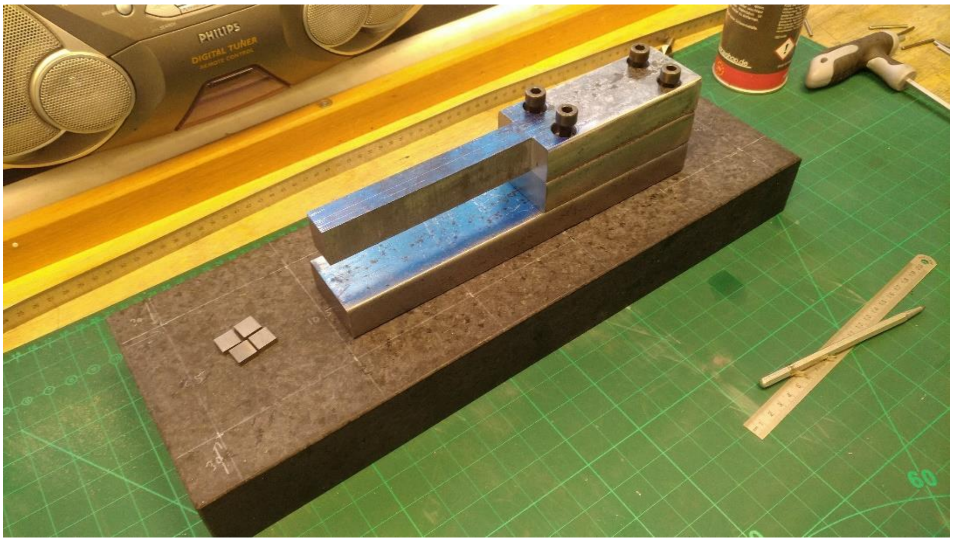


figure 28: raw look from the top; on the left the 4 carbide inserts which become the feet

Once the bar is quite flat and drilled, I glue the 4 carbide pads on the underside. In the original, the distance of the feet -meaured from middle to middle- is always 125mm (=5 inches). There is no reason the deviate from that, so I loctite them to the base (Loctite 648).

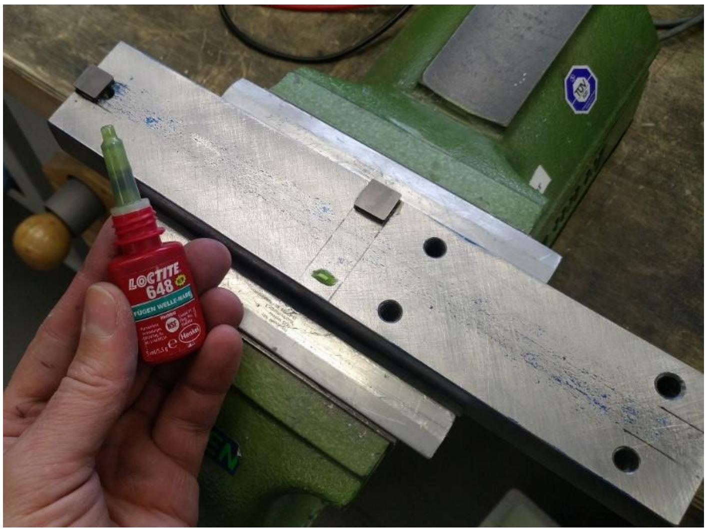


figure 29: glue the carbide inserts to the base

The next thing is, to bring all the 4 inserts (at least minimum the 3 on the not flexing part of the Repeat-O-Meter) to the same plane. As my surface grinder is too small for the 262mm long metal foot bar, I can only cover 3 feet the same time. I try first to grind with a normal grinding stone- and surrender. Ax expected, the carbide is too hard to be ground with normal norton stones. So I change for a diamond wheel that I also have (a cheap chinese one). As I only have one grinding flange, change of the stone for this machine is not a quick job. And I also do not have a balancing adapter, so I need to put the diamond wheel on the flange and be content with the result "as is".

With the diamond wheel, grinding of the inserts is still hard, but possible. Small chatter marks (probably as result of the non weighting-balanced flange) become visible, but I cannot get it better with my possibilities.

I finally handstone the inserts, but in the end the instrument will nevertheless be prone to rock a tiny bit to the left side. Perhaps only 2 or 3 micrometers under one of the feet- but even this causes a deflection of up to 20µm in the DTI afterwards!

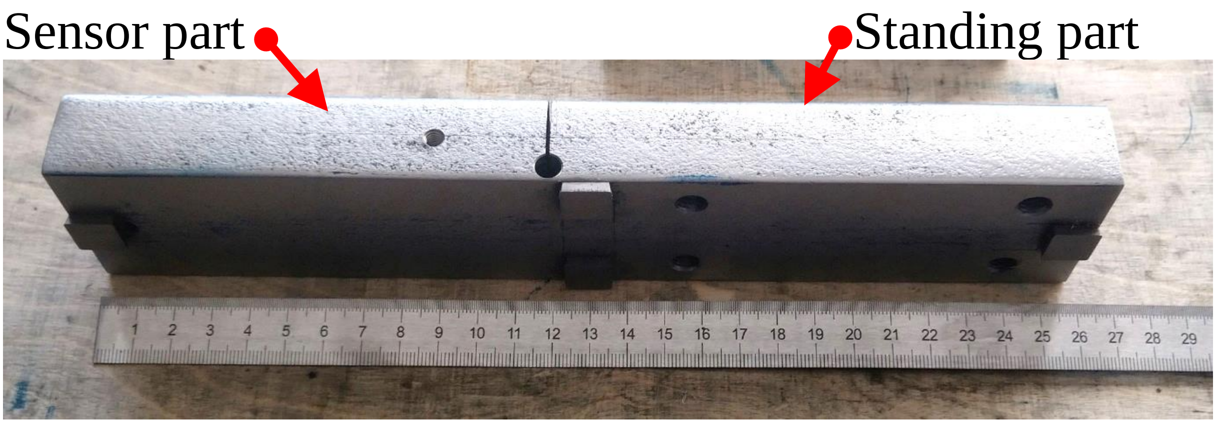


figure 30: the base plate with the flex cut in the middle

The only possibility to get rid of that would possibly be to put the complete instrument on a lapping plate and lap the feet to exactly the same level. Unfortunately I do not own a lapping plate, so I will have to live with this effect.

In the practical usage, this turns out not to be a real big problem. If you do not provoke a rocking, but take care to always move the instrument front and back (as you should) and not push it sideways, it will always produce accurate readings!

The next part, the middle part, is only a 25mm thick, 50mm wide and 125mm long piece of metal with 4 holes of 8,5mm diameter. Filing and deburring again, nothing fancy.

figure 31: the middle part

The top bar is a bit more effort. It needs two long cut-offs, that I perform with my Mössner-Record SM320 bandsaw. It takes a while, even with this solid machine, but the cut itself will be fantastically smooth and even. Not much work to do with the file afterwards. Just a bit finishing, that's all.

At the end of the bar, the material needs another bandsaw cut for the clamping mechanism for the clock. I use a M5 screw for that. I drill the hole for the DTI 10mm in diameter, and I use a selfmade reduction sleeve out of brass as adaptor for the 8mm shaft of the DTI. Brass is softer than steel and I want to take care to protect the shaft of the expensive Mahr test indicator and not making scratches in it when fastening the clamping mechanism.

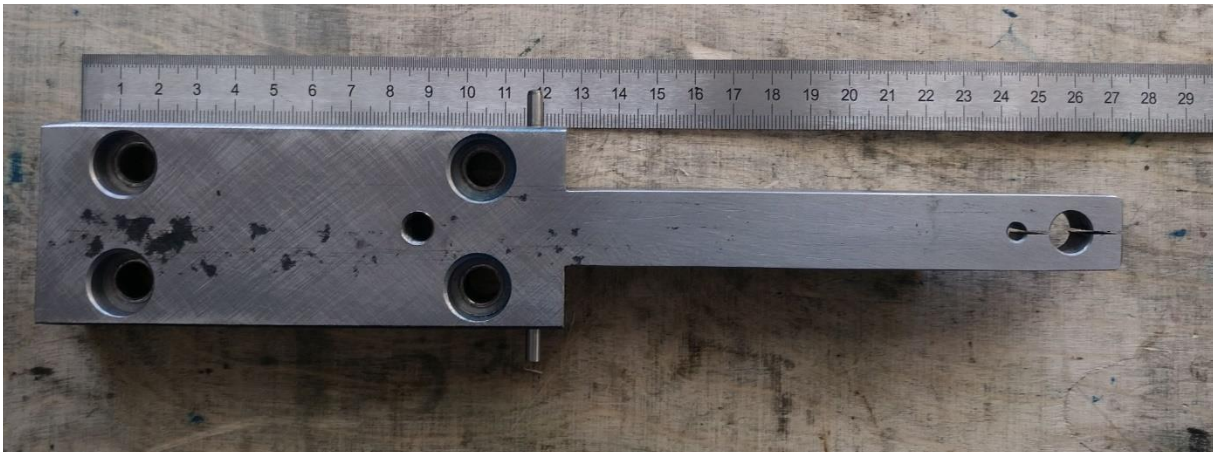


figure 32: the top part

At the underside I also cut our a piece of metal so that the plunger of the DTI is free as well. A bit of filing afterwards, breaking the edges, round the corners. Looks not bad for a quickie project!

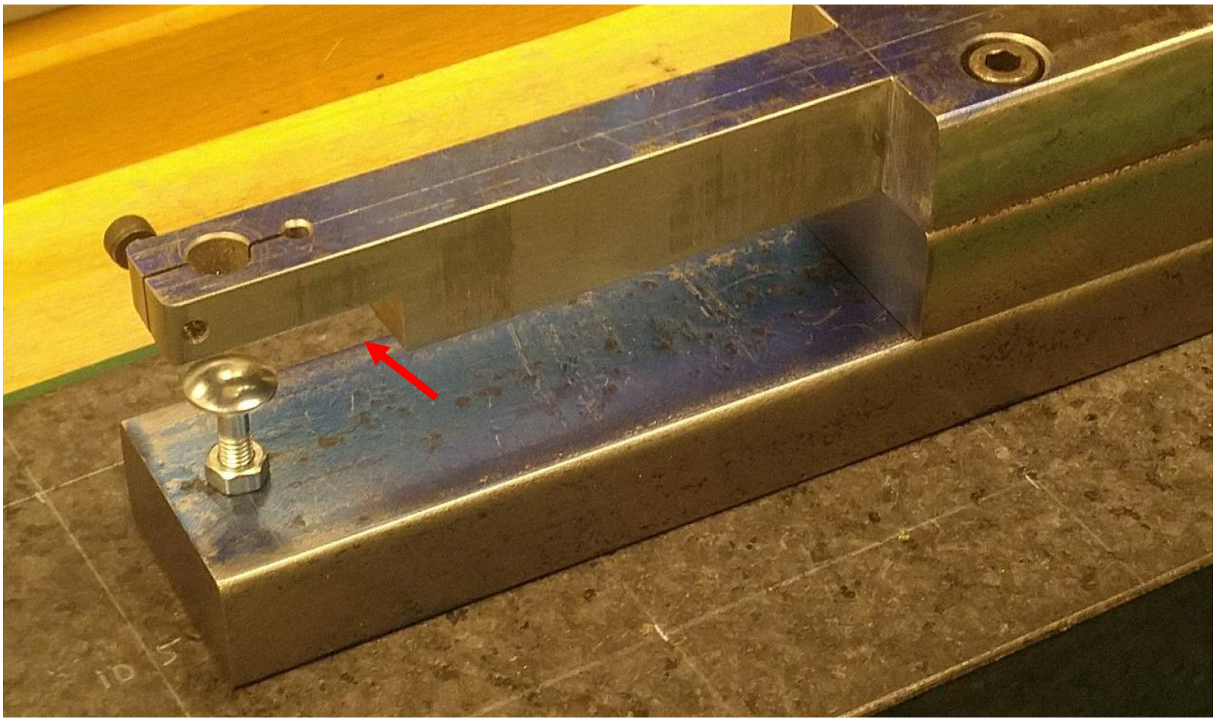


figure 33: a cut from below provides clearance for the DTI

As handles I use a couple of M8 screws, 14mm square metal stock and some turned steel sleeves (inner: 8mm, outer: 13mm). I make a smaller one for the back side and a bigger one for transporting the instruments afterwards.

Apropos: especially for this use case (=transport) we need a mechanism that prevents the flexing arm from over-bending! Because if you lift the complete instrument, the sensor arm would follow along the the gravity- but not being stopped by any surface under it anymore. To stop the motion before the flexing joint get over-bent and thus damaged, two limiting bars have been mounted in an 45°-angle left and right to the sides. I use a 4mm pin on the top and another M5 screw at the bottom. In contradiction to many of the other machinists, I do not produce any fancy parts for that. I just drill the lower hole a bit bigger than the M5 screw, so that it can vary in the hole a bit- but finally limiting the motion of the sensor arm. That's all. And another good thing: if fasten these screws tightly, you can lock the complete mechanism. This can be useful for transport and to prevent the costly DTI from shocks. You only need to loosen the screws a bit once you want to make your measurements, so that the sensor arm gets unlocked again.

17 Final assembly

After the final check was successful, I disassemble all parts again and give them a quick black paint. Not so easy with a spray bottle, as we have currently about -6°C outside. It needs several attempts and the quality of my lacquering is quite poor at the end. But nevertheless still ok, no reason to wait for the summer for a re-paint ;-)

figure 34: lacquering in winter sun - a gamble ;-)

I assemble the instrument and make my first measurements. It is really a big difference, if you svivel around your granite with a normal indicator stand or use this Repeat-O-Meter instead. The complete absence of horizontal shearing forces to the plunger and the 12,6x12,6mm square sensor pad improves the stability of the readings a lot! Differences of 1µm and easily readable- and reproducible!

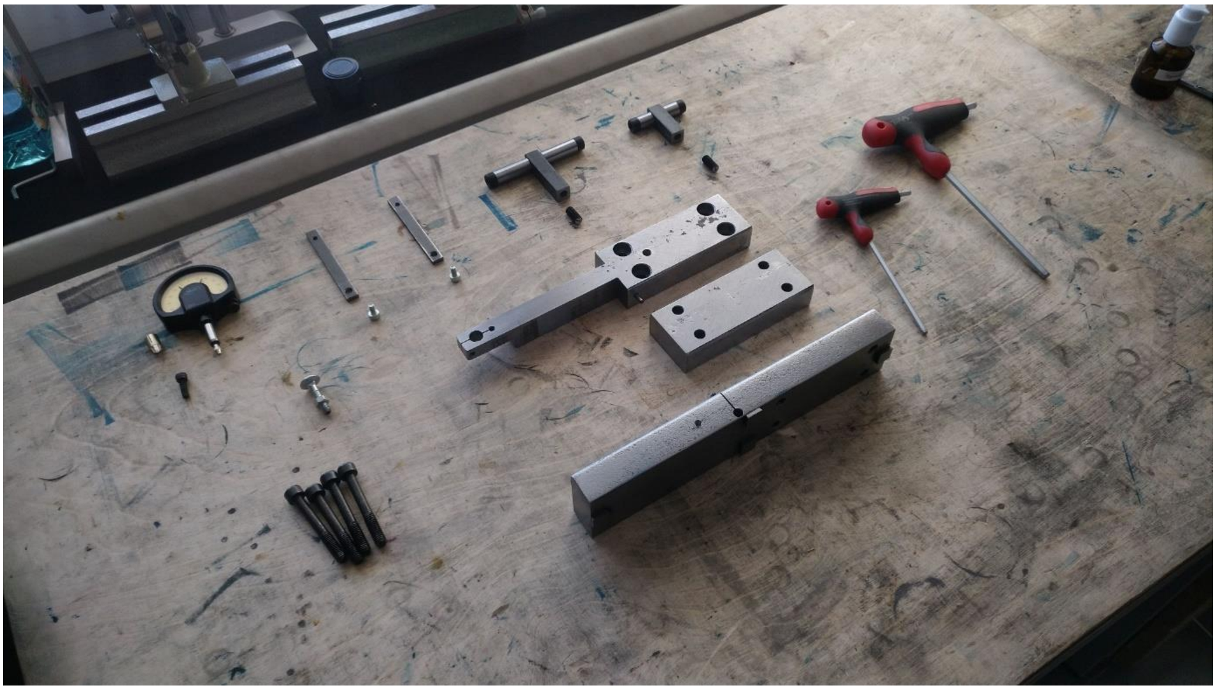


figure 35: all the needed parts for my Clone-O-Meter

But before I start investigating all my granite plates, I decide to build the new instrument a reasonable "home". In my wood stock I find a panel, that was used as light panel in our bathroom before we bought new furniture. It has a few marks of screws inside, however, it is made 100% of pure birch, so a good quality wood actually. I cut it into pieces with the table saw, grind it with the belt sander and glue it together. As top cover, I found another piece of wood, that I first make parallel with an electrical planer and bring it so size of ~12mm. I am sawing a 12,5mm channel into the housing, so that the cover can slide in this channel. In the end I have a sliding top cover that I can completely pull out to give my unlimited access to the inner of the box.

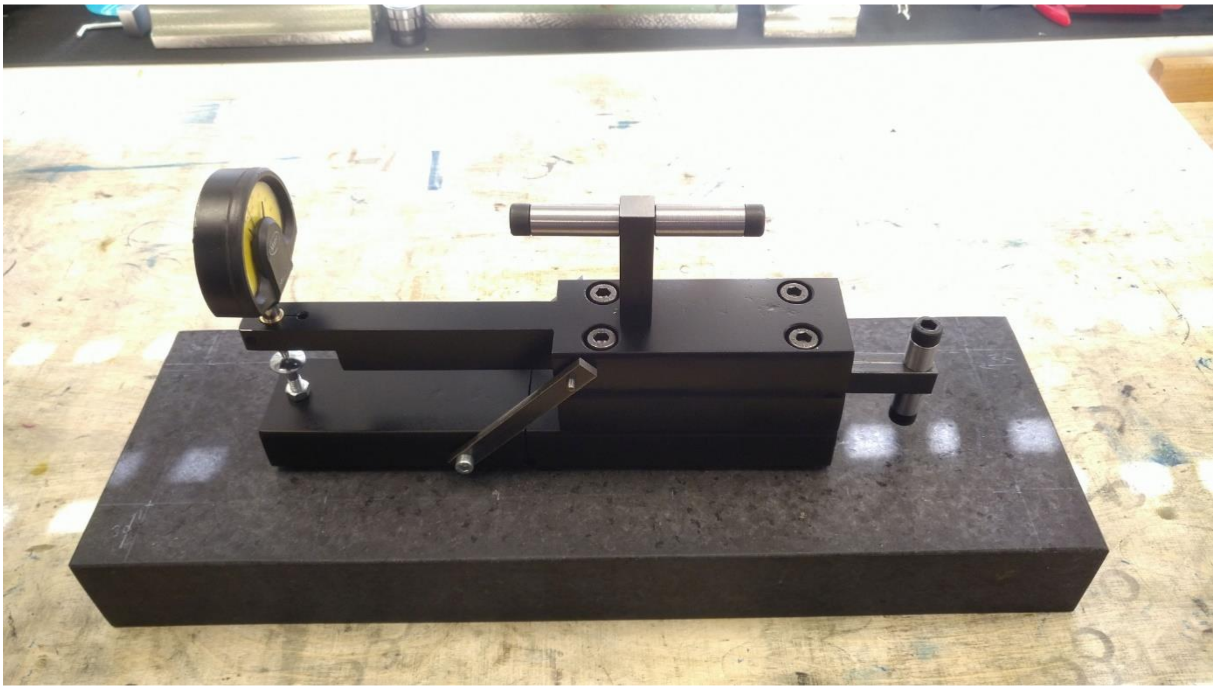


figure 36: ready! My Clone-O-Meter

Next, I bandsaw three templates, so that the Repeat-O-Meter shall finally be securely fixated within the box. My idea is, to free the carbide feet to that the instrument is hold a few millimeters above the box'es floor. I glue a few strips of green felt around the wooden templates so that the black paint will not be accidently scraped off when putting the meter into the box.

Finally I add two allen wrenches in a wooden holder. A 8mm one for the screws on the handles and the instrument itself, and a 5mm one for the locking mechanism and the clamping screw for the meter. I design the box in a way, that I can stow the complete instrument in it (including the installed Millimess).

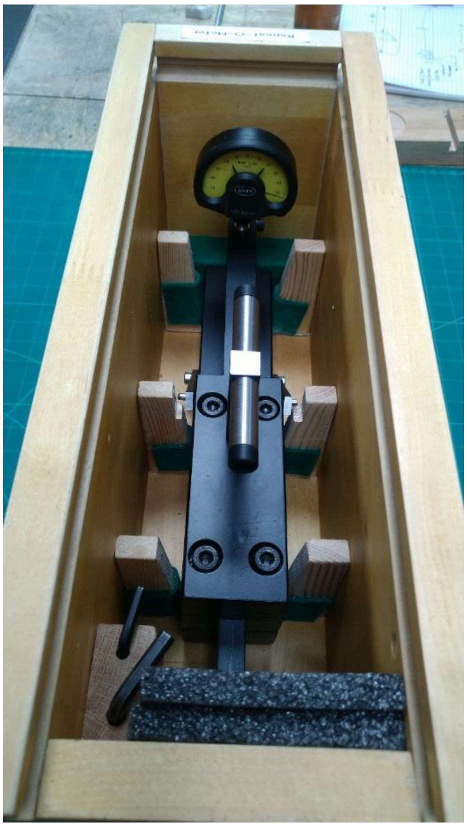


figure 37: the wooden box for the Clone-O-Meter

For me, it looks really good this way. Although I would admit, that -for safety reasons- I probably would remove the Millimess from the instrument and stow it seperately in an insulated cardbox, before I would take my Repeat-O-Meter on a long journey or road trip. But for just keeping it in my workshop, there is no reason why not to keep it in "ready-for-use" condition- with the installed meter.

figure 38: this is the look of the closed box

18 USEAGE

So, as the Repeat-O-Meter is finished now, what is its use at all?
First, I need to say, that I really do not like its name: "Repeat-O-Meter". In my opinion, it is a bit misleading. The repeatability of statistical processes is typically not that, what this meter gives you an answer for. What it does, is, to detect local Hi- and Low-Spots on a surface plate. It is the ideal complement to the level system: whereas the levels do detect the entire "global landscape", the Repeat-O-Meter can find local dents and irregularities. Those local "irregularities" do for sure influence the scraping print on your working piece or cause variations in the readings when measuring it. The "repeatability" means, that on a good plate, it makes no difference, in which area you do your print- you always get the same result. So you can reproduce your result everywhere on the plate- it become "repeatable". This is, what the "repeadability" means: only, if there are no local dents or hi-Spots in your place, the result become "repeatable". To detect these spots, we use the "Repeat-O-Meter".

