Fluke 540B Thermal Transfer Standard

The Fluke 540B Thermal Transfer Standard is a highly accurate AC voltage measurement device. This allows AC voltmeters to be calibrated and calibrators to be set and maintained. Thermal transfer standards are among the most accurate measurement methods for AC voltages.

DC voltages can be measured with a significantly higher level of accuracy than AC voltages, which is the main advantage and actual purpose of this device. It is about converting the AC voltage, which is more difficult to measure, into a DC voltage that is easier to measure, to transfer it, hence the term transfer standard. If the thermocouple has succeeded in converting the AC voltage into its associated DC effective value, this can be determined much more easily by means of a comparison measurement using a galvanometer, internal reference voltage and the externally applied DC reference voltage.

The device can therefore not output a direct measured value, as one is used to from a voltmeter - it can only say: "The applied AC voltage now has the same effective value as the applied DC reference voltage". The specified device values refer to the previous statement of how accurately the AC voltage has been transferred to the associated effective value. Therefore, precise, stable and finely adjustable DC voltages are absolutely necessary for a transfer. There are many such DC calibrators, one possible example is the 343A .

If both applied AC and DC voltages have the same RMS value, they generate the same amount of Joule heat at the same thermocouple under the same ambient thermal conditions. A small electrical voltage/heat is generated at the thermocouple, whether this was generated by AC or DC does not matter. The output voltage of the thermocouple (Transfer DC or Transfer AC) is compared with the adjustable internal reference voltage using a sensitive galvanometer that easily detects the smallest differences. If the galvanometer no longer deflects in both switch positions "Transfer DC or Transfer AC" in relation to the internal reference, the transfer has been completed.

Without detailed manuals, you should buy devices in this category with a certain amount of caution, it can be an indication of bad handling, but it doesn't have to be. But it can also be that the device just sat in the corner unused for years, which was often the case. Anyone who has never measured with it needs the manual to use it correctly, otherwise it will be very difficult. However, once you understand it, it's easy.

ACCURACY:

Range	frequencies	AC/DC difference
All except 1000V	5Hz to 50kHz	+/-0.01%
1000V	5Hz to 20kHz	+/-0.02%
1000V	20kHz to 50kHz	+/-0.04%
0.5 through 50V	50kHz to 100kHz	+/-0.05%
20 through 50V	100kHz to 500kHz	+/-0.1%
0.5 through 10V	100kHz to 1MHz	+/-0.1%
100 through 500V	50kHz to 100kHz	+/-0.2%

INPUT IMPEDANCE:

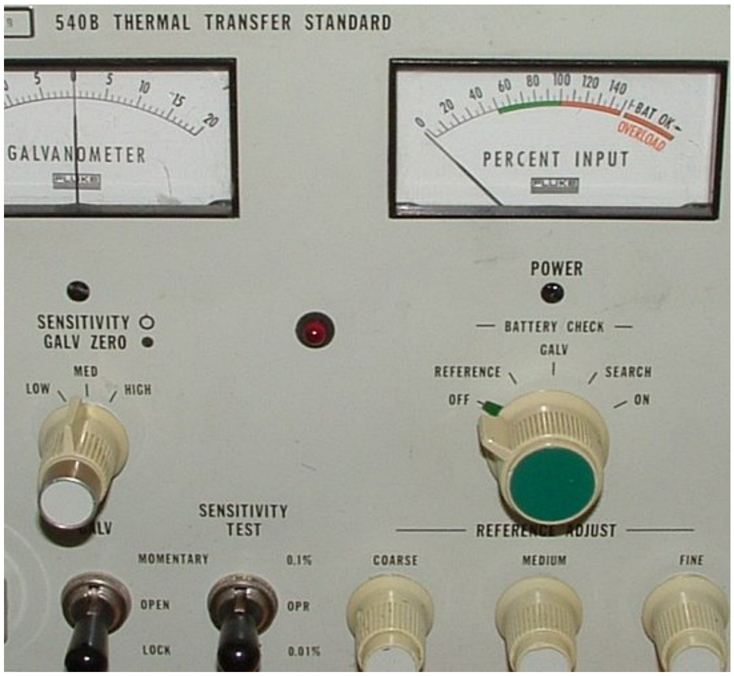
182 ohms/volt in all voltage modes.

OVERLOAD PROTECTION:

The entire instrument is protected from accidental overloads of up to 1500 VDC or rms AC in any range.