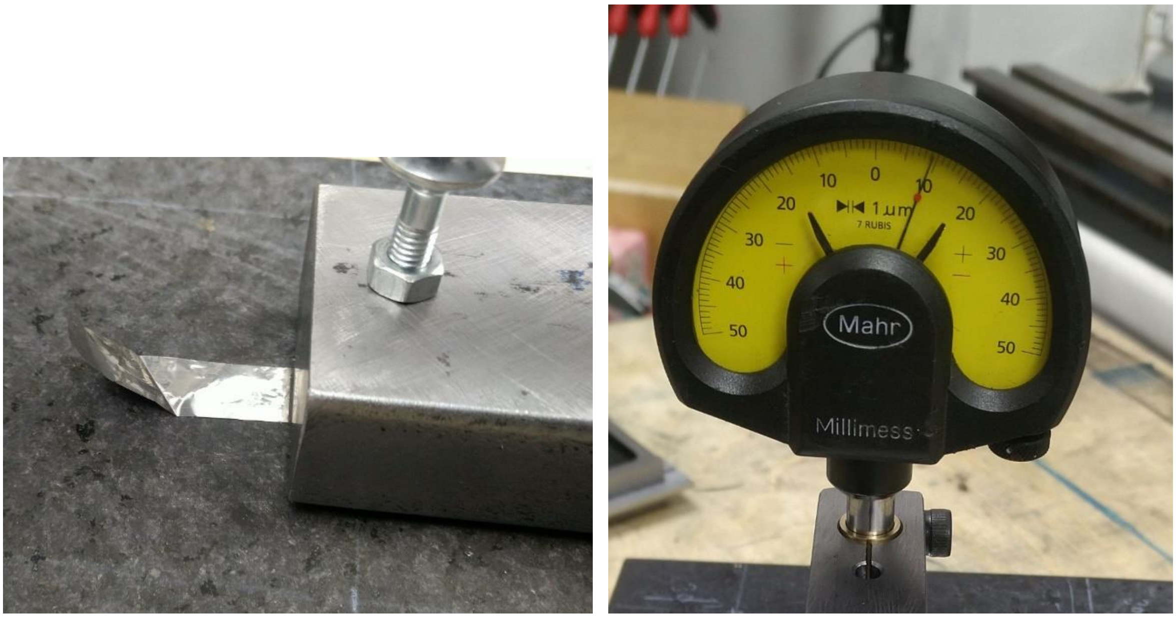


figure 39: a 10µm feeler gauge under the sensor pad produces almost exactly 10µm reading

Is you ask me, I would better call it "Dent-o-Meter". Because it detects dents. Or local hills. A "Hill-O-Meter" so to say ;-)

In the end, the name does not matter. More important is, that the instrument does fulfil his job: always and robustly! And it does! Once set on the plate and zeroed, you can slide it forward and back and it gives you really excellent results. For sure, the smaller the plates that you wanna inspect, the more problematic it becomes. The instrument is more than 10inches long (262mm), so a 300mm plate cannot really be inspected properly this way by just observing the needle movement on the remaining travel distance of just 38mm. In this case, the useage of a precision ground "Haarlineal" is probably the better choice for a flatness check of very small items.

19 Fun with my meter :-)

After having had fun with its construction, I can now swivel it across my 1000x630mm surface plate and search for local dents. For sure, I cannot really find some. As I said already, I bought the plate with a factory lap according DIN867/00 including certicifacte and during the last two years for sure I have used it, but always with care and very gently only. I am also hobbyist, so I would assume, that during that time its wear was really only minimal. The Repeat-O-Meter overall confirms this expectation. I cannot find any dents or specific irregularities. What I can see is a slightly falling niveau (~3µm) towards the borders of the plate. But if you compare with the certificate, you really can understand its behaviour. If you zero the instrument in the middle of the plate (where it is high compared to the borders), then it is logical, that the sensor of the Repeat-O-Meter drops slightly towards the borders.

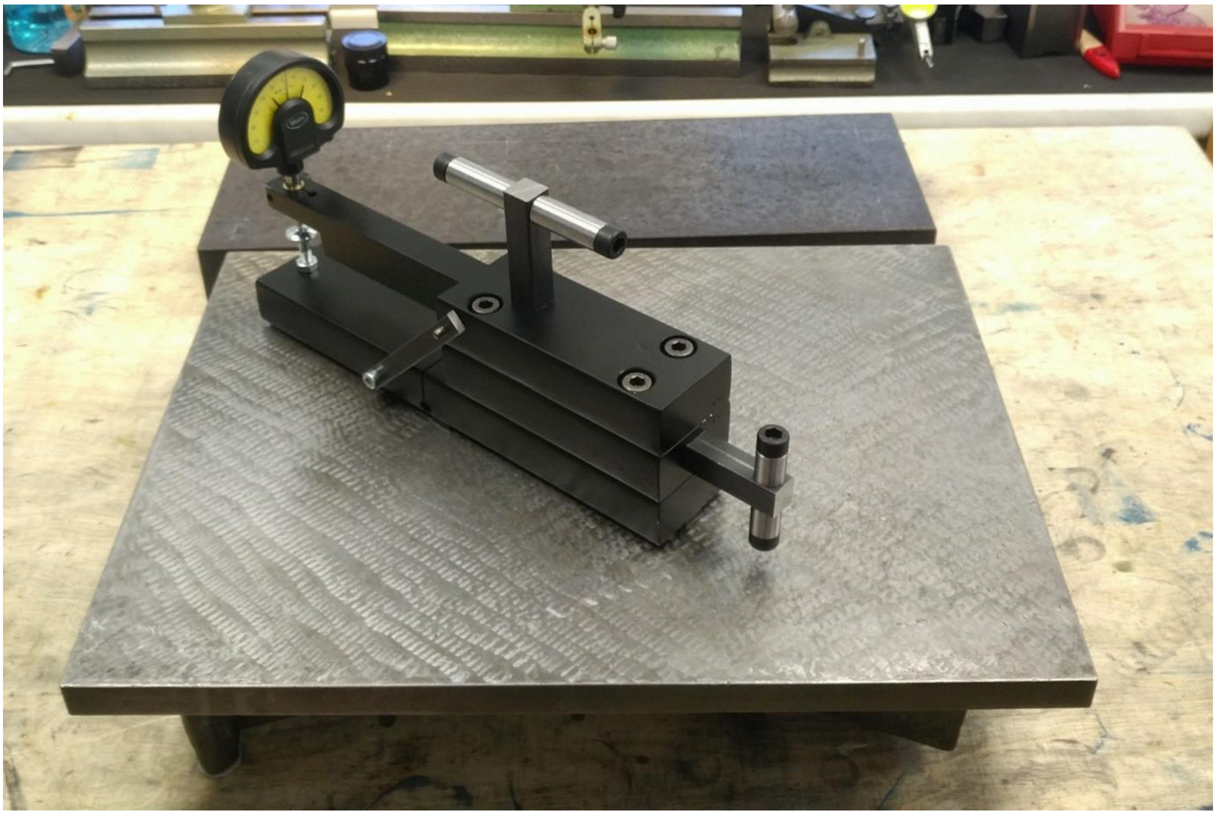


figure 40: check of my small cast iron plate

20 I need software!

What?? Really? Marc! You always tell us, that you try to avoid modern computers as good as you can- und now this statement?

I have to confess, that there is really some use cases where software really does a good job and support you. The measurement and final alteration of the "closing error" is such a case. I tried to program it in Excel, but surrendered finally by the limited Excel possibilities to present 3D graphics of the measurement grid. I need something professional- no way!

First, I checked in my standard forum "zerspanungsbude.com", if somebody has hints for me what kind of software I could use. Being normally professionally used, I am sure, that I cannot buy such a software just for a random use for my "nerdish" hobby. So I asked, if there are some free alternatives on the market; e.g. a open-source solution or a Excel table programmed by someone who might be signficantly better educated in Excel usage than I am.

But the result was quite discouraging: no hint for any small-budget hobby-software or even a Excel-Tool that would do this job. Nothing.

So. What to do?

Ask Wyler!

21 Wyler!

After a couple of days of hesitation, I finally dared it. I did not expect much support, because as hobbyist there is not really much money from me to earn and at least I do only cause effort for them and nothing else.

But I thought, that on any friendly given question there should be a friendly given answer as well, even if not positive. So I will try my luck and give the company "Wyler" a phone call!

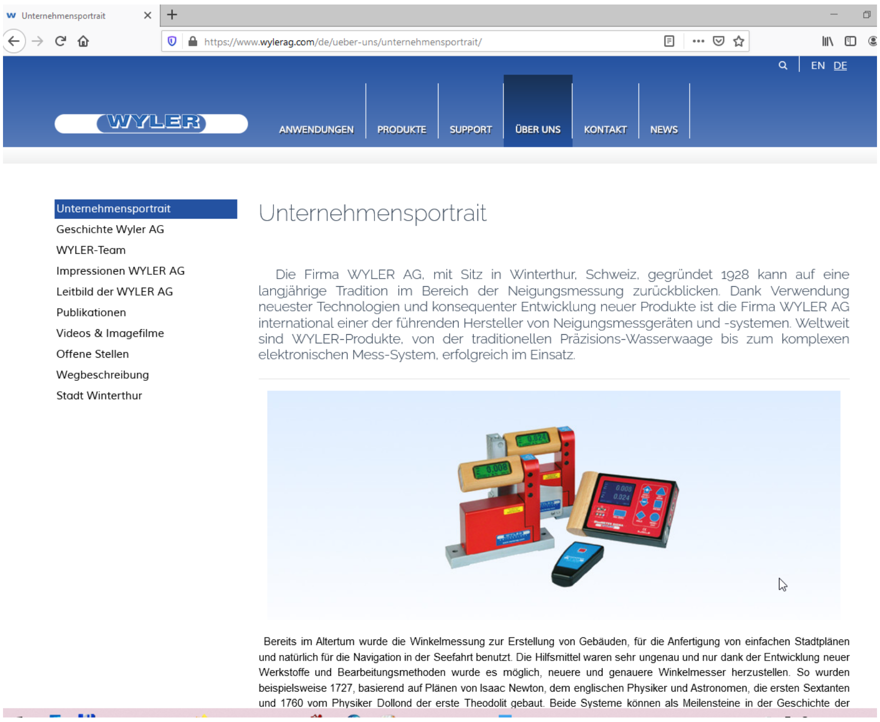


figure 41: the manufacturer of my levels: The Wyler company -located in the nice switzerland!

I reach the companie's main office and I am full of admiration for the youn lady who really gives her best to speak "german hochdeutsch"- what is not normal for swiss people. The have their own dialect, sometimes even regionally "coloured", which I can very barely understand. The number "3" as example ("three" in englisch; "tree" in malayan english!), in german "drei" will be pronounced like "drü" in switzerland. If you don't know that- no chance for a german guy like me, ha ha ha ;-)

But back to the levels! I explained my situation: I do this all just for internal education, to gain personal knowledge and competence about this fascinating topic of mechanical metrology and have absolutely no commercial interest. I just want to learn something and at least "play" with my restored Wyler Minilevels and have fun with them in their use. Being a pure hobbyist, I earn no money with my activities at all, so my budget for SW licences is not zero, however, not compareable with any professional calibration service company at all. I could spend perhaps 100 Euro or a bit more, but defintately not afford a commercial, industrial licence.

The Wyler guy at the telephone (it was a sales guy) had astonishingly open ears for my request! He totally understood and proposed, to download the current "wylerSPEC" software and just activate a temporarily tryout-licence that is available for free! It activates the software for 14 days, after that it will be switched back to "view mode" only and that's it! No duties to buy anything or no fees for usage, just the time limit to care for.

Hey, that is a nice idea! I will try it. At the end, the friendly guy in switzerland even offered me his personal telephone help in case of problems. Wow, that is really very, very friendly and I haven't expected this great support!

So thank you, Wyler, and let's try!

figure 42: there is the wyler headquarters- located in the very nice switzerland! (Source: Google Maps)

22 First try....

Okay, I make my first try. I stumble across a few road blocks. First, my homemade setup for differential measurement is -what a surprise ;-) - not supported by the software. When I read in the unit "Millivolts" on my voltmeter, whereas 1mV represents 1µm/m, the wylerSPEC does for sure not expect to key in two more digits for my improved resolution. I also does not accept tenths to be keyed in (e.g. like "1,4"), it only expects odd numbers like "5" or "-7".

Next, the system is modellig the "differential measurement" internally- not expecting that I do this already electronically outside. So if I choose the "with Reference" mode, it consequently wants you to put in TWO values for each measurement: one for the MEAS level and another for the REF level. Then, the software calculates the difference internally.

In my setup, this "difference-calculation" is already done by the electronics. And I enjoy this, because it prevents me from always reading 2 values instead of one.

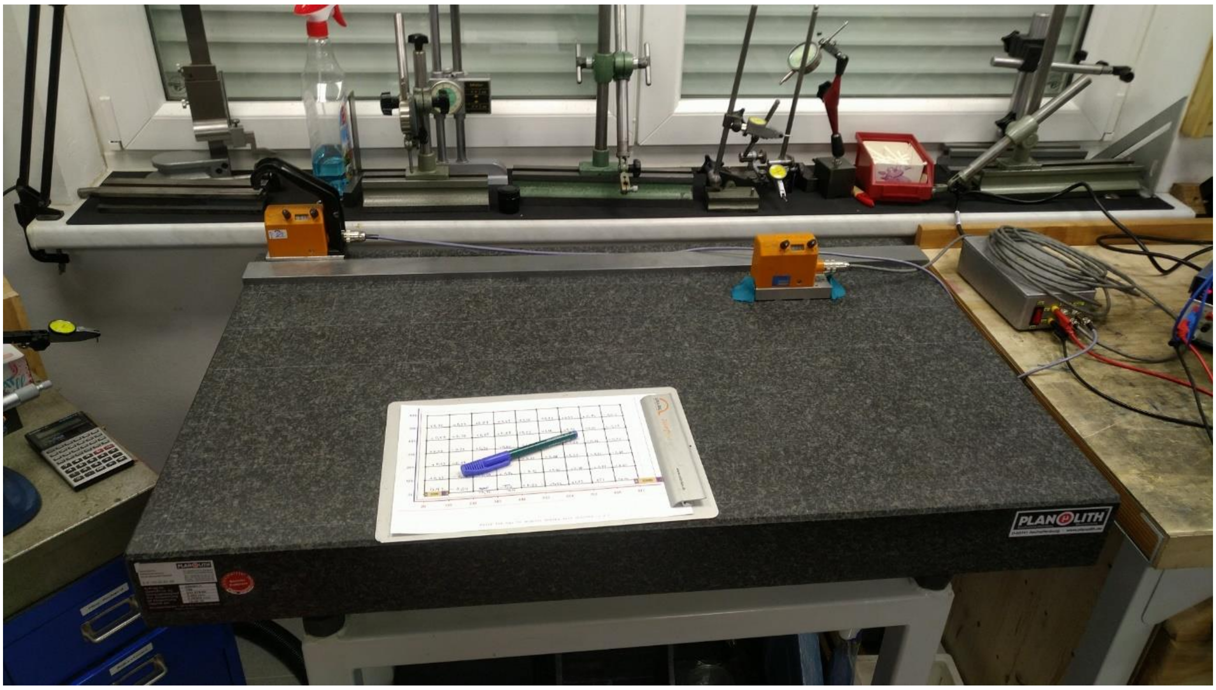


figure 43: first try! The REF-Level was stuck with children's elastics ("Knete") to the plate to avoid unwanted movement during the measuring process

I understand, that with modern wireless levels (like Wyler is using), this implemented procedure in wylerSPEC is absolutely senseful! But in my case, with my old levels, I need to "improvise" a little bit. I need to select the "absolute" mode instead- and secretly making my internal differential measurement externally ;-)

But this has also impact on the measurement's procedure: suddenly the software wants me to perform a "reverse measurement" for Y-axis, which I could not know during I was in the workshop, doing the level measurement and noting down all the values on my paper.

So for my first try I ignored this and just put all values into the software.

After a bit of testing and playing around with the wylerSPEC, I can proudly present my first grid! Compared to the original (on the right side) you can identify a lot of similarities like characteristical lo-spots or hi-spots.

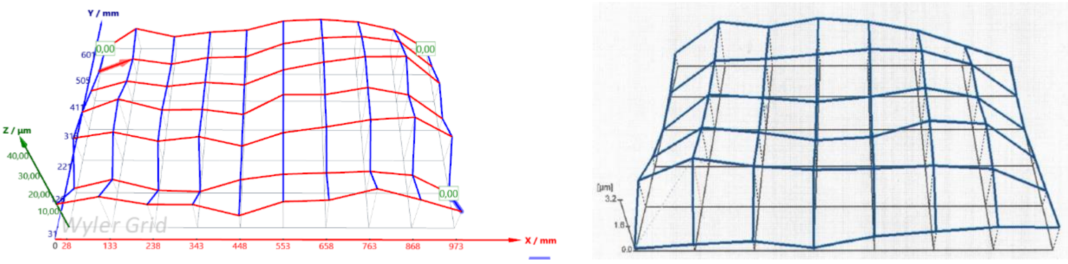


figure 44: left: my first try; right: the official measurement of Planolith, SEP2018

But there are also a lot of differences and the closing error (=effort, to bring the two measured grids (vertical and horizontal) to a commond grid) is without discussion. It's awful. I definately need to do a second, improved run!

But for that, I will go a step back and use a smaller plate. My 1000x630mm one needed at least about 1 hour measuring time for me. A lot of time, if you just want to try out something. I guess I will instead measure my smaller chinese granite plate of 300x200. Measuing her, and verifying the results, should be much, much quicker due to only a few readings!

23 Second try: a chinese 300x200mm granite

So I start with the smallest plate I have: my chinese import surface plate- sold as DIN876/00. Will I be able to proof this??

Hmm....

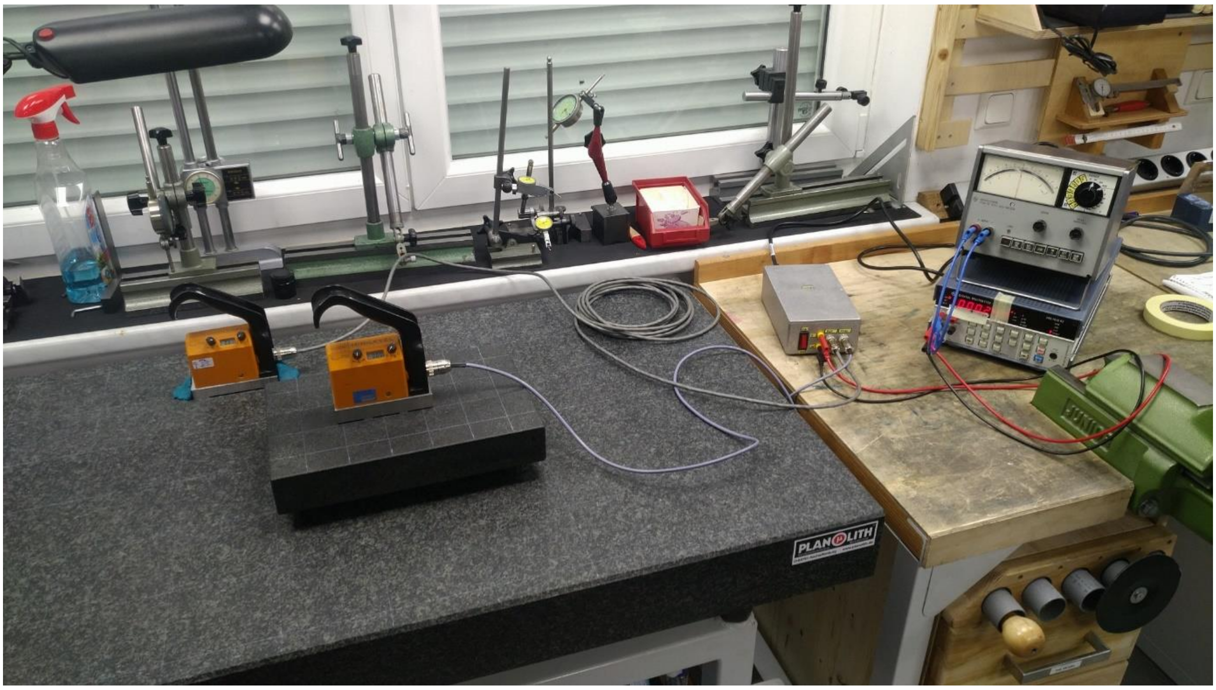


figure 45: measurement setup

I am measuring and get the following result, but soon I will see, that it was a bad idea to place it on two parallels on my big granite. Why? Because the small plate is rocking!!

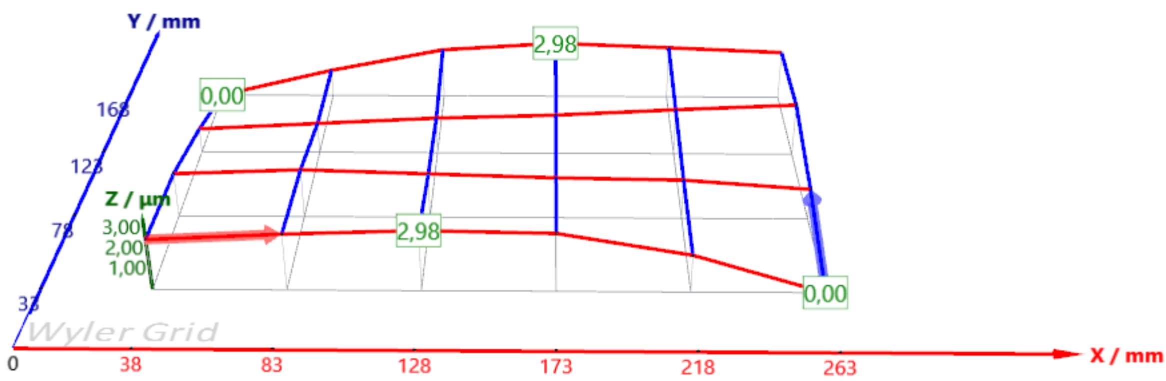


figure 46: Chinese plate - still with rocking feet...

So I need to change the setup and measure again.

By the way: the input mask of the wylerSPEC looks like this:

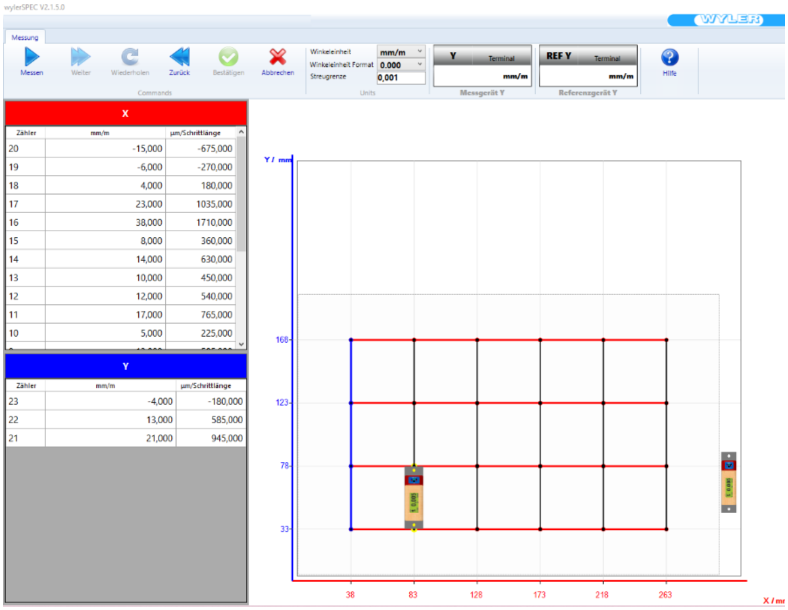


figure 47: the wylerSPEC software during keying the values in it

24 Third try: Yeah!

But with the third try it looks like, that I really make progress!

First, I put the surface plate on a 3-point stand to eliminate the slight rocking, that I could observe before. Three metal rings with metal balls inside have been very useful to me as rigid and stable measuring basis!

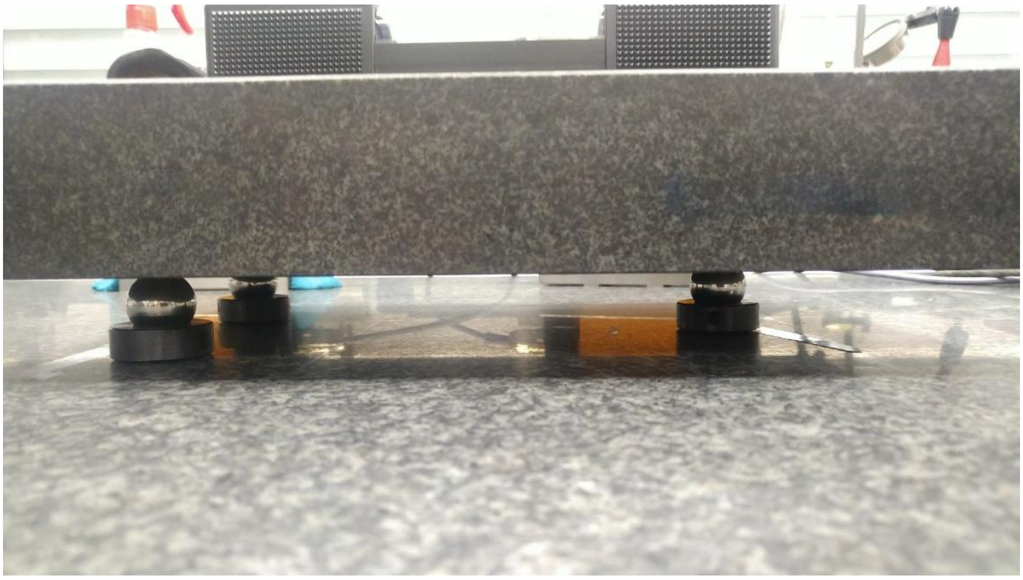


figure 48: three points for rocking-free setup

Next, I need to level the baby within 50µm/m. At least this is, what wyler says to do. So I take my Röckle precision level (sorry, it's not a Wyler, I know... ha ha ha) and put feeler gauges under my 3-point-system.

figure 49: levelling with a 20µm/m level

I tip the plate with the finger on some places. But it does not rock any more!