ACCESSORIES:

Nine Fluke Model A55 High Frequency Therma Converters are available for use with the Model 540B extending the frequency response to 50 MHz. See Instruction Manual of A55 converters for details. Fourteen Fluke Model A40 Current Shunts are available. Transfer measurements of 2.5 mA to 2A over a frequency range of 5 Hz to 100 kHz with a basic transfer accuracy of +/-0.02%. Also available Shunt A40A with special cable 6002-212860 and A45 Current Transfer Switch. See Instruction manual for details. The Fluke 540B Thermal transfer standard is equipment for highly accurate AC voltage measurements as well as for the calibration of AC voltmeters and calibration devices themselves. The equipment compares the applied AC voltage with an external DC voltage, which corresponds to the AC rms voltage. Both voltage produce the same amount of Joule' s heat at equivalent Ohm's resistances under same thermal site conditions. DC voltages are measurable with clearly higher accuracy than alternating voltages. The thermal transfer standard lets the AC voltage measure by more accurate DC voltage instruments. Necessarily for the AC measurement is a stable, well-known, adjustable DC reference voltage, the amplitude of the AC voltage should be as constant as possible. To AC-DC transfer inaccuracy is to be added the inaccuracy of DC reference voltage. Without the very detailed instruction manual described, measurements are difficult to handle, special at your first time. Don't buy instruments of this outstanding class without an instruction manual, it could also be an indication on bad device treatment. DC voltages are measurable with clearly higher accuracy than alternating voltages. The thermal transfer standard lets the AC voltage measure by more accurate DC voltage instruments. Necessarily for the AC measurement is a stable, well-known, adjustable DC reference voltage, the amplitude of the AC voltage should be as constant as possible. To AC-DC transfer inaccuracy is to be added the inaccuracy of DC reference voltage. Without the very detailed instruction manual described, measurements are difficult to handle, special at your first time. Don't buy instruments of this outstanding class without an instruction manual, it could also be an indication on bad device treatment. DC voltages are measurable with clearly higher accuracy than alternating voltages. The thermal transfer standard lets the AC voltage measure by more accurate DC voltage instruments. Necessarily for the AC measurement is a stable, well-known, adjustable DC reference voltage, the amplitude of the AC voltage should be as constant as possible. To AC-DC transfer inaccuracy is to be added the inaccuracy of DC reference voltage. Without the very detailed instruction manual described, measurements are difficult to handle, special at your first time. Don't buy instruments of this outstanding class without an instruction manual, it could also be an indication on bad device treatment. Necessarily for the AC measurement is a stable, well-known, adjustable DC reference voltage, the amplitude of the AC voltage should be as constant as possible. To AC-DC transfer inaccuracy is to be added the inaccuracy of DC reference voltage. Without the very detailed instruction manual described, measurements are difficult to handle, special at your first time. Don't buy instruments of this outstanding class without an instruction manual, it could also be an indication on bad device treatment. Necessarily for the AC measurement is a stable, well-known, adjustable DC reference voltage, the amplitude of the AC voltage should be as constant as possible. To AC-DC transfer inaccuracy is to be added the inaccuracy of DC reference voltage. Without the very detailed instruction manual described, measurements are difficult to handle, special at your first time. Don't buy instruments of this outstanding class without an instruction manual, it could also be an indication on bad device treatment.



The left pointer belongs to the galvanometer, it shows the zero value when the device is balanced, the effective value of the applied AC voltage then corresponds to the applied DC voltage. The Percent Input should be as close to 100% as possible. Left instrument on galvanometer, the measurement is complete if the needle shows zero. The left rocker most used. Keep the signal level in the right instrument close to 100% for best accuracy.

14 measuring ranges from 0.5 volts to 1000 volts. In the shunt position, alternating currents can be measured with external shunt resistors. Using small external thermal converters A55, even frequencies up to about 50 MHz can be measured. 14 measurement ranges from 0.5 volts up to 1000 volts. Shunt position uses A40 resistors for AC current measurements. The HF thermal converter A55 expands frequency range up to 50 MHz.