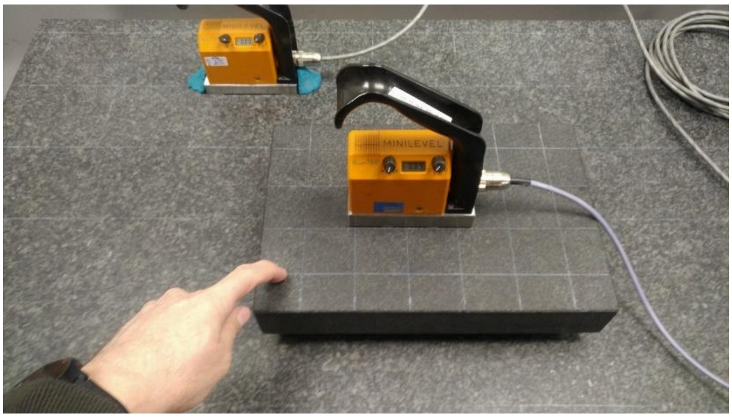


figure 50: now it is stable!

I start with the measurement. My combination of the digital Multimeter (Rohde&Schwarz UDS5) with the analog Null Detector Voltmeter HP419A is an absolute winner. The analog display shows very well, if the niveau is rising or falling and the UDS5 gives me immediately the numeric value to write into my protocol. And finally it proofes against each other!

figure 51: dual display - analog und digital! (I used tape to mask the smaller digits to avoid unnecessary distraction)

In the end, I get ths following result:

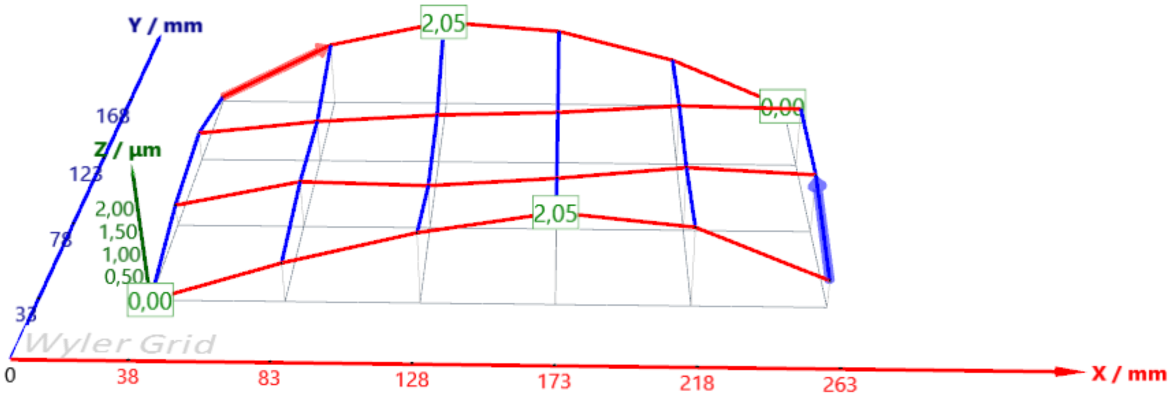


figure 52: the final result of my chinese 300x200mm plate

Two things, that make me really happy!

The first:

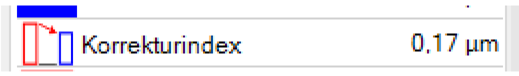


figure 53: very good closing error (at least for me!)

The closing error seems to be now much better than before. Okay, probably does still not meet professional standards, but -hey!- for me as hobbyist? Not really bad!

And the second:

figure 54: rating is DIN876/00!

My tiny plate is really rated as DIN876/00!

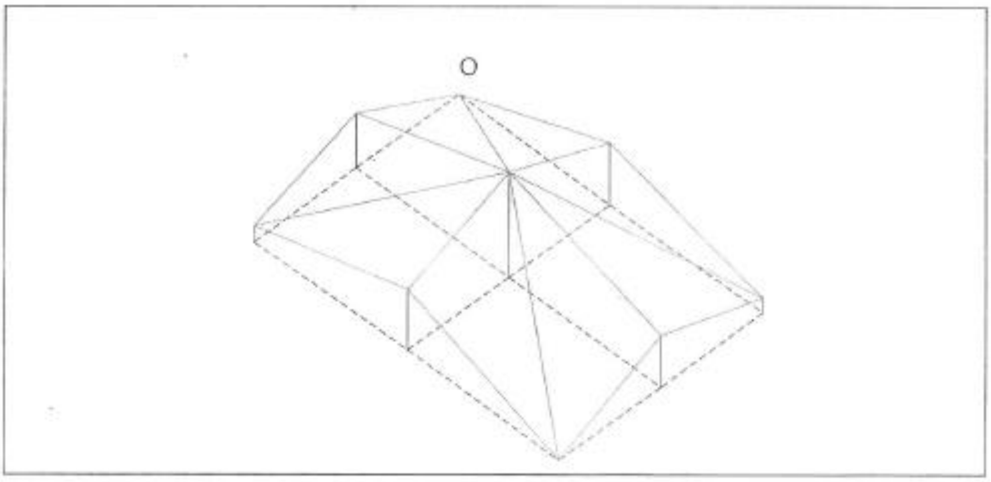
What makes me really laugh is, what the manufacturer gave me as measuring protocol with this surface plate:

REPORT

Diagonal Measurement

Factory:	
Product: Granite plate	SerialNo. 2016071149
Size: 300x200 mm	Precision: 0.001 mm/m
Standard: DIN876-83	Client:
Page No.:	Date: 11/07/2016

0.0	1.4	0.3
1.2	2.4	1.1
0.3	1.3	0.0



Conclusion:

The ACCURACY = 2.4 μm, 00 Level

figure 55: Chinese Test report for the same 300x200 plate...

At least, I have not much trust in this report- although the total max. deviation of 2,4µm is not so far away from my result (2,05µm). It also agrees, that all borders of the plate are a little bit konvex, so bowed to the "sky". The difference is the middle: whereas the chinese protocol sees the high spot in the middle, my own measurement says, that there is a nice flat area of about 1µm hight from left to right.

To show up this, I use the 3D rotation functionality of the wylerSPEC. I can rotate the grid in any direction I want (even a view from below is possible!):

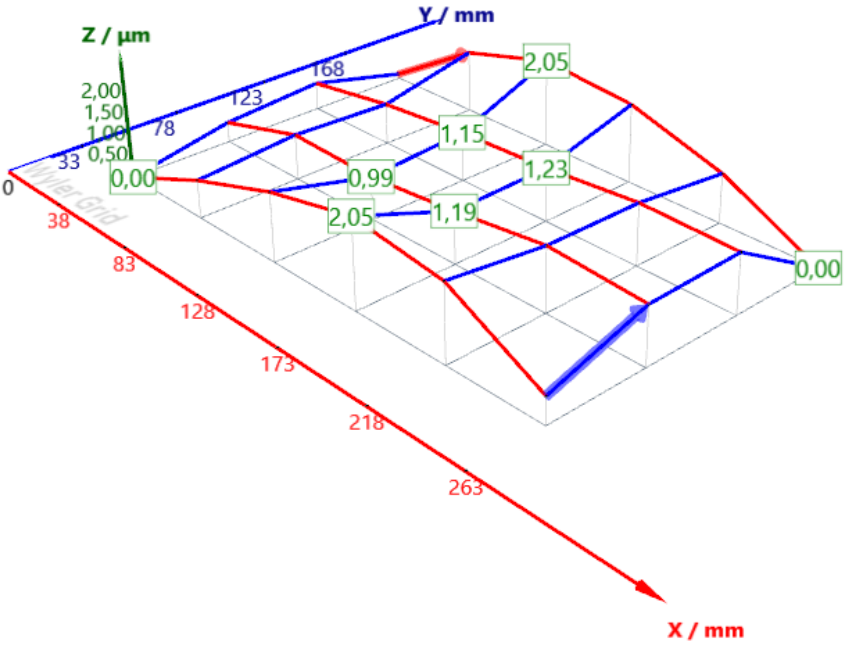


figure 56: the same diagram, but different view

I must confess: dear Wyler developer: your software is really great!! It is a pleasure wo work with and it does not happen very often, the I am recommending computer applications. But this time, I really do with a big thumbs up!! It did convince me!

What I am really pleased with, is the automatical calculator for the definition of the test grid. This is awesome, because it is so helpful and shortens your testing time significantly.

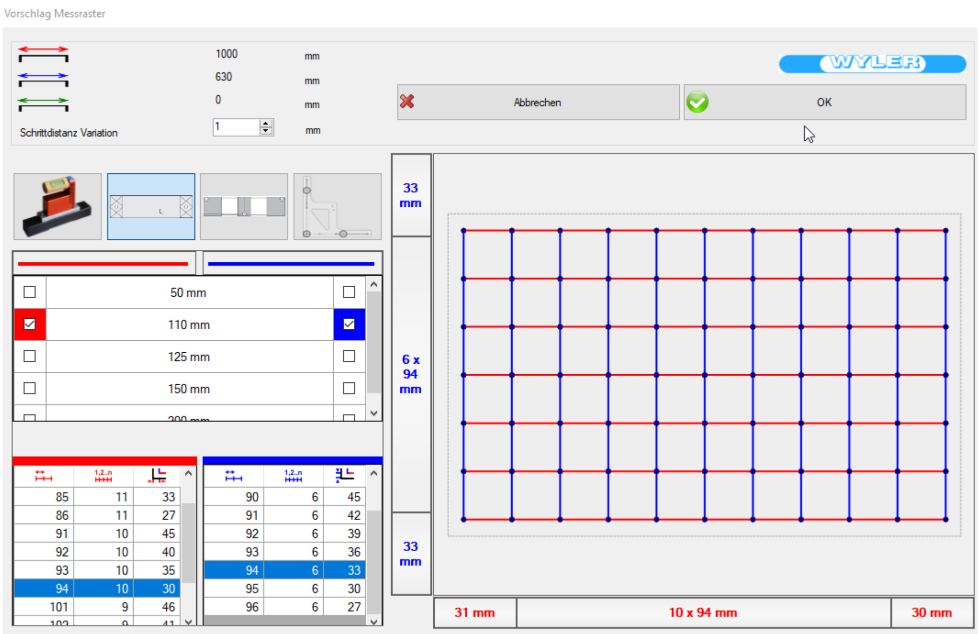
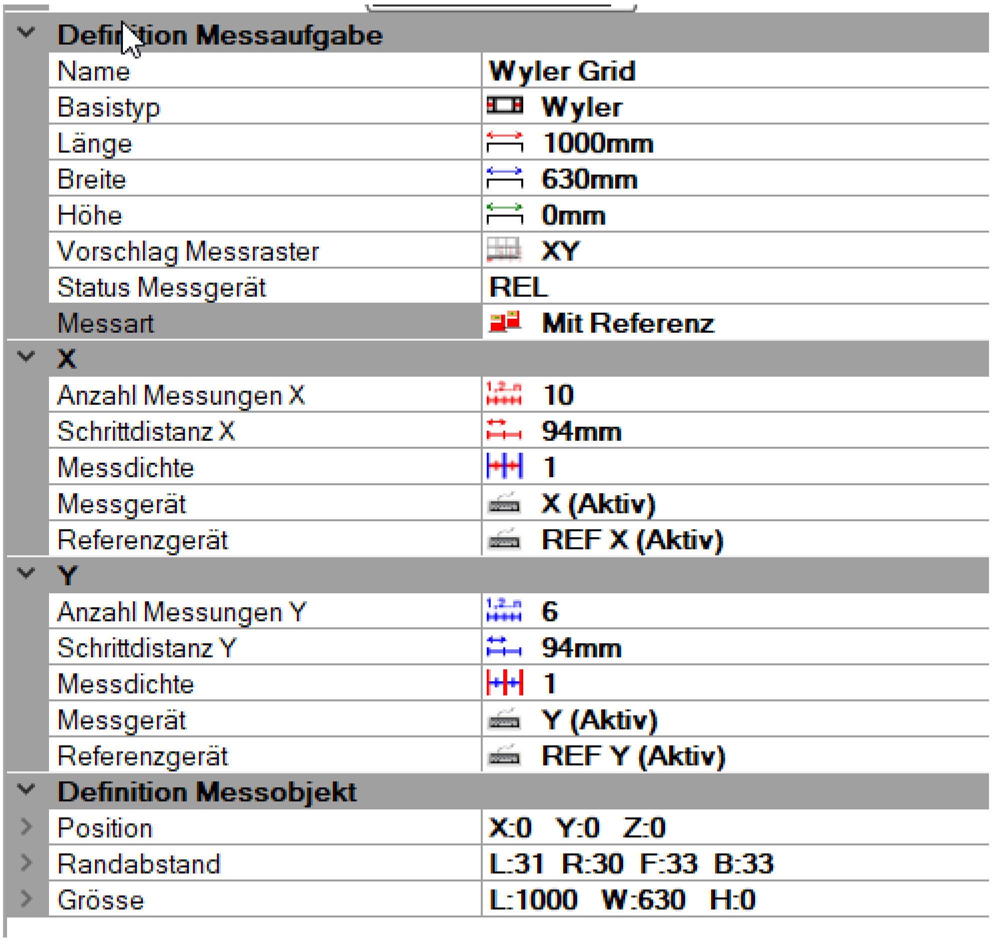


figure 57: picture of the Auto-Grid calculator

25 Re-Measure my 1000x630mm plate!

So, am I already prepared for the "big thing"? Can I do this?

I guess so. I take these parameters:



Definition Messaufgabe	
Name	**Wyler Grid**
Basistyp	**Wyler**
Länge	**1000mm**
Breite	**630mm**
Höhe	**0mm**
Vorschlag Messraster	**XY**
Status Messgerät	**REL**
Messart	**Mit Referenz**
X	
Anzahl Messungen X	**10**
Schrittdistanz X	**94mm**
Messdichte	**1**
Messgerät	**X (Aktiv)**
Referenzgerät	**REF X (Aktiv)**
Y	
Anzahl Messungen Y	**6**
Schrittdistanz Y	**94mm**
Messdichte	**1**
Messgerät	**Y (Aktiv)**
Referenzgerät	**REF Y (Aktiv)**
Definition Messobjekt	
Position	X:0 Y:0 Z:0
Randabstand	L:31 R:30 F:33 B:33
Grösse	L:1000 W:630 H:0

figure 58: parameter set that I gonna use

And my chosen grid is this one:

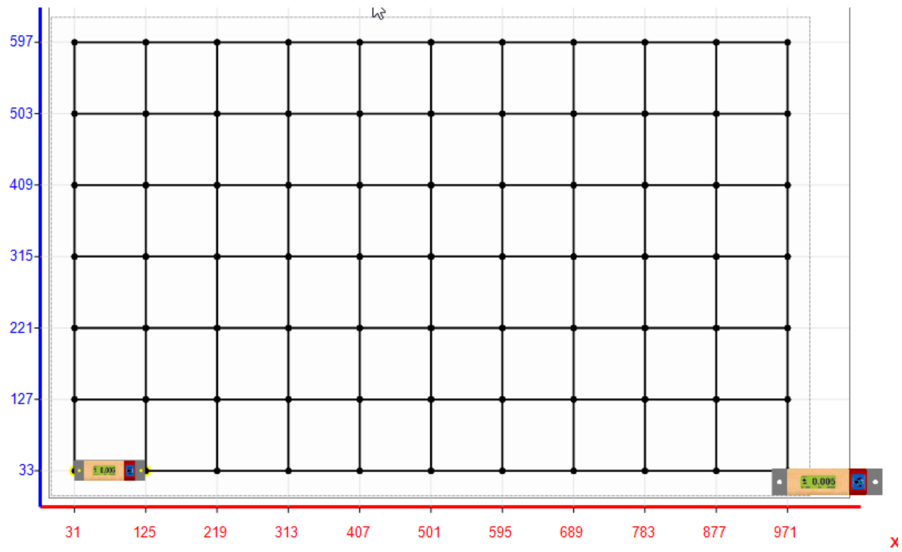


figure 59: selected grid

All in all, it took me about 1 hour to do the entire measurement and note down all the values to paper. And another 15minutes or so to key the values all into the wylerSPEC software.

Then, I get this result:

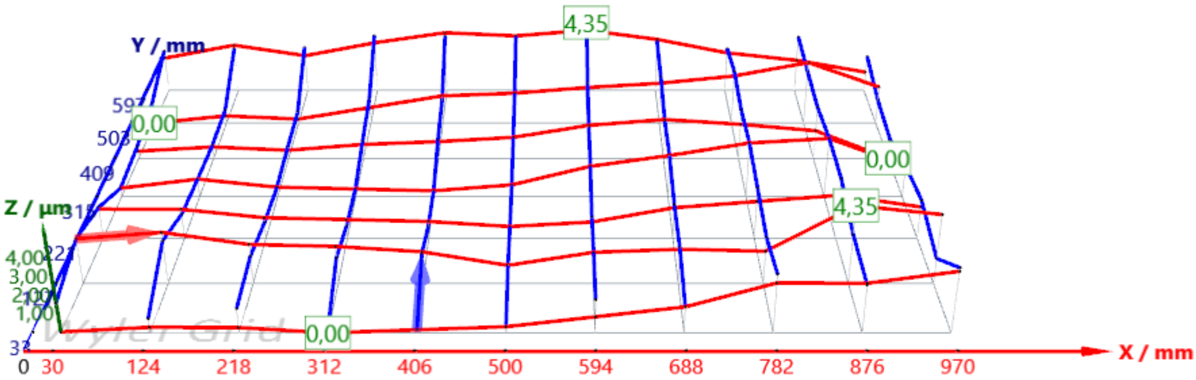


figure 60: my final measurement of my Planolith 1000x630 plate (without closing-error correction)

I become a bit disappointed, because, the result is currently only Grade0 (and not 00 as bought). But I need to take care for the "closing error". You can see it in this picture quite well:

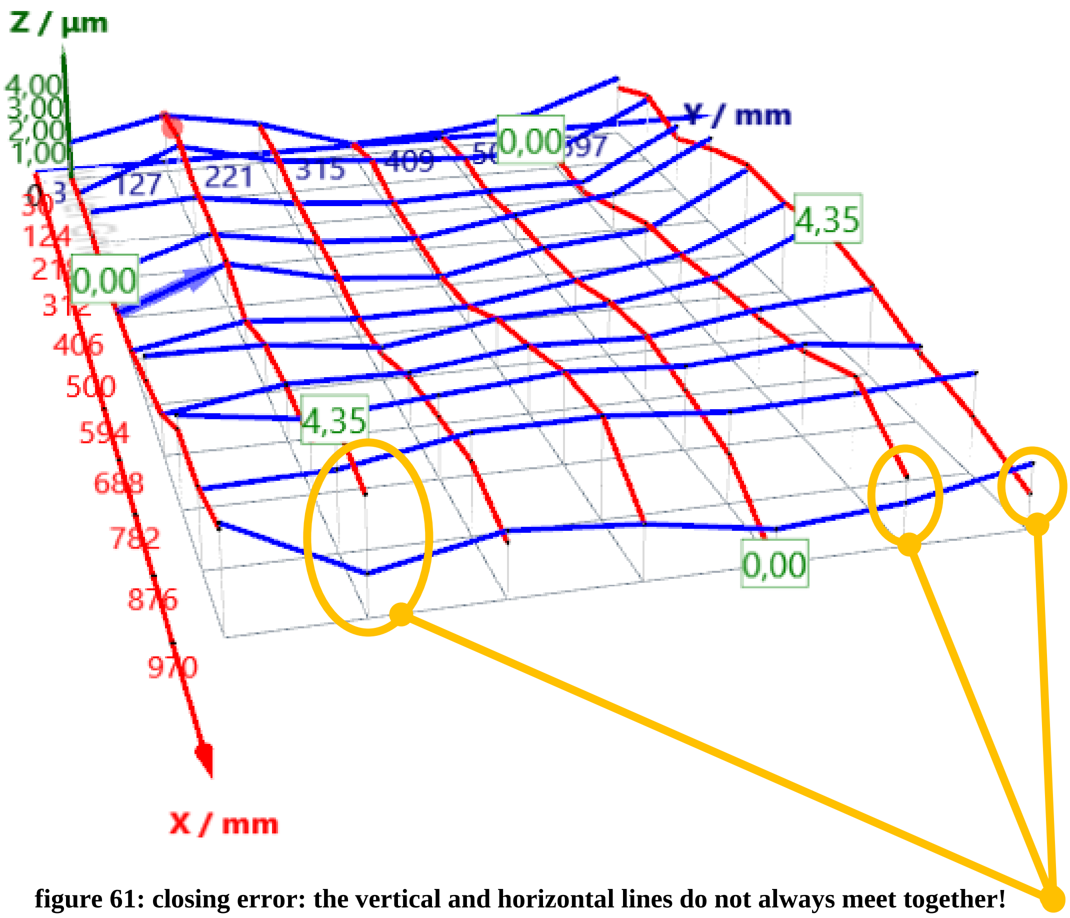


figure 61: closing error: the vertical and horizontal lines do not always meet together!

This effect is normal. It is the result of summing up the errors of each individual measurement and becomes worse the more steps you have. In my setup, I have 10 steps in X and 6 steps in Y. So in X-direction, I have 10 possibilities for errors to sum up and it looks like, that this effect is now giving me the max error value of 4,35µm- destroying my DIN876/00 grade which allows max. 4,0µm error for a plate of my size.

But we can try to correct this "closing error" by activating the "Schließfehler-Correction". This is for sure one big advantage of this SW. I do not know, how exactly they do this, perhaps it's a kind of averaging out mechanism, but I just cannot say. Wyler provides a presentation to describe this, but for sure gives you not the mathematical model. ;-)

If I activate the correction, my plate looks like this:

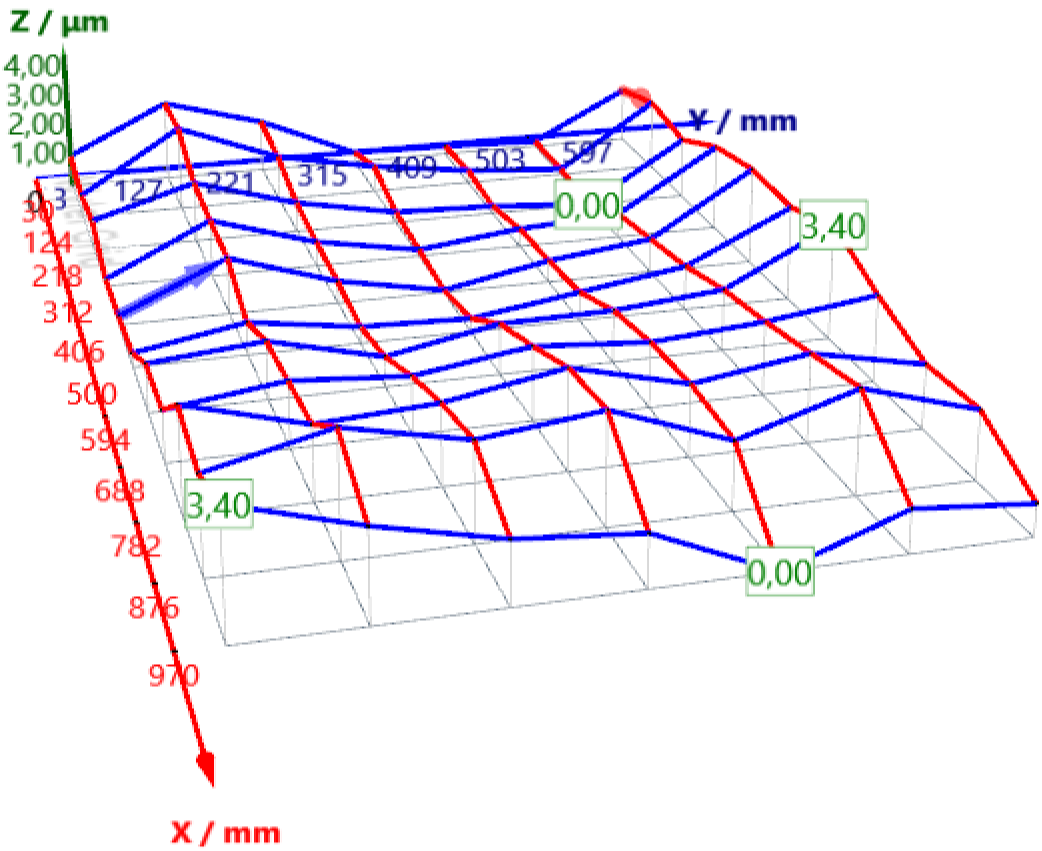


figure 62: the same measurement, but with "closing-error correction" actived

And this finally brings me down again to DIN876/00, because the max values are now 3,4µm only. This single µm improvement is probably not really significant for my work, but would definately be a big argument if you sell these plates. A plate with Grade00 will be for sure more expensive than a Grade0 one.

So, how good has our hobby measurement been turned out? Let's compare again with the Planolith certificate.

26 The result (comparison)

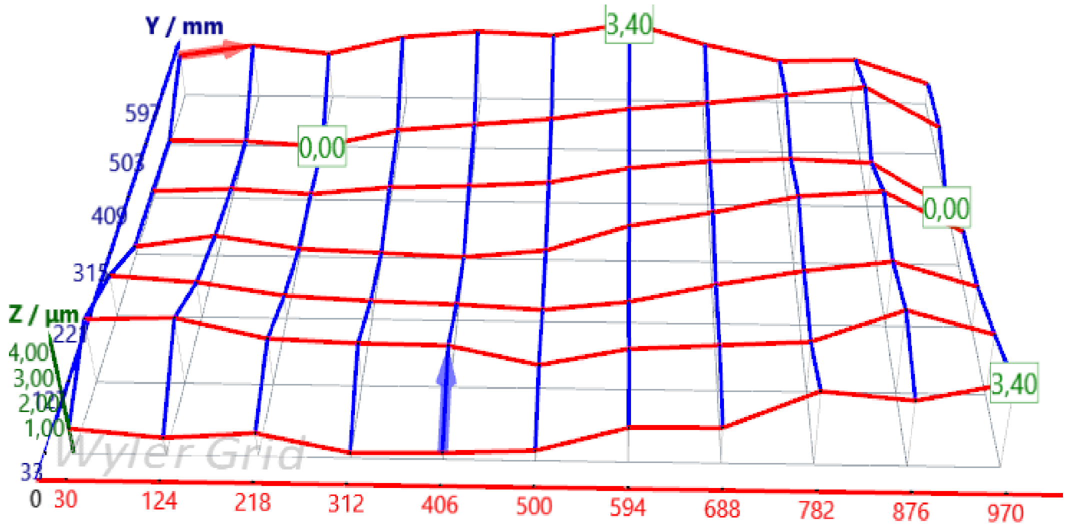


figure 63: my final own measurement from 2021

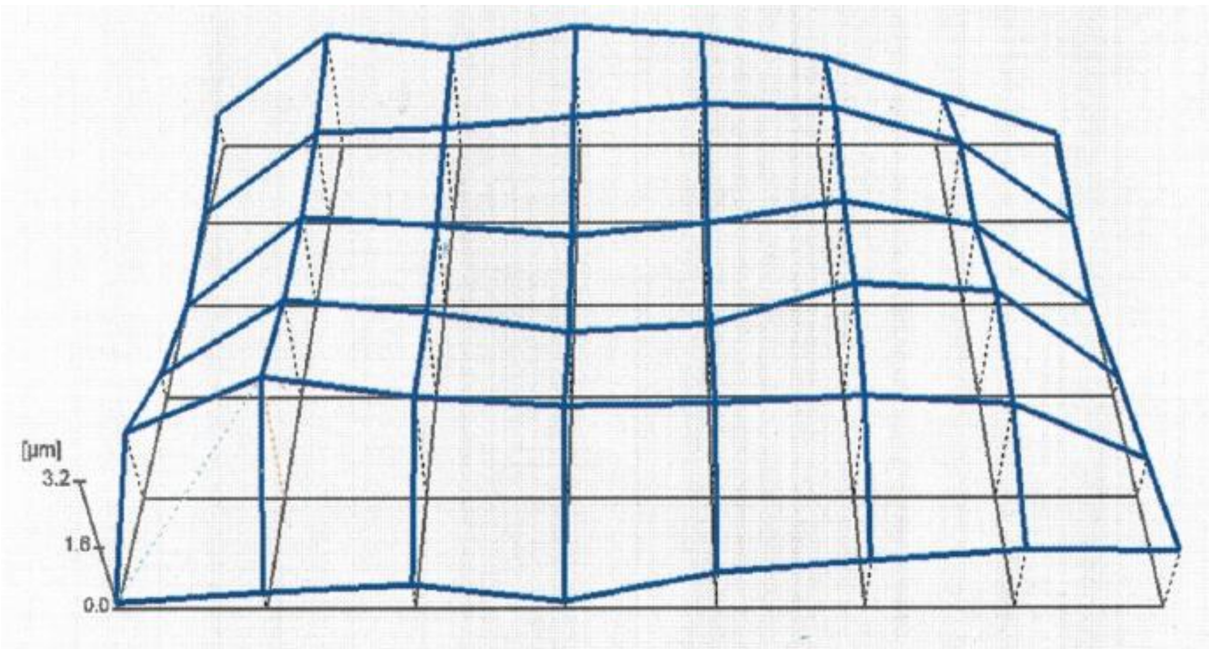


figure 64: the original measurement that came with the plate in 2018

So how do they match?
At least, probably better than you see first. I get a maximum deviation of 3,40µm; Planolith measured 3,02µm. That is about 10% difference only- which could have different reasons:

- wear over time
- different measurement conditions (e.g. temperature, humidity!)
- calibration of the test setup (levels ;-)
- different size of measurement grid(!)

For me, it is very interesting, that -again- I see some characteristical points confirmed. I almost detect the same "hi spots" with my Minilevels like Planolith did 3 years ago. Maybe not in all aspects and details. But at least I can see many similarities that make me quite confident of having done something in the process the right way!

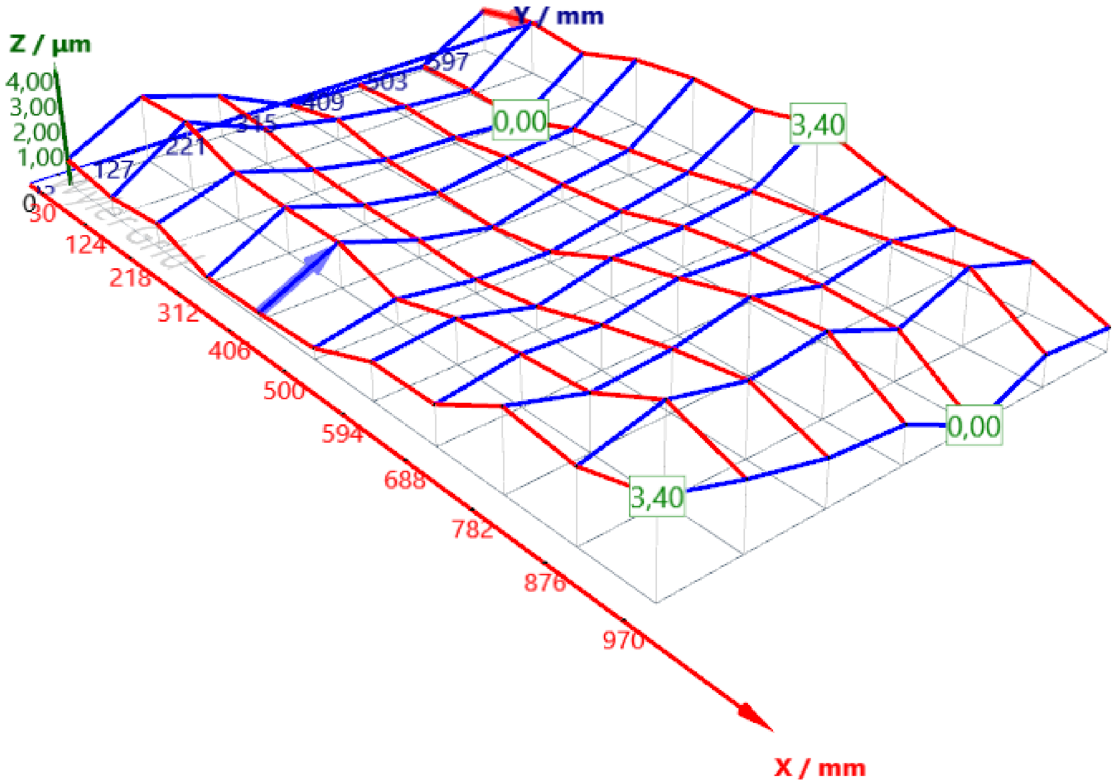


figure 65: different view of the same measurement- no problem for thewylerSPEC software! :-)

Again: so what to do now?

Verification measurement! :-)

27 Verification measurement

As for any techincal measurement process, all of my readings do include a certain amount of measurement error. It is the job of a metrologist, to evaluate this error and understand it. Inside my measurement, there is a lot of possibilities that produce errors; systematical ones (e.g. limited resolution of the instrument, "chaining" all the values will even summing up this error!) or statistically distributed errors, like e.g. noise.

For a surface plate measurement like I do, there is no chance for a hobbyist to analyze all of influences to the measurement as there are too many of them. Do not believe? Here are a few examples of dependencies that need to be verified and briefly understood, if I were a metrologist:

Influences in my test setup:

LEVEL:

- stability of power supply of my levels
- influence of this stability to the readings
- influence of noise of the power supply to the readings
- drift (manual zeroing with trimpot)
- influence of correct leveling of the granit plate (50µm?)
- calibration of the level (sensitivity, drift, etc..)
- et,c

ENVIRONMENT:

- performance of weight compensation (differential measurement)
- influence of vibrations in the house (e.g. children running around in the basement)
- Temperature consistency
- Humidity consistence
- particles (dust!) in the air
- etc.

GRANIT PLATE:

- bow due to thermal inhomogenity (partially warming!)
- dimensional changes due to humidity
- cleanlyness

MEASURING SYSTEM:

- measurement error of the R&S UDS5
- measurement of the HP419A

SYSTEMATIC:

- influence of limited resolution of the readings (e.g. "0,1" or "0,0001")
- errors, that sum up by building the measurement chain along the grid

And believe me- there are even many more effects that you need to know, to limit or even to control!

One topic that I would like to gain a bit more trust, is the repeatability!

So if I would do the same measurement again- would I roughly get the same results? Normally, as I remember my last statistics lesson, you need to do this minimum 20x before you can say anything about the repeatability or stability of the process. But measuring 20 times my surface plate is impossible to me (and too boring ;-) so I repeat it 1x and call it simply "verification".

This is the result:

First Measurement:
as seen in last chapter

Verification Measurement:
two days later (21FEB2021)

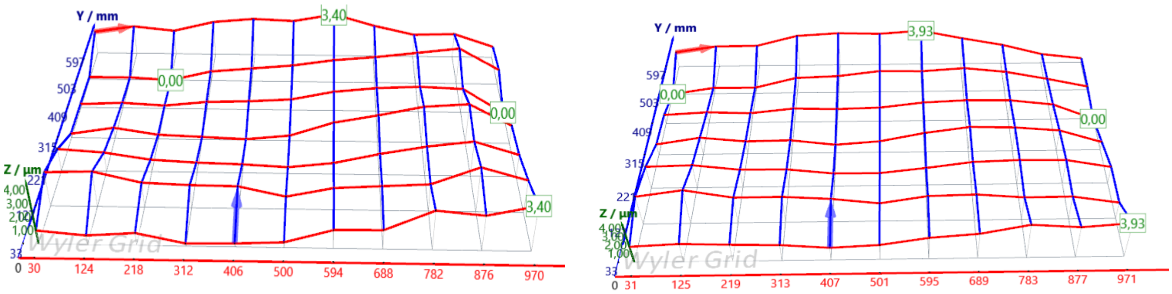


figure 66: check of repeatability

Both measurements end up in Grade00- but only quite barely (max 4µm is allowed). The closing error of the first measurement was 2,44µm; in the verification it was 2,54µm.

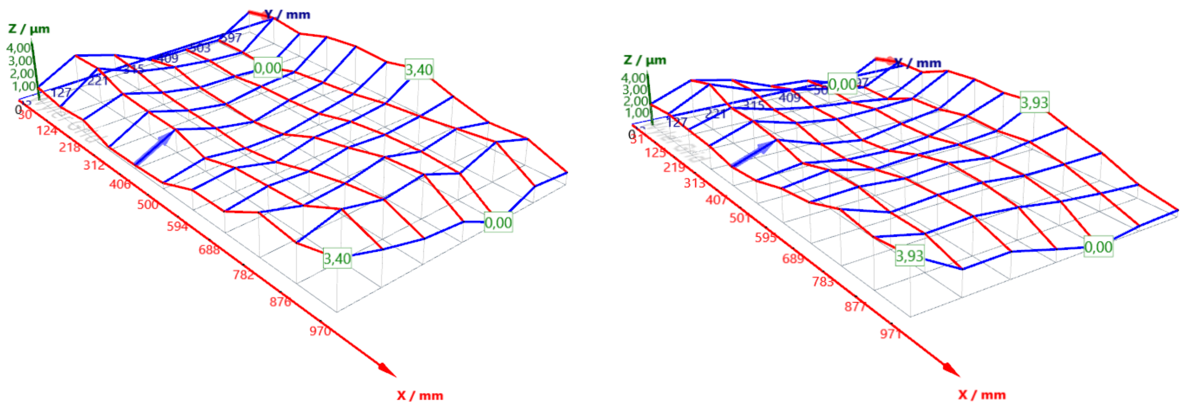


figure 67: the same data, but different view

So- it that good or not?
I don't know. At least I get the impression, that the entire "look" is similar. The variation of the maximum points is 3,40µm to 3,93µm - which is about 16% error.

And here probably ends the capabilities and possibilities of an hobbyist! To know, if that is "state-of-the-art" or not, you need to be a professional with lots of experience. Or do the measurement 20x and calculate a statistical standard deviation from that ;-)

28 Room for improvement

So if you would now to improve your surface plate- how would you do this?

First, I would identify the "hi spots" that were shown in all the three diagrams:

- the Planolith ceritifcate
- my first "Final measurement"
- my verification measurement

Even if the diagrams do not agree in any details to each other, they all DO agree, that there are the following areas to be a tiny bit high:

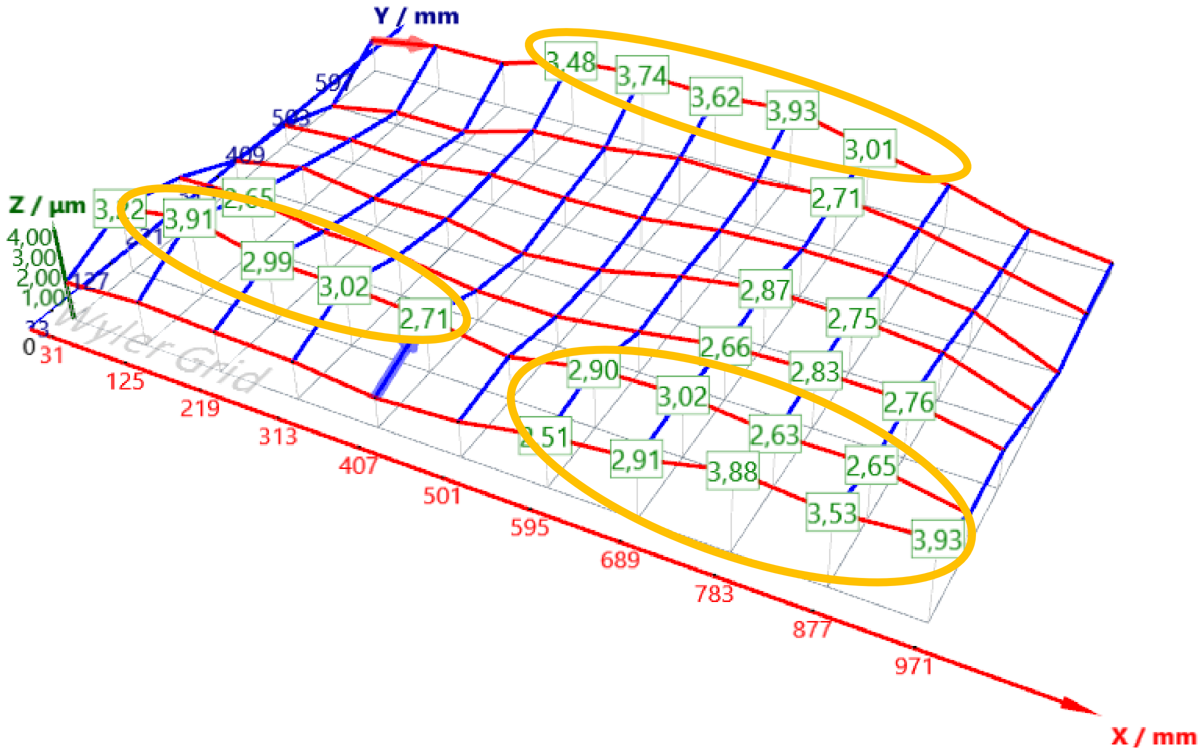


figure 68: areas that are prone for improvement (yellow)! (treshold 2,5µm)

In figure 68 I added a green height label to any grid position that is higher than +2,5µm.

If I move this treshold level to ~3µm, then the biggest areas of "where-to-improve" become quite obvious:

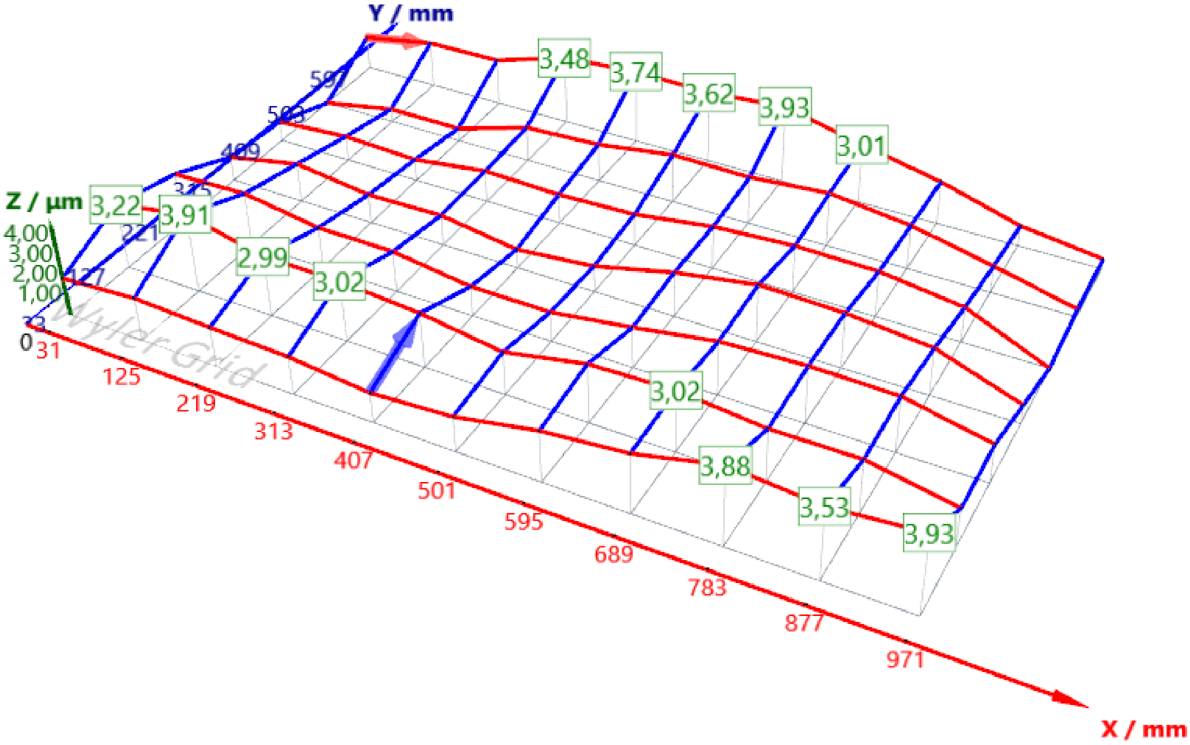


figure 69: picture like before, but treshold 3µm

So if I would have a lapping plate and experience in this lapping process (I would not start to make my very first lapping experiences with my 2 years-old Planolith plate already; I would try it with something older and inexpensive ;-) , then you can easily improve my plate by removing these areas a bit.

But as I do not have neither a lapping plate nor the experience, I will just keep it and by happy being able to verify my plate to be within the DIN876/00 given limits! Great!

29 Fun with "low budget"

I have to admit, that I recently bought a "low-cost" granit surface plate for about 50Euros only. According to the label, its "accuracy" should be within "0,000025 inch".

figure 70: new fun object: a low cost granite plate

That is a strong statement, folks. Because when I calculate this, I end up with an "accuracy" (I guess they mean the flatness with it) of only 0,6µm!

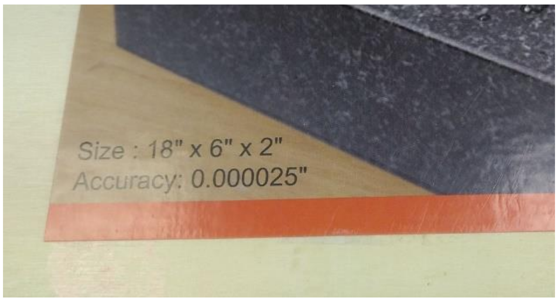


figure 71: encouraging specification!