A small example of how to operate the device:

The effective value of an unknown AC voltage is to be measured:

Presets:

- Effort to maintain a constant room temperature
- Turn on AC source, set to setpoint, allow to warm up for approximately 1-2 hours depending on model
- Turn on the DC source, adjust to setpoint, allow to warm up for approximately 1-2 hours depending on model
- check both sources for setpoint and unexpected anomalies using DMM and oscilloscope
- Disconnect the DMM and oscilloscope again

- Power OFF
- Mode switch to OFF
- Range switch to 1000V
- DC Polarity Switch PULLED, pulled out
- Sensitivity LOW
- Galv OPEN
- Sensitivity test OPR

Prepare professional cabling, ie massive, bare, non-oxidized copper, e.g. multi-wire telephone cable, bare copper cable lugs, short lines, flexible measuring lines are to be avoided if possible, use sense connections or deliberately without a sense line with a defined measuring cable length, which can then be seen as a permanent part of the measurement object is a question of what you want.

Start of the measurement on the AC voltage

- Power REFERENCE, check for sufficient battery voltage of the internal 1.35V reference
- Power GALV, checking for sufficient battery voltage of the internal 12.5V galvanometer supply
- Power SEARCH, check for sufficient battery voltage of the internal 12.5V Search Amplifier supply

- Power ON, device is switched on
- Connect AC source, DC source is not connected.
- Mode AC SEARCH, checking the measuring range
- Range 1000V, 500V..... down until the correct measuring range is reached, where the PERCENT INPUT meter is within the green area, if possible in the upper third.
- AC TRANSFER mode, the AC voltage to be compared is now present at the thermocouple and heats it up. Since this thermal transient process takes a while before it assumes a very constant value, at least 10 minutes should be allowed for this process, 1/2 or a whole hour is of course preferable.

- Tap Galv MOMENTARY momentarily, observe galvanometer reading
- Reference Adjust COARSE, turn so far that the galvanometer deflection is as small as possible under MOMENTARY
- Galv LOCK
- Reference Adjust MEDIUM, turn so far that the galvanometer deflection under Galv LOCK is as small as possible

- Galv OPEN
- Sensitivity MED
- Galv Zero, twist until the galvanometer is exactly at zero
- Briefly tap Galv LOCK or MOMENTARY, observe galvanometer reading
- Reference Adjust MEDIUM, turn so far that the galvanometer deflection under Galv LOCK is as small as possible

- Galv OPEN
- Sensitivity HIGH
- Galv Zero, twist until the galvanometer is exactly at zero
- Briefly tap Galv LOCK or MOMENTARY, observe galvanometer reading
- Reference Adjust FINE, turn so far that the galvanometer deflection under Galv LOCK is as small as possible.

Ideally, there is no difference when switching Galv OPEN and LOCK back and forth, the pointer stands still. In this case both inputs to the galvanometer are the same magnitude, the divided down internal reference is equal to the divided down AC voltage at the galvanometer. You should observe the state in the sensitivity HIGH position a little more closely, if you have to constantly readjust this state, for example, either the internal reference battery is not sufficiently stable and constantly loses voltage or the AC amplitude drifts away or, as another possibility, thermal transfer has not yet settled down to a sufficiently stable value.

Start of the measurement on the DC voltage:

AC source remains connected, DC source is not yet connected.

- Mode DC SEARCH, checking the measuring range
- Range 1000V
- Connect DC source
- Range 1000V, 500V..... down until the correct measuring range is reached, where the PERCENT INPUT meter is within the green area, if possible in the upper third.
- DC TRANSFER mode, the DC voltage to be compared is now present at the thermocouple and continues to heat it with the DC voltage. Since most of the thermal transient process has already taken place under AC, the DC TRANSFER can now take place quite quickly.

Reference Adjust must remain unchanged, no longer turn it

- Galv MOMENTARY, tap briefly and adjust the DC reference source until the galvanometer deflection becomes smaller.
- Galv LOCK, fine tune the DC reference until the galvanometer shows no reading.

The DC voltage now found corresponds to the effective value of the AC voltage transferred.

Repetition of the measurement:

the measurements are to be repeated several times, first the same measurement again with the DC polarity switch PUSHED pressed in. The polarity of the applied DC voltage is now reversed. With this device, the polarity of the thermocouple results in a difference of just a few divisions in the sensitivity HIGH position. Probably the more correct value is the mean of the two. I can only speculate about the causes, maybe there are differences in the leakage currents of the protective diodes of the thermocouple. If anyone can explain the cause, please get in touch.

Repeat the whole measurement procedure three times, each time with a different polarity, and average the results.

To calibrate an AC voltage:

the measurement is reversed, first the DC transfer takes place, only then the AC transfer. The AC source to be calibrated is adjusted with its potentiometers until the two transfer voltages are identical. The freshly calibrated AC voltage adopts the previously set DC voltage value.