I use an internet calculator. He gives me the same result:

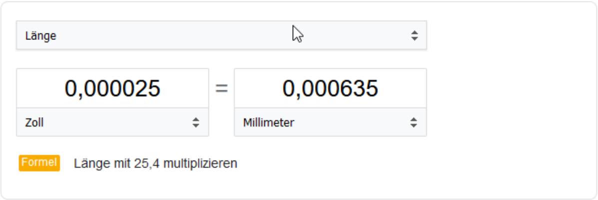
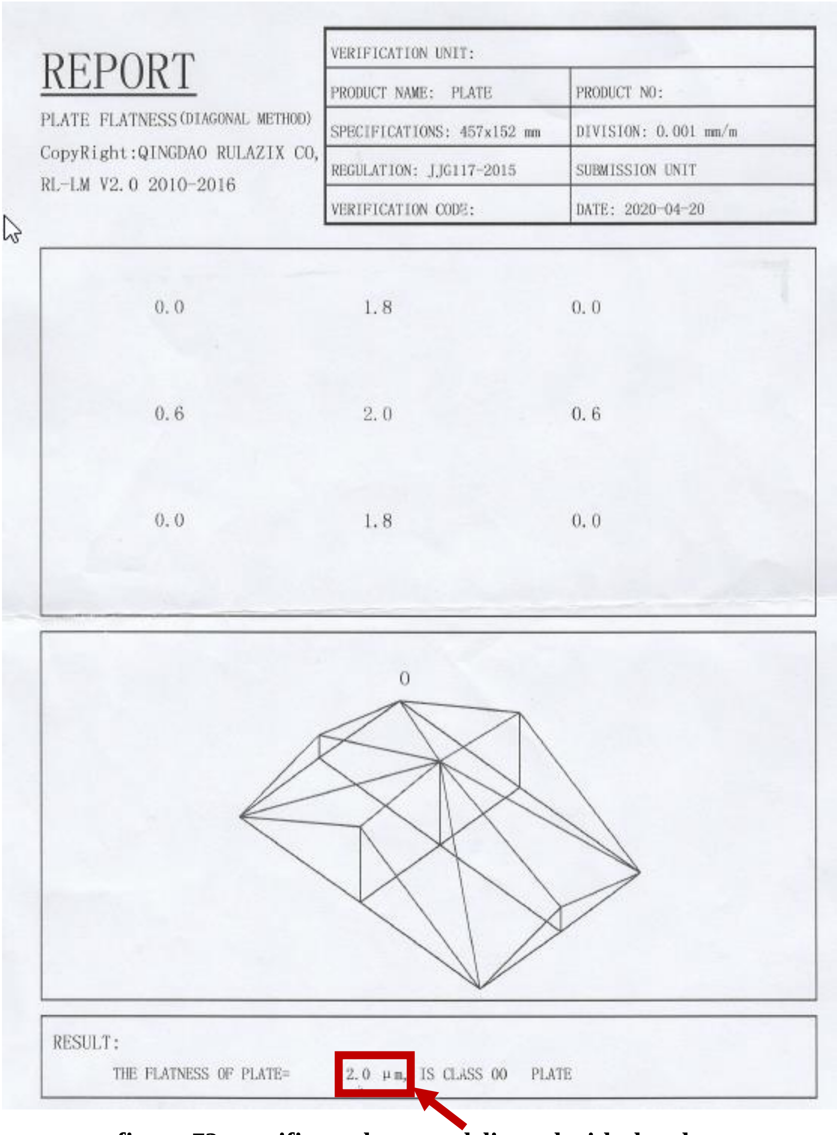


figure 72: conversion to [mm], Source: www.google.com

So we are really talking about 0,6µm. So let's go and have some fun with it and test it.

First thing to do: check the certificate. It looks like that:



REPORT

PLATE FLATNESS (DIAGONAL METHOD)
CopyRight:QINGDAO RULAZIX CO,
RL-LM V2.0 2010-2016

VERIFICATION UNIT:	
PRODUCT NAME: PLATE	PRODUCT NO:
SPECIFICATIONS: 457x152 mm	DIVISION: 0.001 mm/m
REGULATION: JJG117-2015	SUBMISSION UNIT
VERIFICATION CODE:	DATE: 2020-04-20

0.0	1.8	0.0
0.6	2.0	0.6
0.0	1.8	0.0

0

RESULT:
THE FLATNESS OF PLATE= 2.0 μm, IS CLASS 00 PLATE

figure 73: certificate that was delivered with the plate

Funfactor1: I don't know why, but it looks almost as a copy of the certificate of my chinese 300x200 plate (see figure 55). The certificate already tells you, that the plate should have an actual flatness of 2µm although the sticker on the case promises you 0,6µm... hmmmm...so they give you a statement on the parcel sticker and alreay in the test report they are contradicting themselves??!?!??

Strange...

But it will become even better :-)

Let's to the next test. Bridge a precision scale across it and make a leakage test with a light source behind.

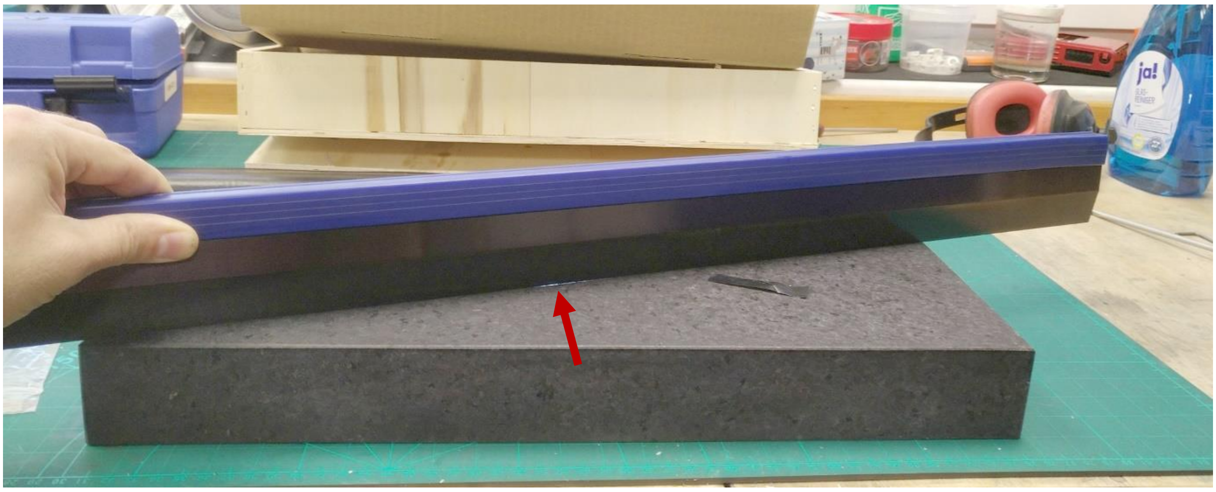


figure 74: light test

So you can see light in the middle. Although my 10µm feeler gauge does not go under it (so the gap is supposed to be smaller than 10µm), this result does absolutely not match to the graphics given in the certificate.

Funfactor2: The shape of the table is concave, whereas the certificate shows a convex shape!

Again: strange. But let's continue the visual inspection of the plate. I turn it around and...

....huhh???? What is that?

figure 75: black on top, white on bottom???

A granit plate with black granite on the top and white granite on the downside?

Funfactor3: the surfaces have been black painted in the factory. In truth, it is a white coloured granite. Or....is it really actually granite??

Now I make the ultimate fun test: I will measure it with my levels!

First, I need to install it on my reference plate and put it on three points- as you should do with any granite plate, if you expect some precision.

figure 76: resting on 3 defined points

As there are no markings on the plate or the certificate where exactly to place my three ball stands, I estimate their Bessel points and place them in their typical arragement.

Then I take some time to bring it in level. The Wyler A10's need to be leveled within 50µm/m to work within specification. I use my 20µm/m Röckle level to verify that. So in X and Y as well are maximal 2,5 ticks of the scale allowed (2,5*20µm/m=50µm/m).

figure 77: leveling the plate before measurement

That does not look bad. It's about 20µm/m only.

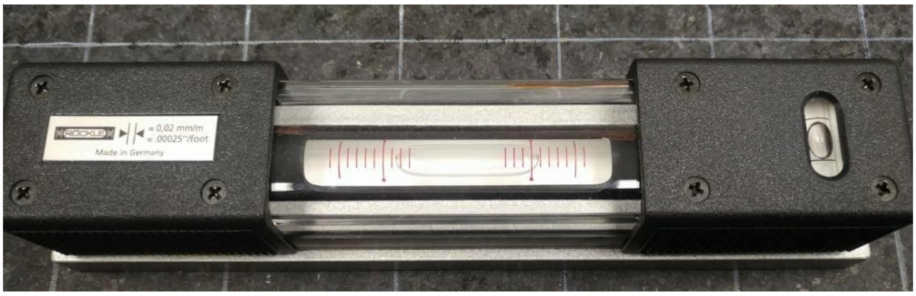


figure 78: leveling

So measurement can start. I use my 100mm level as reference and the 50mm-level as MEAS-level this time, so I get a better resolution (=finer grid). I have at least 44mm step width in both directions.

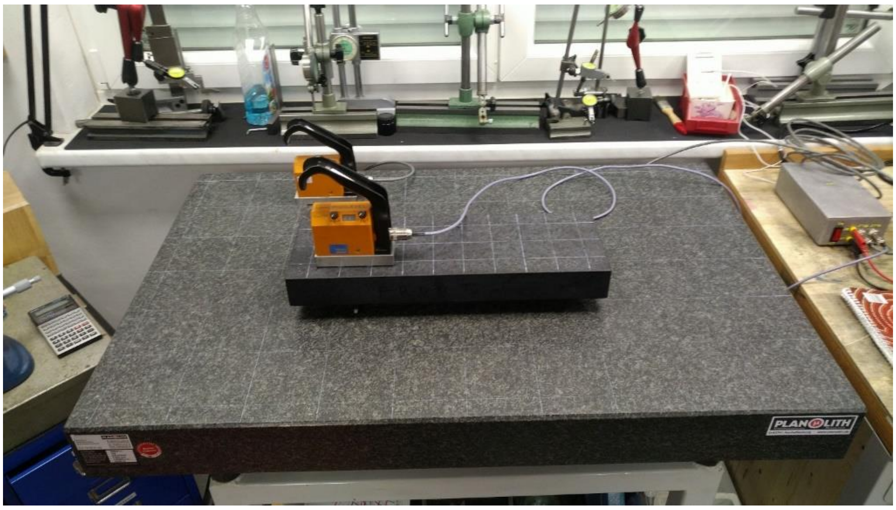


figure 79: we start the measurement!

The temperature is about +21°C, so quite ideal for measurement and all plates have been thermally untouched for hours, so should all be stable.

I get this result:

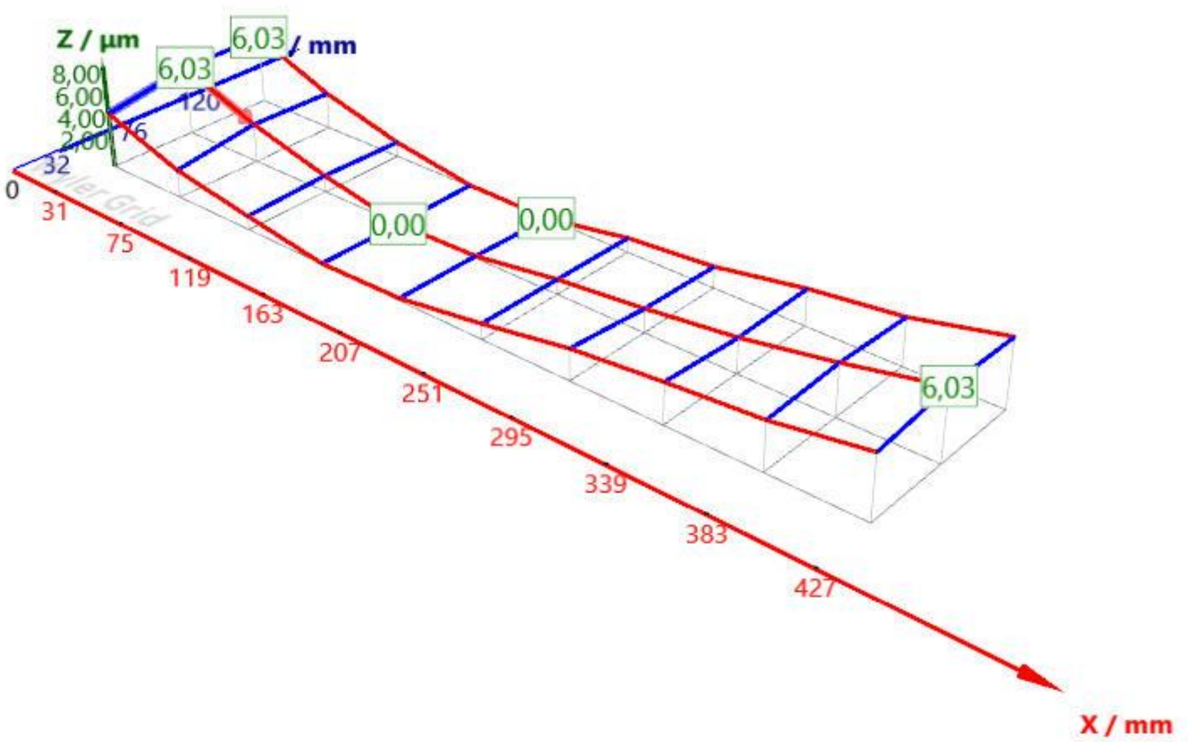


figure 80: test result (=Funfactor 4)

Guys, that is really fun! :-)

Especially of you compare my result with the certificate that they give you with this plate:

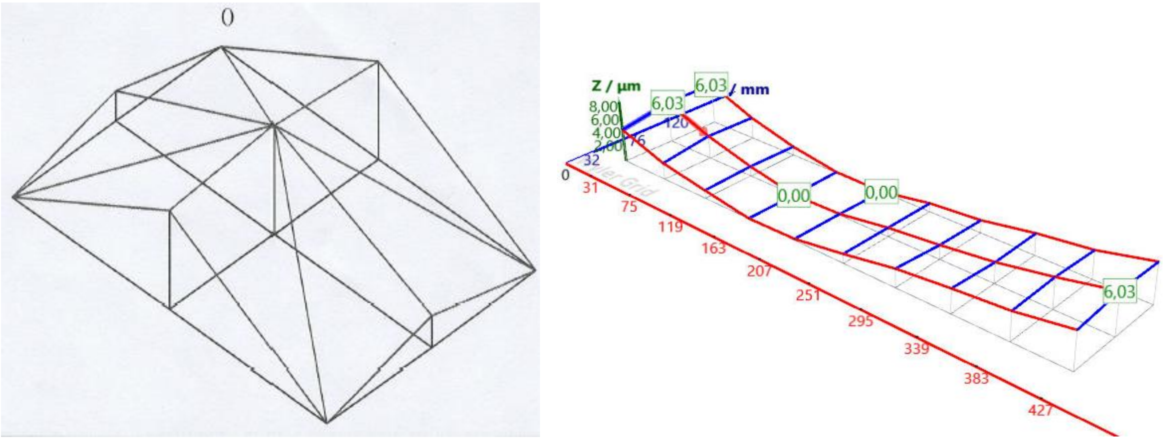


figure 81: left: manufacturer; right: my own measurement

If you compare this now to the certificate of my Planolith plate (see chapter 26), then you can easily see, that this situation is totally different. Whereas in the case of my Planolith the certificate they gave me is really very similar to my own results, this one here is completely out of discussion.

You could argue now, that the testing method of the left ist different (they use the union-jack method and I used the Wyler Grid), but this no explanation for the completely different test result. It is not even similar.

My explanation: the test report they give you is probably not an individually measured one, but just an example of the typical performance of flatness of their products. It is a generic one, so somewhen in the past measured (or invented ;-) on one master plate and then copied and add as an "test protocol example" to their products. But doing this way, it is completely useless for any serious toolmaker. Even more: it is actually even misleading!

30 Check of my 500mm straight edge

I have now measured all my granit tables and still a couple of days left of the 14day trial period for the Wyler software. So I make use of it and measure all of my linear straight edges. It's a good training for me as well and at least very worthful to have this evaluation!

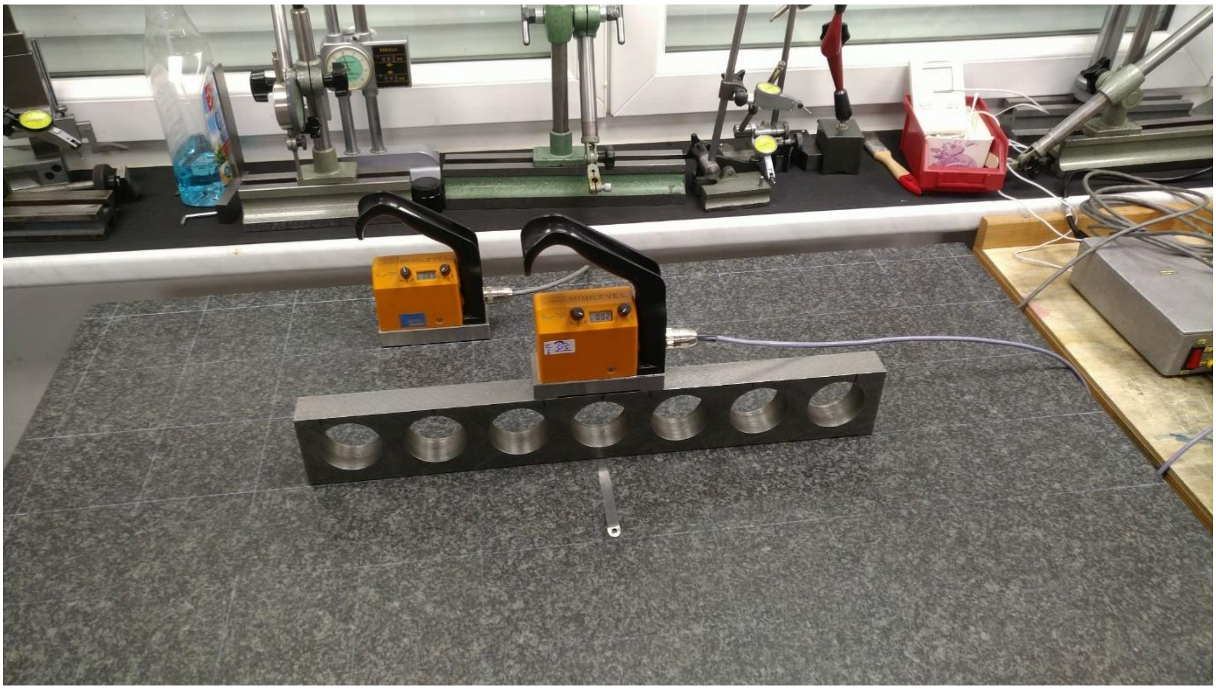


figure 82: test setup for 500mm StraightEdge measurement

The straightedge given in figure 82 is completely homemade. It came as 500mm chunk of gray cast iron. Without have a functional mill, I did all machining by hand, scraper or drillpress. Was a lot of work, so being very curious about the result.

The first side looks like this:

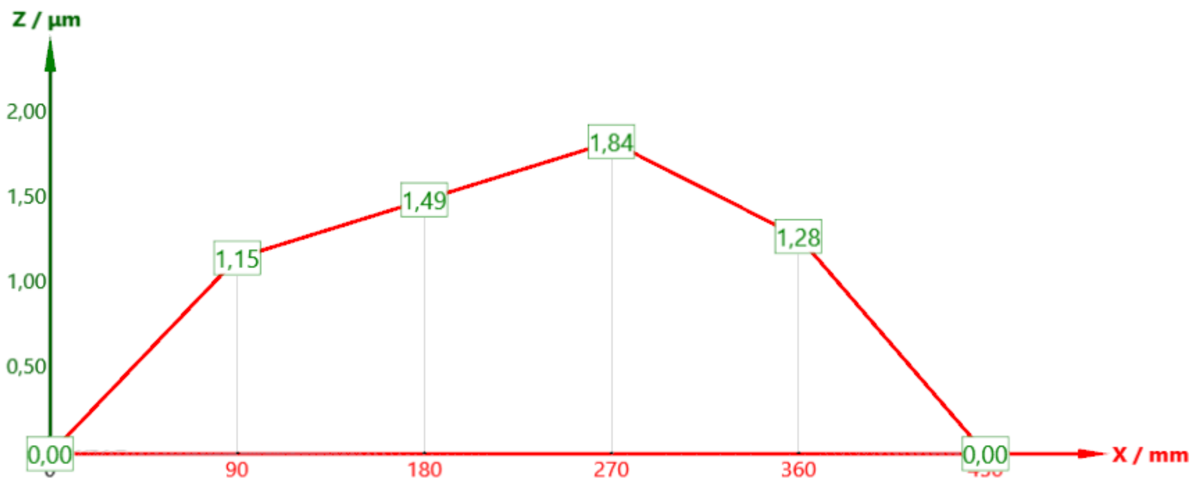


figure 83: top side (side without chamfer)

The bottom side is scraped as well and looks like this:

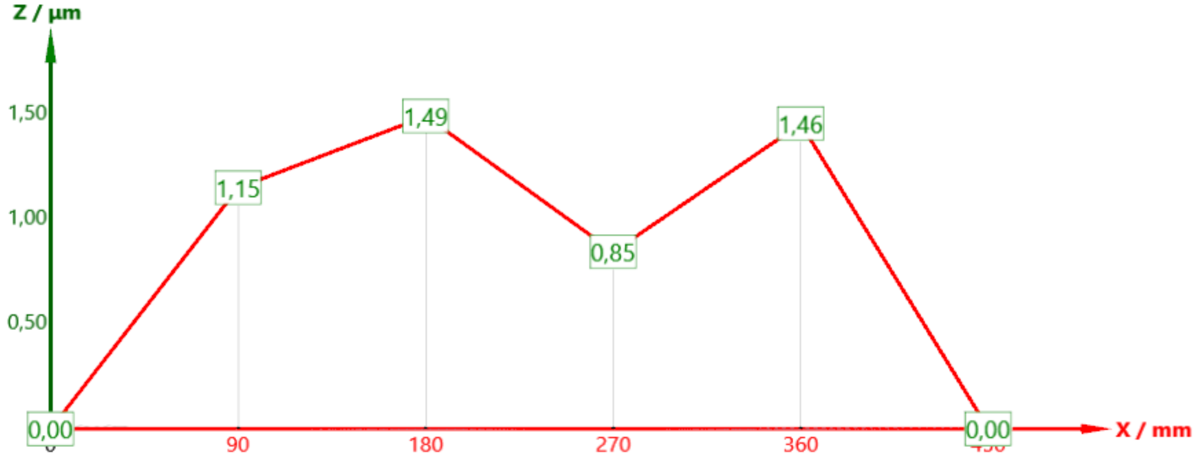


figure 84: down side (side with chamfer)

So both sides are at least below 2µm of flatness wich would fulfil DIN876/00 (max. 3µm) and makes me very happy!

I need to add, that for this kind of precision measurement it is essential not only to level the workpiece in X, but also in Y- even if you only want to measure in X!

I made some very bad experiences, how much effect on the reading a level has, which is not 100% exactly parallel with the X axis. Only 1 mm off axis causes the reading to deviate for even several µm!

To overcome this problem, I also do align the workpieces in X and Y. A set of feeler gauges in different sizes are very helpful to put it under the part and get it levelled.

figure 85: alignment in Y

31 Check of my 750mm straight edge

Also my 750mm straight edge is probably homemade - but not by me. I bought it used and scraped it to precision afterwards.

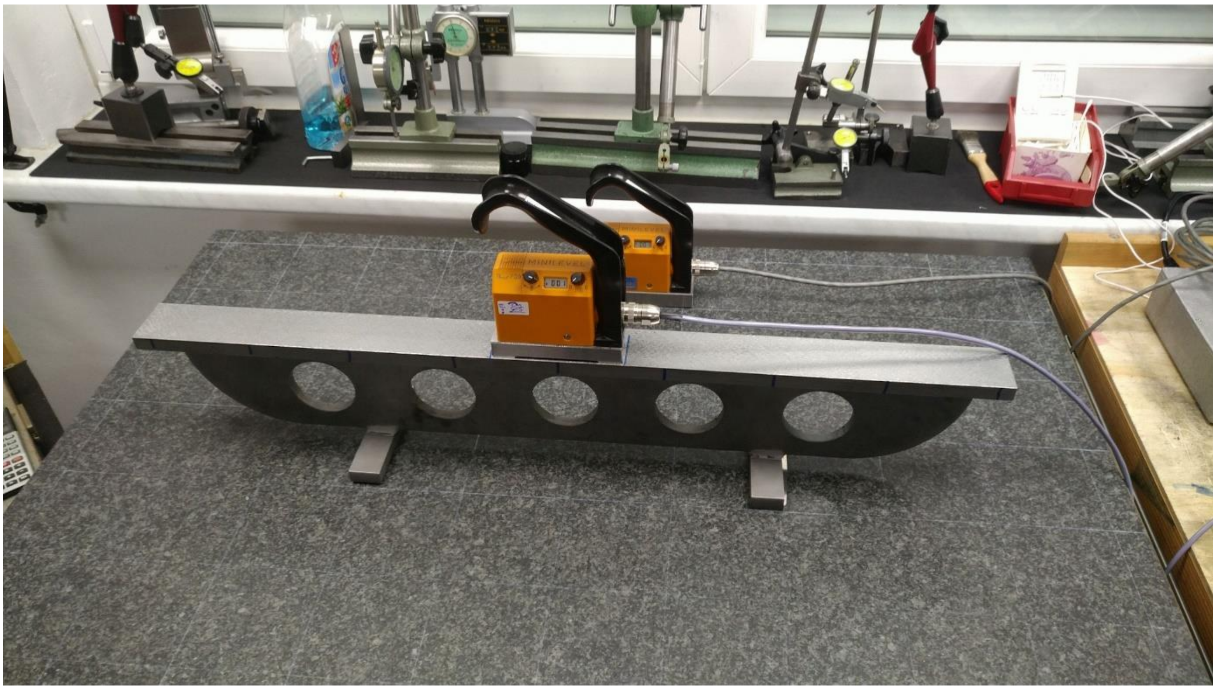


figure 86: my 750mm straight edge

I perform in total 5 runs, whereas the very first two have been messed up to a rocking test setup. With the use of the feeler gauges I can stabilize it and get three measurements that are very close to each other (3,11µm / 3,06µm / 2,81µm).

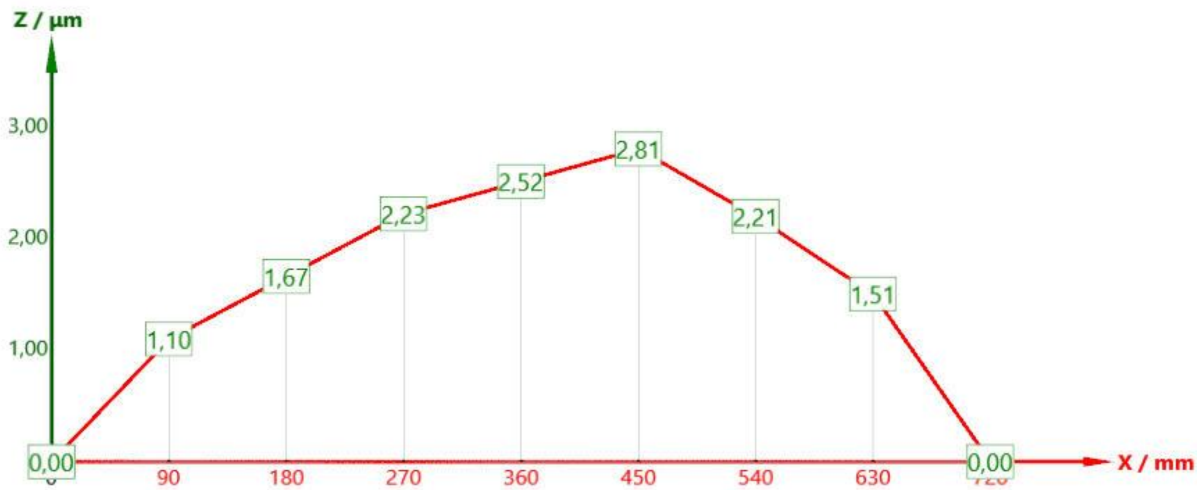


figure 87: flatness of my 750mm straight edge

The value itself with about 3µm un-evenness is not too bad, but I do not like the shape of the curve. It is convex because it is high in the middle. I would prefer to have at least a curve more like figure 84. Nevertheless the straight edge would be still DIN876 grade 00! (4µm allowed)

32 Check of 1000mm straight edge

Next straight edge. A quality brand one with a length of total 1000m. It is already quite heavy, so I had my fun lifting it on the table and align it.

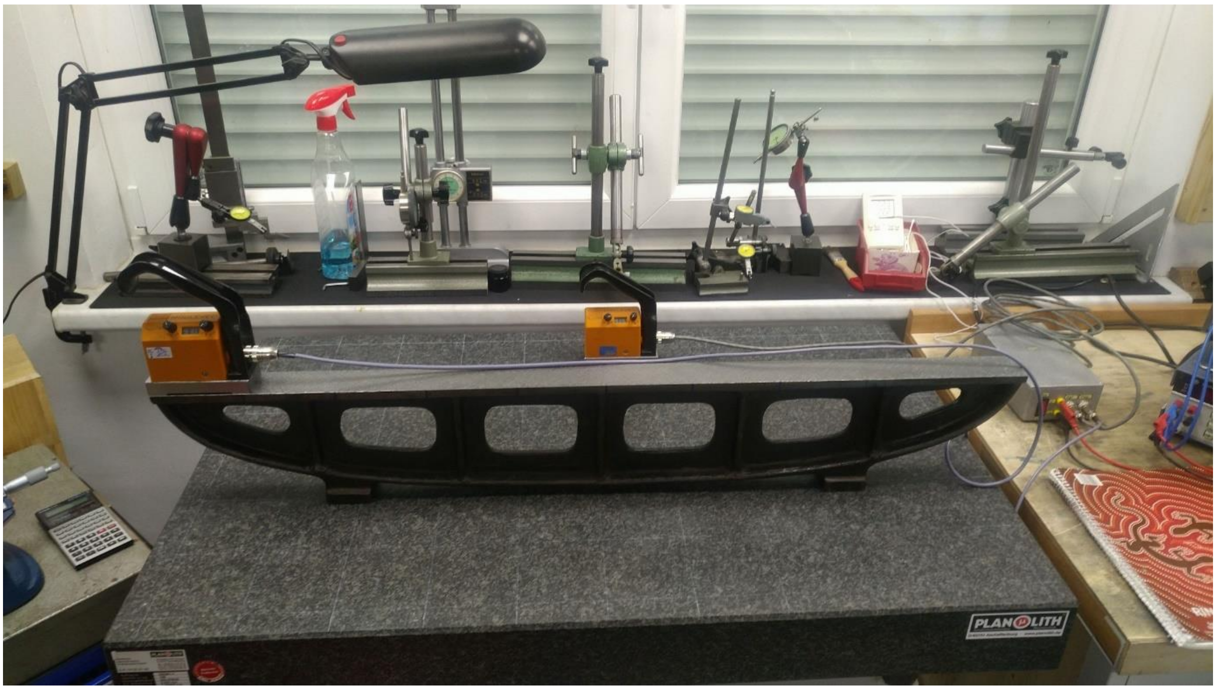


figure 88: straight edge 1000mm on the granit table

With this one, I make a few measurements and check some effects. First, I measure the part 3times the same way. Let's see, how reproducible our measurings are.

First run: 5,30µm max.

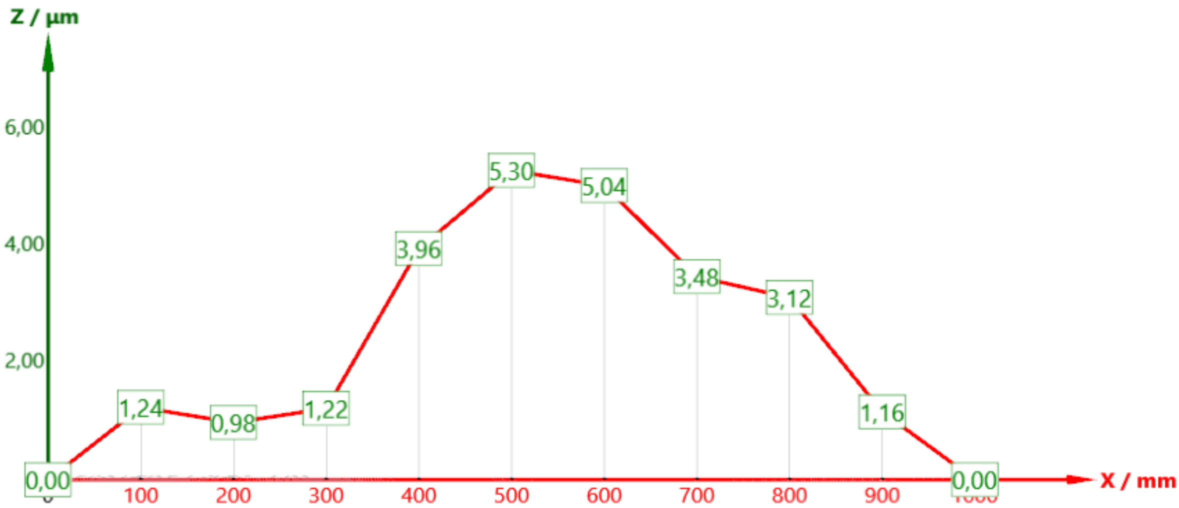


figure 89: Run 1 of 3

Second run: 5,1µm.

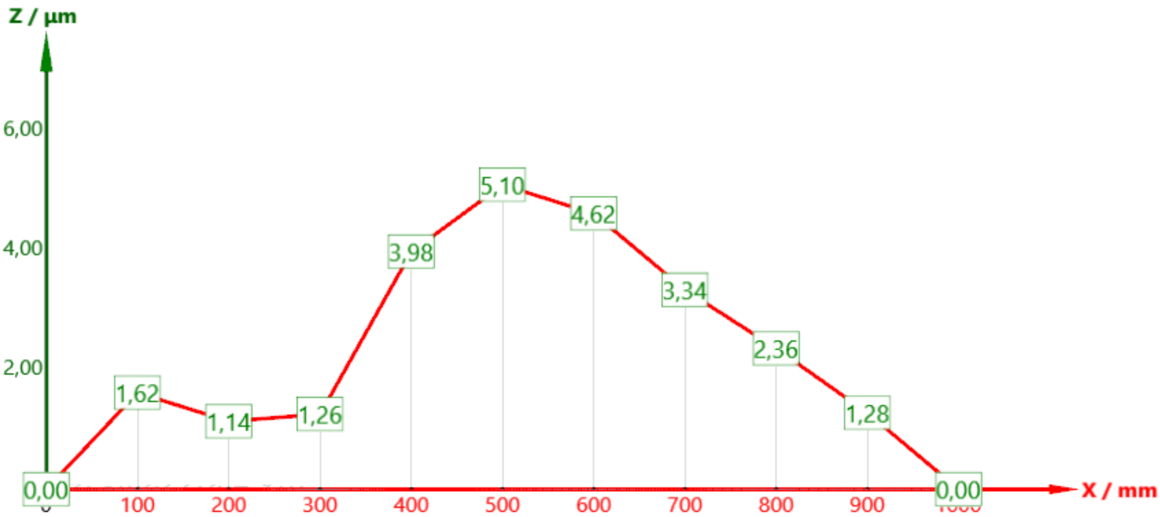


figure 90: Run2 of 3

Thid run: 5,3µm again. Wow! Extremely well reproducible!

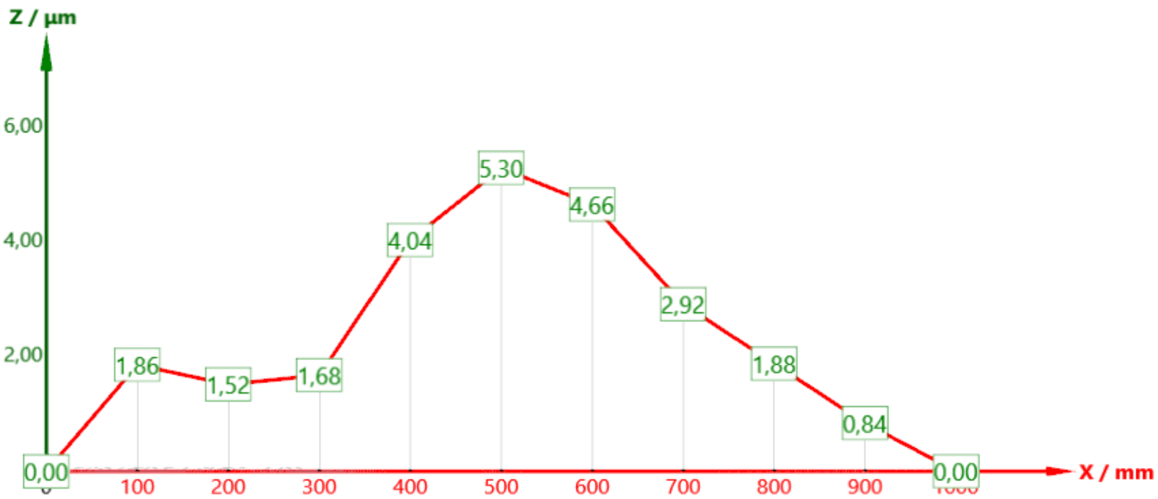


figure 91: Run 3 of 3

DIN876 would ask for a max of 4µm for grade 00; max 8µm for grade00. So this one should fulfil DIN876/0 which is not too bad.

Next, I stone the surface intensively with a set of precision ground flatstones and measure again.

The result is: 5,6µm. I cannot see any other relevant effects of my stoning.

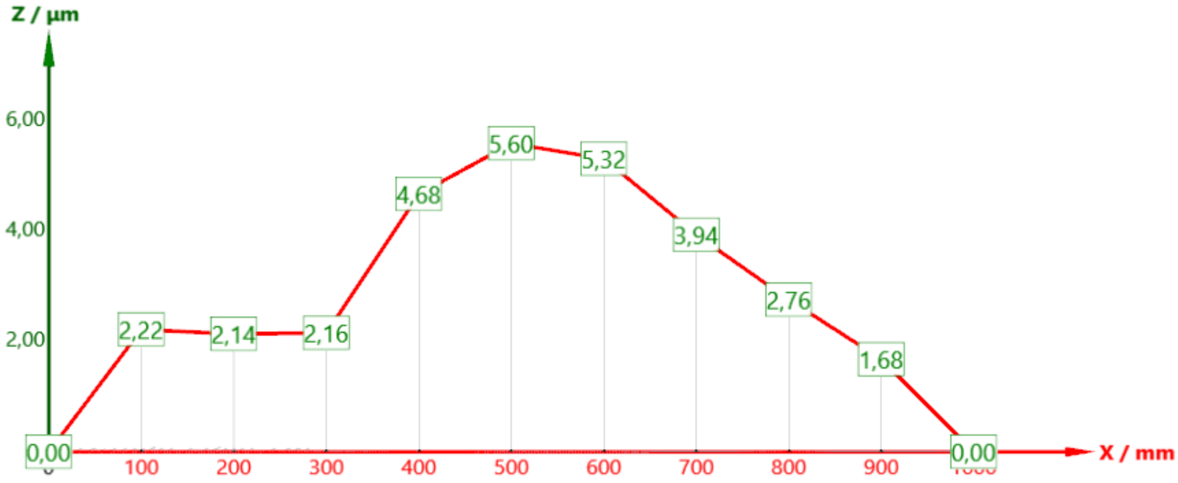


figure 92: the same, but after stoning with precision flat stones

Finally, I do something that does not automatically agree with everyone's opinion, but as I saw this in a couple of youtube videos now, I am very curious about the result: hammering!

As I said: you can be of different attitude to this, but the main idea behind that is supposed to somehow "release" the inner stress of the material- like you also would do with heat treatment. At least when tuning a mechanical piano, I know a similar technique that -after having tuned the string- you give the "adjustment screw" a gently tap backwards(!)- to release some mechanical stress out of the system. If done with care, this really does not affect the tuning of the string- but removes unwanted torque to the adjustment scew (which is definately not the correct english term the I use here ;-). Finally you really hammer(!) with your fingers into the keyboard with fortfortfotissississimo! and hit the tuned note as hard as you can for a dozen of times- this also helps to distribute the tension of the tuned string along the complete length and into the clamping mechanics of the piano.

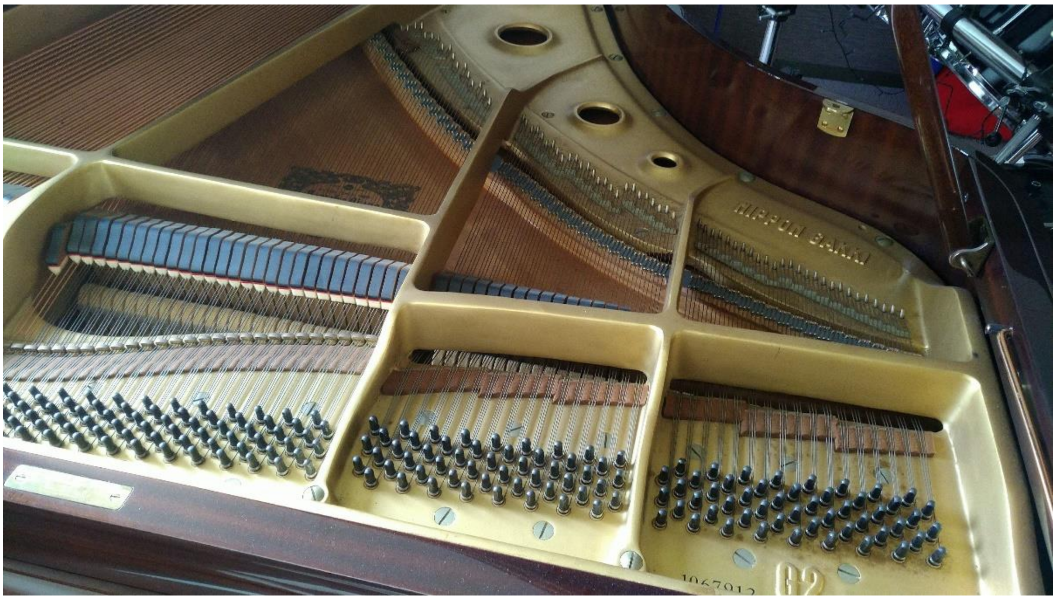


figure 93: "hammering" is also performed when tuning a piano! (here: my Yamaha G2 grand piano)

So the idea behind this "**hammering**" is similar here: you see the guys hanging their straight edge vertically to a rope and hammer it hardly with a rubber hammer. The straight edges "dings" and "dongs" and this shall release its inner stress as well.

But is this moreoreless "voodoo" or can you really measure a positive effect after having hammered your workpiece?

I tried it out. I took a small rubber hammer and got the straight edge a few "dings"- as I have seen it in the videos. Then I measured it again.

The result is like this:

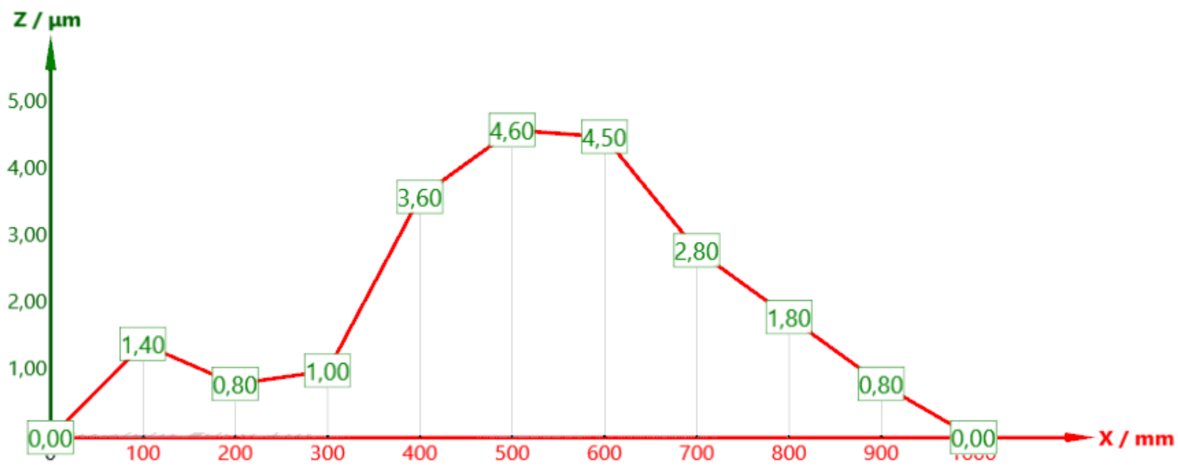


figure 94: after stoning and hammering with plastic hammer (de-stressing)

What a surprise!

The flatness improves from 5,6µm to 4,6µm- just because of the hammering!!! Guys, be honest- did you have expected that?

As I heard, -and already said before- the topic "hammering" seems also to be debated even under experts. I do not want to start a global discussion about the sense and effectiveness about this topic. I just did my own experiment (and only a single time), so that is most probably by far not enough to prove this theory. But in this single experiment I see an improvement of the flatness of almost 20% that cannot be explaned just by variation of my test series. So the result really strengthens the idea, that "hammering" could indeed have a positive effect on straight edges!

But I always try to respect different opinions, so you are free to build your own one. For me, it was just a very intersting and astonishing experiment :-)

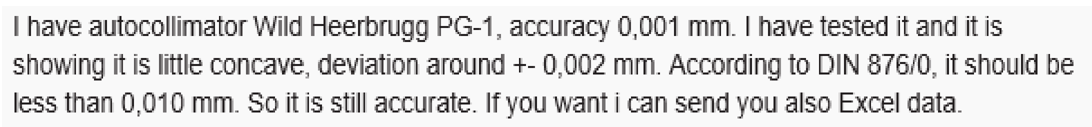
33 Check of my 1500mm straight edge

If you believe, that I already stop with just 1m of metal, then you don't know me well ;-)

I also own actually a 1,5m long, about 40kg heavy Hahn&Kolb straightedge!! This is my "monster" and everytime I use it, I get pain in the back the next day. The monster always "bites" into my back, so I have to confess that I keep it in my roller cart almost all the time. But nevertheless it is cool, just to have one, so let's measure it as well!

figure 95: test setup for my 1500mm straight edge

I bought this part from a guy in slovenia. I really admire the efforts of all the postmen handling this monster box to germany into my house. The seller told me this:



I have autocollimator Wild Heerbrugg PG-1, accuracy 0,001 mm. I have tested it and it is showing it is little concave, deviation around +- 0,002 mm. According to DIN 876/0, it should be less than 0,010 mm. So it is still accurate. If you want i can send you also Excel data.

figure 96: statement of the seller

So- will we be able to confirm his statement?

Yes, we can!

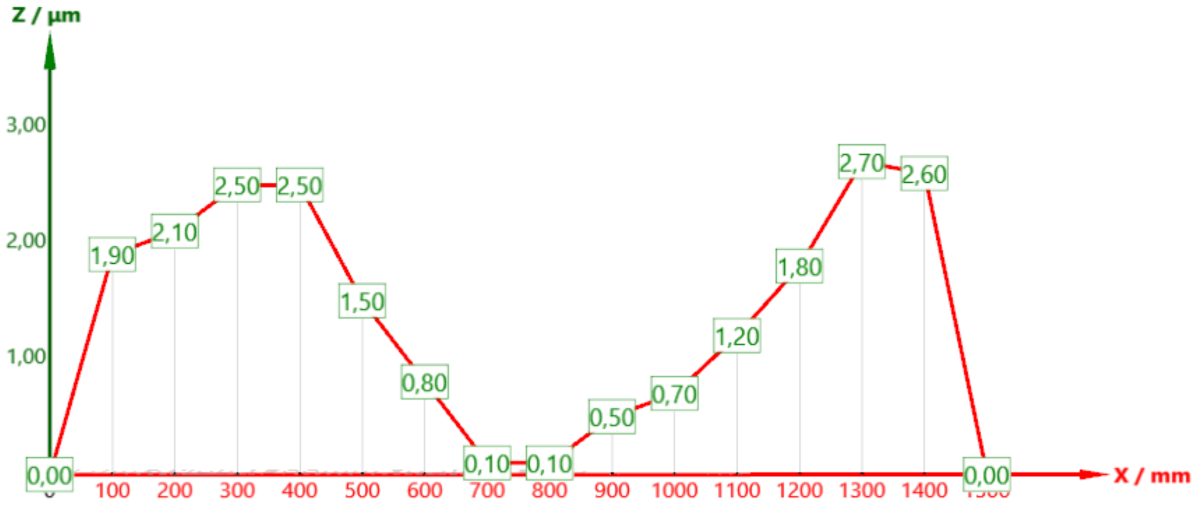


figure 97: flatness of my 1500mm straight edge

According to my measurement it is even a bit better than the given +/- 2µm (=4µm). I can totally confirm the concave shape of the surface and with a max value of less than 3µm it does easily fulfil the seller's promise.

He also sent me an Excel sheet with the values, but I must confess, that I cannot understand his testing method. I looks like he did not perform a chain measurement as a series of overlapping sinlge measurements, but did some "interlaces" inbetween. I do not know this method, and neither the diagrams nor his calculation do show any physical units, so I was not able to re-engineer his Autocollimator-measurement.

But it does not matter: my "monster" is well within 3µm wich would even fulfil a DIN876/00 grade (5µm for 1500mm allowed)!

34 Cast Iron plate 400x300mm

In two days my trial license of the wylerSPEC software will expire and I am not sure, when I will be able to re-install this software again. So I better make use of it as good as I can. For "normal" straight edges, who do not necessarily require some closing-error-calculations, I still can do the measurements and analysis in Excel with some self-made templates. But for plates, I hardly can't do it without this software.

So I conclude to also measure the last item that I have: a cast iron plate which I bought used on an internet fleamarket. Its size is 400x300mm and it is labelled at the left side with "DIN876/2", so we can expect maximum 28µm "un-flatness" for this unit.

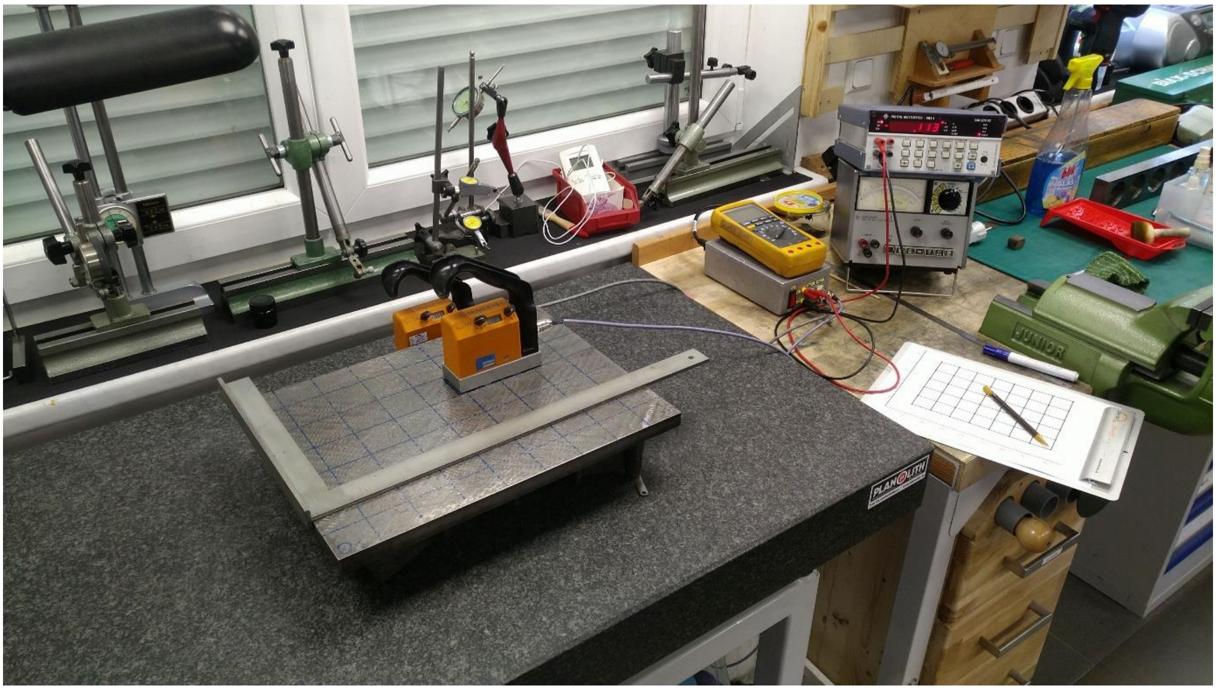


figure 98: measurement of my cast iron plate

My first check with the clone-o-meter (see figure 36) already identifies some falling surface towards tweo of the corners. But because of the realtively small size of the plate, it is not so easy to really swivel around that much, so most of it will be now up the the measurement with the Wyler levels.

So I do the test as usual. The correct levelling of the cast iron plate prior to the measurement has turned out to be very important, so I do this with care.

The result after the measurement is this:

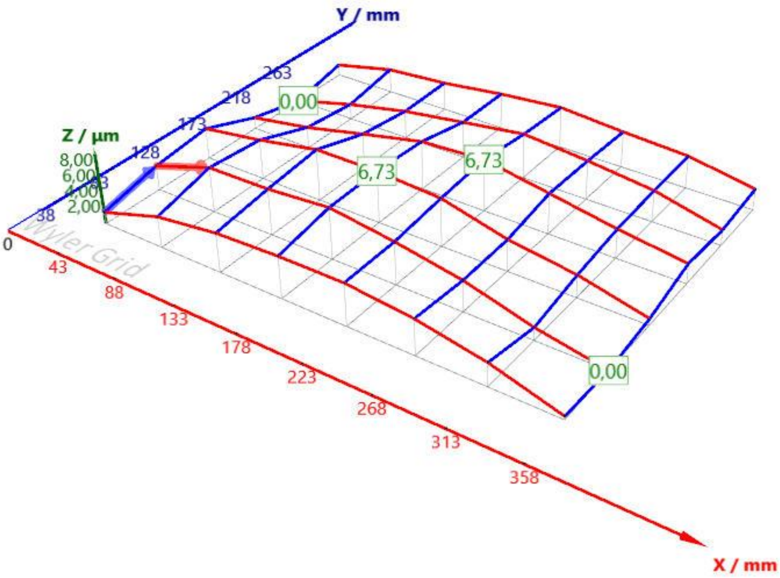


figure 99: result of the cast iron plate

The closing error in the end will be 1,71µm and the rating of the plate will be even DIN876/1!

And another extremely interesting thing: with a maximum flatness error of 6,73µm this plate is only 730nm away from DIN876/0! How cool is that! :-)

The entire look of the result is a quite homogenous convex shape that remembers me of a bridge.

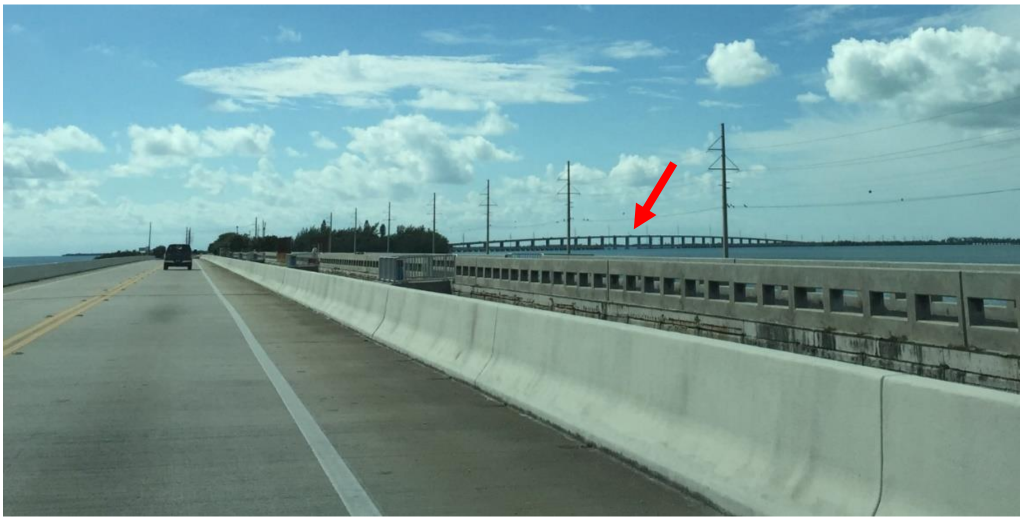


figure 100: this bridge on the way from Miami to key west has the same shape- maybe it's DIN876/1000? :-)

35 Measurement of 24hrs-drift

So-to-say "as a bonus", I also checked the 24hrs-drift of the levels a bit more seriously than I already did in chapter 13. I want to see the behaviour of the drift over 24hrs, see the trends and drift change rates as a graphical plot, not only just as a single reading after 24hrs. So how to achieve that?

Easy!

I own two HP34401 6,5digit multimeters which are remote-controllable via IEC-625 (=IEEE488 = GPIB = HPIB) interface bus. This is a data interface that is very often used in the area of electronical measurement stuff. Both of my HP34401 also do provide this interface.

figure 101: HP34401A multimeter

So I used them as "data logger" and recorded their measurements for 24hrs. An old PC (still running under MS-DOS 6.22!) with a programmed software in RS-BASIC (!) acted as controller to initiate the measurements each 30seconds, and stored them to a *.csv-file on the harddisk. The multimeters have been connected to the analog outputs of the two levels who have been placed on the chinese plate in the window sill. This has the disadvatage of being close to the windows itself (which is more dependent to temperature changes outside than in the inner of the room), but it has one unbeatable advantage: this place is not moving! For anyone to understand the reasons why- see next Bonus Chapter :-)

figure 102: drift test station in the window sill

So I ran the programm and took the measurement on the 28FEB2021. It ran the complete 24hrs in my electronics lab, where there is normally no risk for interferences, disturbance of running people, etc..

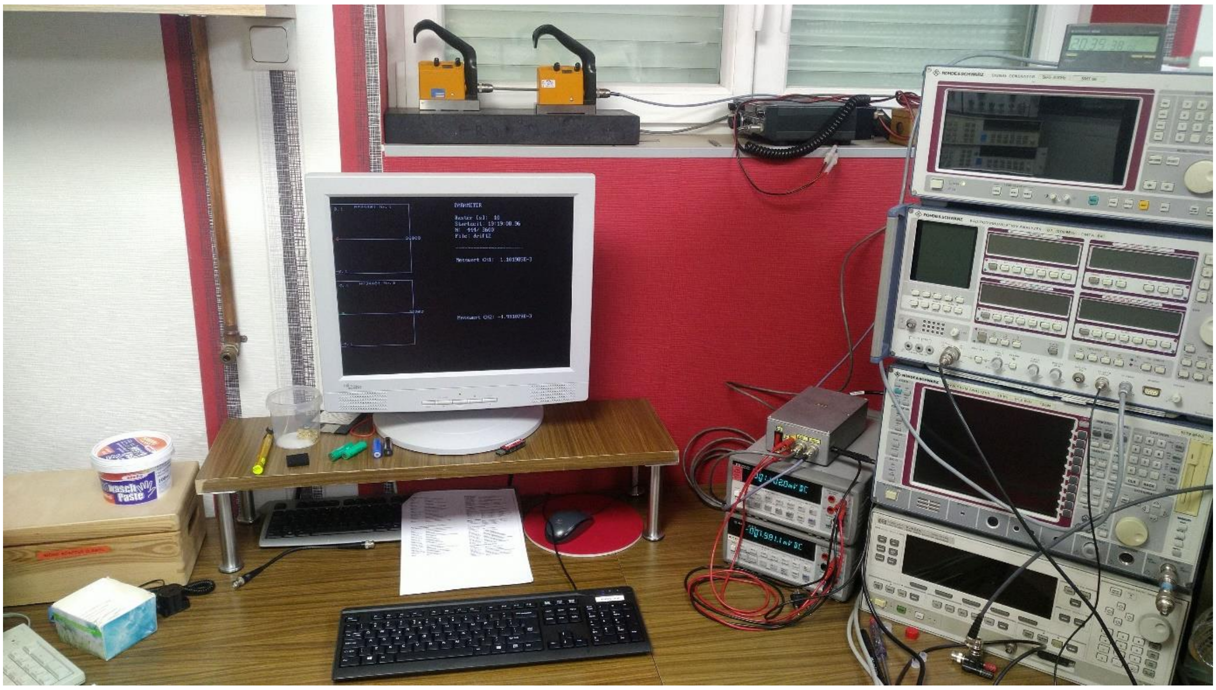


figure 103: drift test station

And: there is no heater in this room, as I have to share this chamber with the central heating system of our house. This small amount of heating leakage is enough to always keep nice and comfortable temperate of about +21°C in the room. This makes it ideal for my measurement.

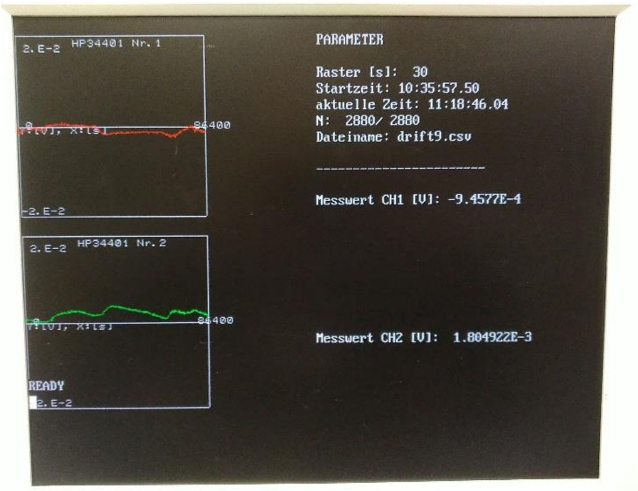


figure 104: this is how my software looks like

But now let's have a look to the result!

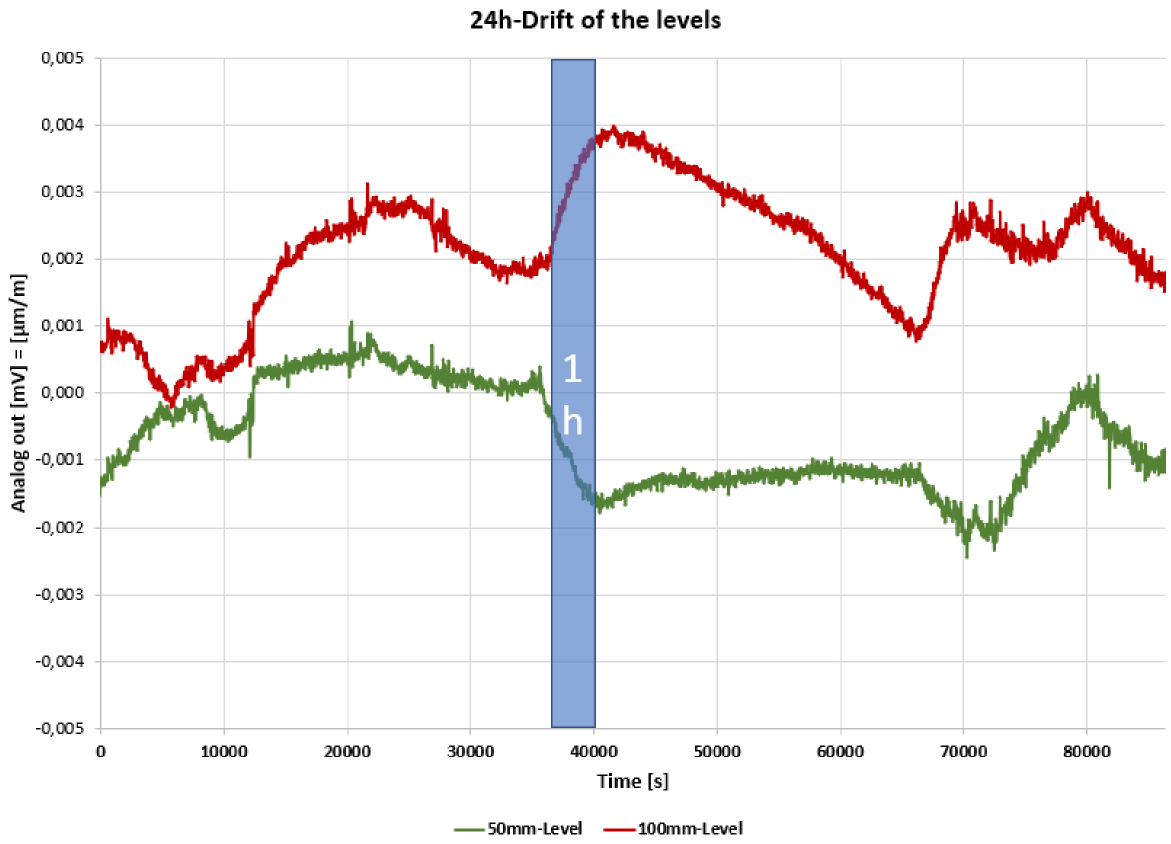


figure 105: result of the 24hrs drift test

The levels are specified as having a maximal drift rate of 24counts = 24mV = 24µm/m within 24 hours. So that means, they are allowed to vary in a range that is more than 5times bigger as we can see here.

As I have learnt now, a measurement of one axis of my granit plate typically needs a bit more than 30minutes. So if you consider the "unlucky" case that you are interrupted somehow (by your wife;-) and need 1hour of continuous measurement. How big can the drift effect be in maximum?

You could now run statistical tools or calculate the Allan deviation to this graph, but I will do the simplest method: I eyeball a blue box in the graphic that represents a 1hr time interval and optically find the worst condition. This is -for sure- the case when both graphs have the highest gradient - and in our case they even have opposite direction! So that is really the worst worst-case.

If you would have single measurement, it looks like the slope of one level can be ~2µm/m per 1hour. So the reading can vary for 2 Millivolts just because of drift.

But in differential measurement, unfortunately this will be worse in our case: due to the fact, that both level drift into the oppisite direction (2mV each), we have a resulting drift of

4µm/m per hour!

That is still acceptable, (for sure very easy still in spec), but nothing, that makes us happy. It also would be nice, to understand the reasons for drift effects that seem to start suddenly or even random, but to identify that triggers, there would be a lot of more equipment and time necessary that I cannot spend, sorry. The influences could not only be thermal incidents, but also variating supply voltage, or aging effects in the electronics. Remember, that these levels are probably more than 30years old- and in general still are functional!

36 my HP34401 drift test software

In case you also want to use my HP34401A logging software for your own projects, here is the listing. It is written in RS-Basic, which still requires line numbers.

I need to say that I am absolutely no SW application expert, so I will definately violate a bunch of sw design rules. But this one did work for me and it even is able to handle the real time clock of the PC to reset at midnight when being in the waiting loop.

You may use the SW as you want, but no guarantee and no promise for correct behavior, ok?!?!? :-)

```
10 'Programm zum Einlesen von Spannungswerten mit 2xHP34401
20 'M. Michalzik, for private use only!
25 REM Version 1.0, 26FEB2021
30 REM ------------------------------------------
35 REM Parameter- und Einheitendefinition
37 REM ------------------------------------------
40 Adr1=22: REM IEC-Adresse HP34401 Nr.1
41 Adr2=17: REM IEC-Adresse HP34401 Nr.2
50 REM ----- Einheiten---------------------------
51 Mw1_x=0: REM X-Komponente Messgeraet 1 [s]
52 Mw1_y=0: REM Y-Komponente Messgeraet 1 [V]
53 Mw2_x=0: REM X-Komponente Messgeraet 2 [s]
54 Mw2_y=0: REM Y-Komponente Messgeraet 2 [V]
55 Mw1_xdavor=0: REM wie Mw1_x, aber einen Takt zuvor
56 Mw1_ydavor=0: REM wie Mw1_y, aber einen Takt zuvor
57 Mw2_xdavor=0: REM wie Mw2_x, aber einen Takt zuvor
58 Mw2_ydavor=0: REM wie Mw2_y, aber einen Takt zuvor
60 REM -----Parameter fuer Diagramm-----------
70 Y1_min_volt=-0.02: REM Bereich Grafik Ch1
71 Y1_max_volt=0.02: REM Bereich Grafik Ch1
72 Y2_min_volt=-0.02: REM Bereich Grafik Ch2
73 Y2_max_volt=0.02: REM Bereich Grafik Ch2
74 X1_min_s=0: REM Start bei t=0
75 X1_max_s=1: REM Dummywert
76 X2_min_s=0: REM Start bei t=0
77 X2_max_s=1: REM Dummywert
80 REM --- IEC Anweisungen ------
81 IEC TIME 5000
82 IEC TERM 10
90 REM
99 REM --------------------------------
100 REM Benutzerabfrage
105 GOSUB Bildschirm_leeren
110 INPUT "(1) oder (2) HP34401 Geraete angeschlossen? ",Anz_messgeraete
120 GOSUB Hp34401init1: REM initialisiere erstes HP34401
130 IF Anz_messgeraete=2 THEN: REM initialsiere auch zweites HP34401
140    GOSUB Hp34401init2
150 ENDIF
160 REM ----------
169 REM ----------
170 INPUT "Anzahl der Messungen (max. 65535): ",Anz_messungen
175 PRINT "Hinweis: Zeitraster exklusive(!) Zeit fuer Messwerterfassung!"
180 INPUT "Zeitraster [s], (1..65535): ",Traster
181 X1_max_s=Anz_messungen*Traster: REM Autorange in X
182 X2_max_s=Anz_messungen*Traster: REM Autorange in X
190 PRINT USING "####.#","Laufzeit [min]: ",Anz_messungen*Traster/60
199 REM ----------
200 INPUT "Datei anlegen (1=ja/0=nein)? ",Dateianlegen
201 IF Dateianlegen=1 THEN
202    INPUT "Dateiname: ",Dateiname$
203    INPUT "Bemerkung: ",Bemerkung$
204 ENDIF
219 REM ----------
220 INPUT "Start -> RETURN,     (A)bbruch",Losgehts$
230 IF Losgehts$="a" OR Losgehts$="A" THEN STOP
240 REM
279 REM ---------------------------------------
280 GOSUB Bildschirm_leeren
```

```
281 GOSUB Diagramm_aufbauen1: REM Grafik Ch1
282 GOSUB Diagramm_aufbauen2: REM Grafik Ch2
283 Startzeit$=TIME$: REM fuer Dateikopf
284 IF Dateianlegen=1 THEN GOSUB Dateioeffnen
299 REM ---------------------------------------
300 REM HAUPTSCHLEIFE
310 FOR N=1 TO Anz_messungen
320    GOSUB Mwrx1: REM Messwert Geraet1 holen
330    IF Anz_messgeraete=2 THEN GOSUB Mwrx2: REM Messwert Geraet2 holen
340    IF Dateianlegen=1 THEN GOSUB Werteschreiben
350    REM Koordinaten berechnen fuer Grafikausgabe
360    Mw1_x=N*Traster: Mw1_y=Mwrx1
370    Mw2_x=N*Traster: Mw2_y=Mwrx2
380    GOSUB Channel12_ausgabe
390    GOSUB Mw1_setzen
400    IF Anz_messgeraete=2 THEN
410       GOSUB Mw2_setzen
420    ENDIF
430    REM
440    REM
450    REM
460    Wartezeit_s=Traster
470    GOSUB Warten_s
500 NEXT N
510 IF Dateianlegen=1 THEN GOSUB Dateischliessen
999 END
1000 REM ------------------------------------------------------------
1010 REM ab hier Subroutinen
1020 REM ------------------------------------------------------------
1200Warten_s: REM Warteroutine, auch bei Tagesuebergang
1205 Zweiteiliges_warten=0: REM 0=ohne, 1=mit Tagesuebergang
1210 REM Eingangsvariable: Wartezeit_s
1220 Wartezeit_10ms=Wartezeit_s*100
1230 Astart_10ms=TIME: REM aktuelle Systemzeit in 10ms nach Mitternacht
1240 Astop_10ms=Astart_10ms+Wartezeit_10ms: REM Stoppzeitpunkt Warteschleife
1250 IF Astop_10ms>8640000 THEN Zweiteiliges_warten=1: REM Tageswechsel!
1260 REM Berechnung der Aufteilung bei Tageswechsel
1270 Wartezeit_tag2_10ms=Astop_10ms-8640000
1299 REM ----------------------------------------
1300 REM einteiliges Warten (kein Tagesuebergang)
1310 IF Zweiteiliges_warten=0 THEN
1320    A=Astart_10ms: REM Wert zwischen 0 und 8 640 000
1330    WHILE A<Astop_10ms
1340       A=TIME
1350    WEND
1360 ENDIF
1399 REM ----------------------------------------
1400 REM zweiteiliges Warten (mit Tagesuebergang)
1410 IF Zweiteiliges_warten=1 THEN
1420    REM bis zum Ablauf des 1.Tages warten
1421    REM Indikator: REM Delta-T wird negativ bei Tageswechsel!
1422    A=TIME
1430    WHILE (A-Astart_10ms)>0
1440       A=TIME
1450    WEND
1460    REM es ist Mitternacht - Timer startet neu mit 000000ms
1461    REM jetzt die restliche Zeit (Wartezeit_tag2_10ms) warten
1470    A=TIME: REM neue Zeit holen! Sollte nur kurz ueber 0 sein
1480    WHILE A<Wartezeit_tag2_10ms
1485       A=TIME
1487    WEND
1489 ENDIF
1490 RETURN
1499 REM ---------------------------------------------
1500Hp34401init1: 'HP34401 INITIALISIERUNG Geraet Nr.1
1510 PRINT "Initialisiere HP34401 Nr.1 auf Adresse ",Adr1
1520 IEC OUT Adr1,"CONF:VOLT:DC"
1530 IEC OUT Adr1,"*IDN?"
1540 IEC IN Adr1,Idn$
1550 PRINT Idn$
1560 HOLD 100
1570 RETURN
1599 REM----------------------------------------
1600Hp34401init2: 'HP34401 INITIALISIERUNG Geraet Nr.2
1610 PRINT "Initialisiere HP34401 Nr.2 auf Adresse ",Adr2
1620 IEC OUT Adr2,"CONF:VOLT:DC"
1630 IEC OUT Adr2,"*IDN?"
1640 IEC IN Adr2,Idn$
```

```
1650 PRINT Idn$
1660 HOLD 100
1699 RETURN
1999 REM----------------------------------------
2000Mwrx1:
2010 IEC OUT Adr1,"READ?"
2020 IEC IN Adr1,Rx$: Mwrx1=VAL(Rx$)
2049 RETURN
2099 REM----------------------------------------
2100Mwrx2:
2110 IEC OUT Adr2,"READ?"
2120 IEC IN Adr2,Rx$: Mwrx2=VAL(Rx$)
2149 RETURN
2499 REM----------------------------------------
2500Diagramm_aufbauen1:
2510   WINDOW X1_min_s,X1_max_s,Y1_min_volt,Y1_max_volt
2520   CLEAR
2525   SET 1,1,0: REM Stiftfarbe weiss
2530   VIEWPORT 0,200,200,380: REM Kanal 1
2540   REM Rahmen zeichnen
2541   MOVE X1_min_s,Y1_min_volt
2542   DRAW X1_min_s,Y1_max_volt
2543   DRAW X1_max_s,Y1_max_volt
2544   DRAW X1_max_s,Y1_min_volt
2545   DRAW X1_min_s,Y1_min_volt
2550   REM Diagrammbeschriftung
2551   MOVE (((X1_max_s-X1_min_s)/2)*0.6),(Y1_max_volt*0.95)
2552   LABEL "HP34401 Nr.1",0,0,0: REM Titel
2553   MOVE X1_min_s,(Y1_max_volt*0.9)
2554   LABEL STR$(Y1_max_volt),0,0,0: REM Y-Achse oben
2555   MOVE X1_min_s,(Y1_min_volt*0.9)
2556   LABEL STR$(Y1_min_volt),0,0,0: REM Y-Achse unten
2557   MOVE X1_min_s,(Y1_max_volt*0.05): REM vorne, aber etwas nach oben
2558   LABEL STR$(X1_min_s),0,0,0: REM X-Achse vorn
2559   MOVE X1_max_s*0.9,(Y1_max_volt*0.05)
2560   LABEL STR$(X1_max_s),0,0,0: REM X-Achse hinten
2570   MOVE X1_min_s,0: DRAW X1_max_s,0: REM Horzontallinie
2571   MOVE X1_min_s,Y1_min_v: REM Einheiten
2572   LABEL "Y:[V], X:[s]",0,0,0
2590 RETURN
2599 REM----------------------------------------
2600Diagramm_aufbauen2:
2610   WINDOW X2_min_s,X2_max_s,Y2_min_volt,Y2_max_volt
2620   REM
2625   SET 1,1,0: REM Stiftfarbe weiss
2630   VIEWPORT 0,200,0,180: REM Kanal 2
2640   REM Rahmen zeichnen
2641   MOVE X2_min_s,Y2_min_volt
2642   DRAW X2_min_s,Y2_max_volt
2643   DRAW X2_max_s,Y2_max_volt
2644   DRAW X2_max_s,Y2_min_volt
2645   DRAW X2_min_s,Y2_min_volt
2650   REM Diagrammbeschriftung
2651   MOVE (((X2_max_s-X2_min_s)/2)*0.6),(Y2_max_volt*0.95)
2652   LABEL "HP34401 Nr.2",0,0,0: REM Titel
2653   MOVE X2_min_s,(Y2_max_volt*0.9)
2654   LABEL STR$(Y2_max_volt),0,0,0: REM Y-Achse oben
2655   MOVE X2_min_s,(Y2_min_volt*0.9)
2656   LABEL STR$(Y2_min_volt),0,0,0: REM Y-Achse unten
2657   MOVE X2_min_s,(Y2_max_volt*0.05): REM vorne, aber etwas nach oben
2658   LABEL STR$(X2_min_s),0,0,0: REM X-Achse vorn
2659   MOVE X2_max_s*0.9,(Y2_max_volt*0.05)
2660   LABEL STR$(X2_max_s),0,0,0: REM X-Achse hinten
2670   MOVE X2_min_s,0: DRAW X2_max_s,0: REM Horzontallinie
2671   MOVE X1_min_s,Y1_min_v: REM Einheiten
2672   LABEL "Y:[V], X:[s]",0,0,0
2690 RETURN
2999 REM----------------------------------------
3000Mw1_setzen:
3003   WINDOW X1_min_s,X1_max_s,Y1_min_volt,Y1_max_volt
3005   VIEWPORT 0,200,200,380: REM Kanal 1
3008   SET 1,2,0: REM Stiftfarbe rot
3010   MOVE Mw1_xdavor,Mw1_ydavor: REM Cursor auf alte Position
3020   DRAW Mw1_x,Mw1_y: REM Messwert plotten
3030   REM Messwert veralten lassen
3040   Mw1_xdavor=Mw1_x: Mw1_ydavor=Mw1_y
3090 RETURN
3099 REM----------------------------------------
```

```
3100Mw2_setzen:
3103   WINDOW X2_min_s,X2_max_s,Y2_min_volt,Y2_max_volt
3105   VIEWPORT 0,200,0,180: REM Kanal 2
3108   SET 1,4,0: REM Stiftfarbe gruen
3110   MOVE Mw2_xdavor,Mw2_ydavor: REM Cursor auf alte Position
3120   DRAW Mw2_x,Mw2_y: REM Messwert plotten
3130   REM Messwert veralten lassen
3140   Mw2_xdavor=Mw2_x: Mw2_ydavor=Mw2_y
3190 RETURN
3199 REM----------------------------------------
3200Dateioeffnen:
3210    OPENO# 1,Dateiname$
3220    PRINT# 1,"File: ";Dateiname$
3240    PRINT# 1,"Startzeit: ";Startzeit$
3250    PRINT# 1,"Datum: ";DATE$
3260    PRINT# 1,"Anz. Messungen: ";Anz_messungen
3270    PRINT# 1,"Zeitraster [s]: ";Traster
3280    PRINT# 1,"Bemerkung: ";Bemerkung$
3290    PRINT# 1,"------------------------------------"
3300    PRINT# 1,"N, Zeitstempel [s], Ch1 [VDC], Ch2 [VDC]"
3390 RETURN
3499 REM----------------------------------------
3500Dateischliessen:
3510   CLOSE# 1
3520 RETURN
3599 REM----------------------------------------
3600Werteschreiben:
3610   IF Anz_messgeraete=1 THEN
3620      PRINT# 1,N;" ";(N-1)*Traster;" ";Mwrx1
3630   ENDIF
3640   IF Anz_messgeraete=2 THEN
3650      PRINT# 1,N;" ";(N-1)*Traster;" ";Mwrx1;" ";Mwrx2
3660   ENDIF
3670 RETURN
3699 REM----------------------------------------
3700Bildschirm_leeren:
3710 PRINT "[2J": PRINT "[h": CLEAR
3790 RETURN
3799 REM----------------------------------------
3800Channel12_ausgabe:
3810 PRINT "[1;40H";"PARAMETER"
3820 PRINT "[3;40H";"Raster [s]: ";Traster
3830 PRINT "[4;40H";"Startzeit: ";Startzeit$
3835 PRINT "[5;40H";"aktuelle Zeit: ";TIME$
3840 PRINT "[6;40H";"N: ";N;"/";Anz_messungen
3845 IF Dateianlegen=1 THEN
3846    PRINT "[7;40H";"Dateiname: ";Dateiname$
3847 ELSE : PRINT "[7;40H";"kein File"
3848 ENDIF
3860 REM
3890 PRINT "[9;40H";"-----------------------"
3900 PRINT "[11;40H";"Messwert CH1 [V]: ";Mwrx1;"          "
3910 IF Anz_messgeraete=2 THEN
3920    PRINT "[20;40H";"Messwert CH2 [V]: ";Mwrx2;"          "
3930 ENDIF
3999 RETURN
```

37 The big drift

With old equipment you sometimes have big surprises. I do not want to hide, that I also had some strange behaviours observed during the tests of my logging software. The below graph shows a curve that I got as a result of a previous "overnight"-test. Look at the scale of the Y-axis: this drift is so strong, that it would even miss the specified goal of 24mv/24hrs!

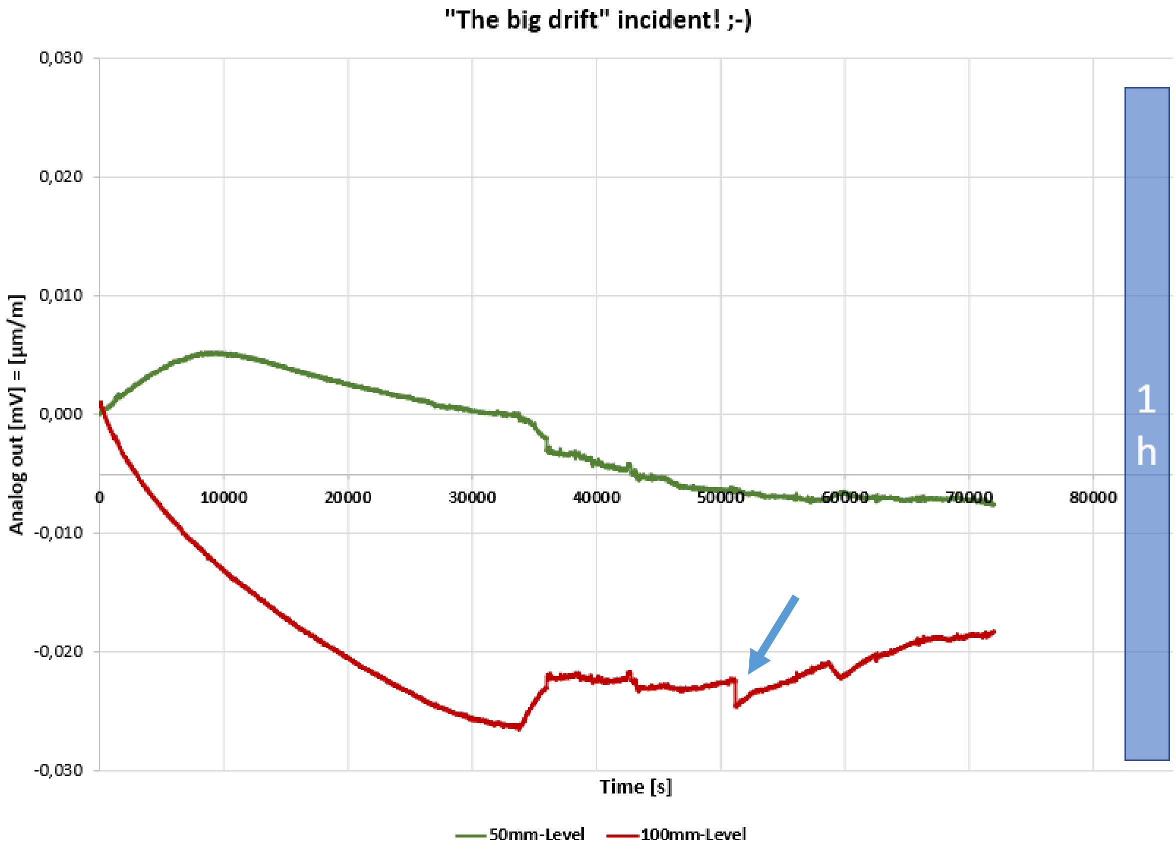


figure 106: The big drift!

Finally, I cannot say, what happened here with the red level. The At timecode 36000, when the overnight test was finished, I restarted the measurement, wanting to know, if the level will drift back or not when I just give her more time. At timecode ~52000 finally I shaked the off-set-poti of the red level a bit in order to try, if the drift could be the result of a mechanical not stress-released poti (blue arrow). But obviously this wasn't the root cause. I got a small peak into the curve, but did not change anything in the trend.

You may consider now bad capacitors in the circuit for effects like that, sometimes bad switching contacts as well. As I already said before: to safely identify those effects -and with-out any doubt- that is a very time and skill consuming issue. At least because of these reasons I will not follow up this. In normal operation, the levels do a very good job, the results are usually quite well reproducible and with that performance I am happy!

38 Bonus material: European houses ;-)

To explain a bit more detailed the topic with the "window sill": european houses are typically built of stone bricks. The bottom of the house is a ~20cm thick beton foundation, stabilized with an inner iron mesh. On this base, there will be layed the bricks to build the walls. If you need a window, you just let this area free of bricks. So any window sill will be directly connected to the house's concrete foundation. If there is not an earthquake (which we usually do not have in germany), there is nothing that can make this foundation moving. And this is exactly what we need: a position that we can rely of to be stable and being independent of footsteps or persons waking around.

figure 107: beton foundation of our house (year: 2003)

figure 108: the walls of the basement do directly stand on this foundation

So what is the difference now compared to the floor?

figure 109: our levels will be placed exactly here on this wall - only about 19years later ;-)

Normally, the floor of an european house is also made of beton. But this floor is a solid piece of concrete (a slice), with -ideally- no connection to the walls. It is laying as an isolated shell and not touching the walls. It is "floating". Between this beton floor and the foundation there is thermal insulation- and that is, what causes the problem now. As we already have noticed in chapter 5, this insulation is a bit compressible. Not much, but sufficent enough to mass up our drift measurement. So I cannot put the levels on any item this is located on the floor- I need to put them into the window's sill, because only this place is really "hardly" and "directly" connected to the house's foundation.

figure 110: here you can see this thermal insulation under the floor! (It is about 5cm thick and will be completely covered with the concrete floor afterwards). The cut-out is because of there will be the shower afterwards, so they left this area free for its installation.

39 Summary

So, that was really a lot of fun! My summary goes about two aspects. First, I will talk about cheap (import) surface plates, then I will sum up the capabilites of a hobbyist to check flatness of plates and straight edges.

figure 111: Yes- even with hobby budget you can strive for precision!

39.1 cheap (import) surface plates

First, the following represents only my personal opinion, ok?!

You always get, what you pay for. If you pay a DAkkS-certified company a quite resonable about of money for a surface place including a certificate, you get one with individual measurement protocol that you can rely on. And if you re-measure it by your own, you will get something very similar to what the manufacturer says. And I am sure, if you need to, you could even trace back the calibration of the used measurement stuff of the company to national standards.

If you buy a 50€ cheap import plate, you get a painted, wrongly labeled plate that nobody can guaratee for keeping its spec (even if there is a spec available). But nethertheless can such a plate still be very useful for many things: with proven 6µm flatness it is already at the border between DIN876/Grade 0 and Grade 1, which is not that catastrophic! Come on: you get a lot of straightness for only 50bucks!
If you are not hunting for the last micrometer, a plate of this grade could even fulfil most of the requirements for (normal) scraping- maybe not precision ones- but until a certain point of machinery rework this cheap plate can be a good partner for your workshop indeed!

And be honest: if you need a flat surface to stick your sandpaper on it for sharpening a chisel or anything else- would you do that on your 2000€ Grade00 precision plate? For sure not!!!!

So even if the certificate handout is absolutely ridiculous, the spec not fulfilled and the paint will resolve itself during the first couple of wipes with glass cleaner: such a low-cost-plate still has its place in a metal workshop. And to be honest: I would buy it again, because I was missing such a plate in my workshop where I am not anytime concerned to make accidently a toolmark or a sratch in it.

39.2 Level measurement for hobbyists

In general: despite of all my efforts and actions done I must admit and realize, that my measurement is still hobby-like! Neither I did a serious verification of my test procedure, nor the test equipment itself. Nothing in my workshop (with the exception of my Planolith 1000x630 granite plate) is really retraceable to DAkkS or similar standards. I do not know any impact of influences or proofed uncertainties of the stuff in my workshop.

Also my own confidence in my test is actually not yet very good: although the closing error calculates a "correction index" (which is in my case 0,69µm for my granite plate), I do not have any experience of repeatability or if such a value is typically "good" or not. You need to be a professional with years of experience to be able to judge that out.

Nevertheless all this thinking shall not harm our happiness about what we did! At least thanks to the support of lots of people (starting with the seller and ending up with Wyler's kind support) I finally was able to get reasonable (hobby)results. The graphs are so much encouraging, that I really think, they could be even more than just "useless hobby-stuff"!

In any case I learned a lot! And that is the most important topic of all!

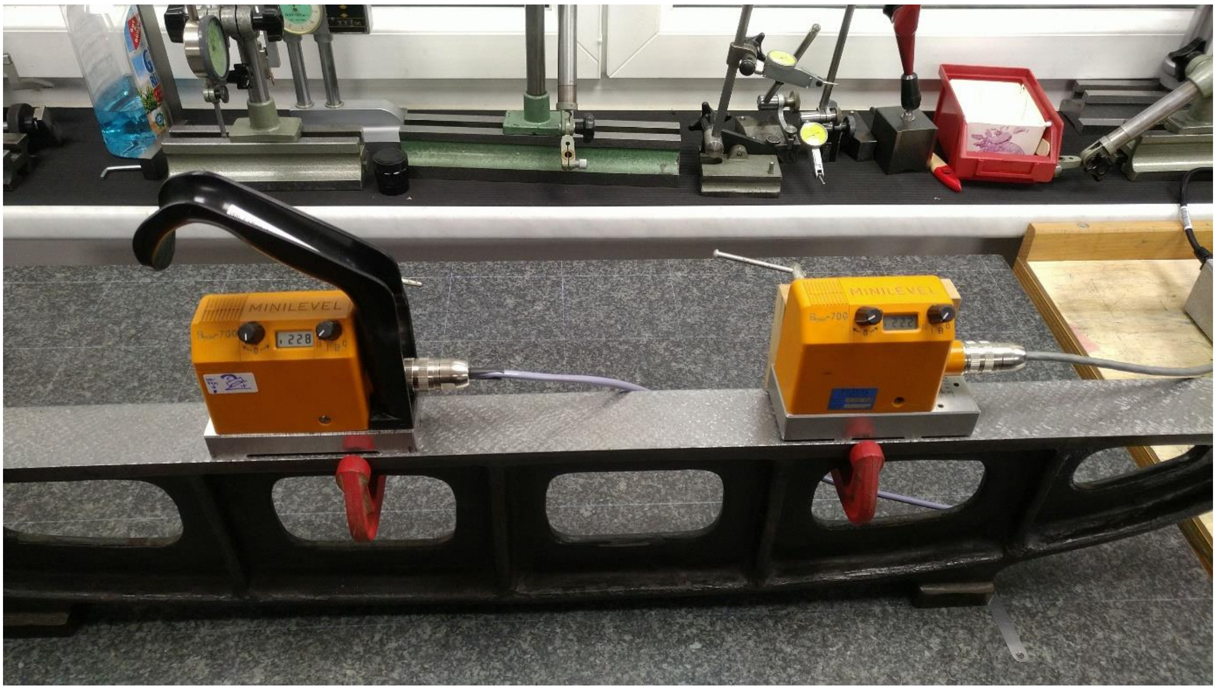


figure 112: verification of the minilevels

40 Closing picture

As used by me, I give you one closing picture. What you can see, is a telephone distributor, seen in the streets of Suzhou, China.

Despite of its appearance, I am sure it will work properly! No doubt! :-)

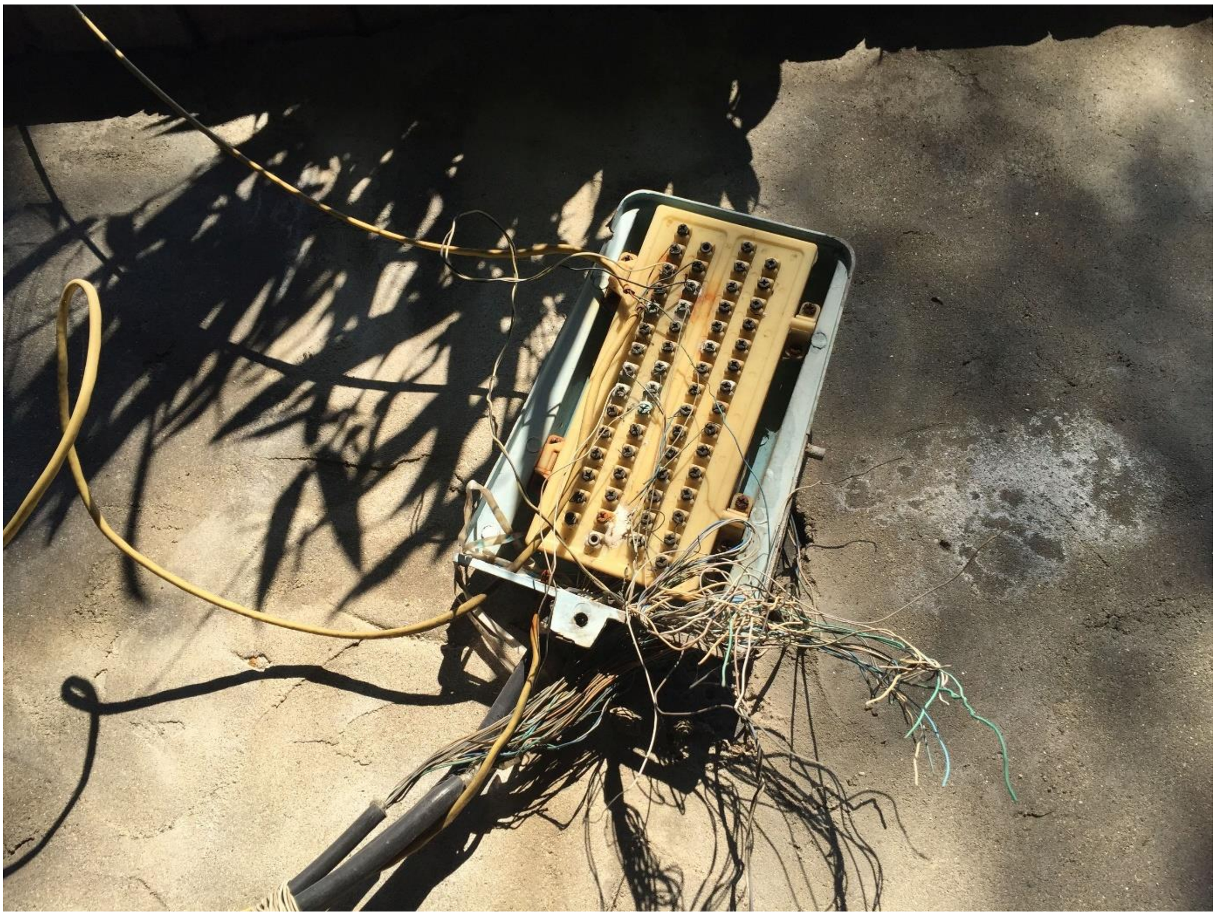


figure 113: precision network engineering :-)

41 Disclaimer

Hinweise
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