Summary:

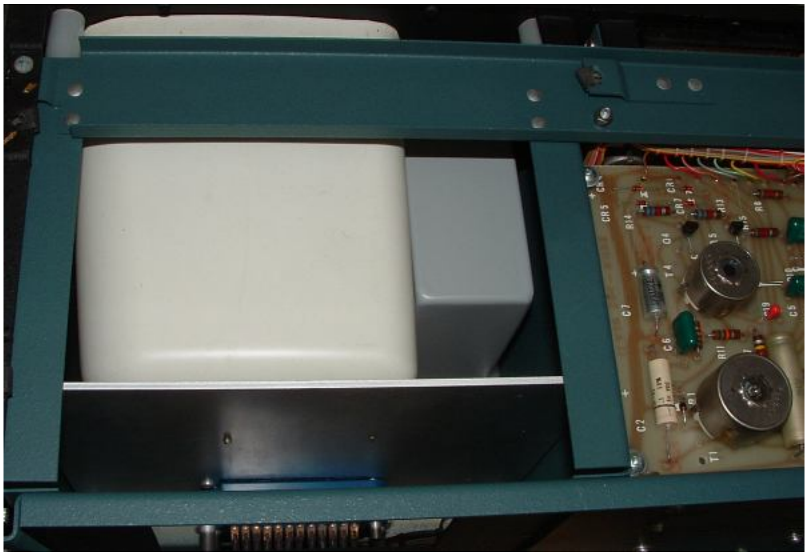
Given the long duration of the measurements, it is obvious that an accurate transfer will only succeed if very low-drift DC and AC sources are used. Using drifting source is pointless. The absence of drift and the quality of the internal reference voltage are also of great importance.

Internal reference voltage:

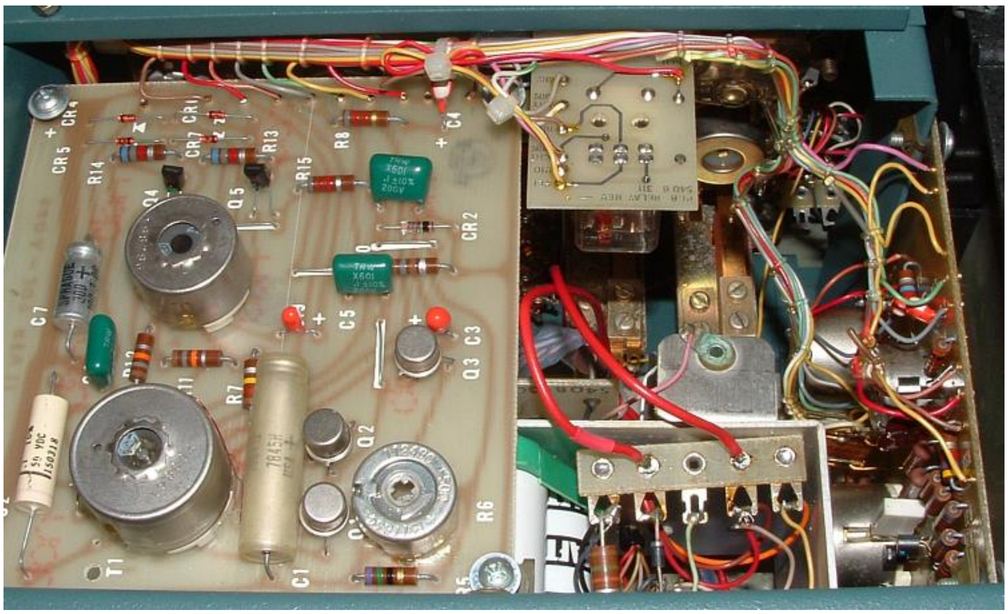
originally a 1.35 volt mercury oxide battery was used for this purpose, designed as a mono cell. Mercury oxide batteries are hardly made any more, if you can still get leftovers from somewhere, you're lucky. Mercury oxide batteries have the property of a very constant discharge curve, an essential property for this application. Users of older photo light meters can sing a song about it, they are often annoyed about bad or less durable PX625 replacement batteries.

The thermal transfer is a ratiometric matter, ie the absolute values of the reference battery are irrelevant, it doesn't matter whether the battery has a value of 1.35V or 1.5V or 1.2V during the measurement, the reference adjust potentiometers compensate for this. Of great importance, however, is the stability of this voltage during a measurement procedure, if the battery runs away during the period, e.g. from DC transfer to AC transfer, the entire measurement is affected by errors and the precision is over.

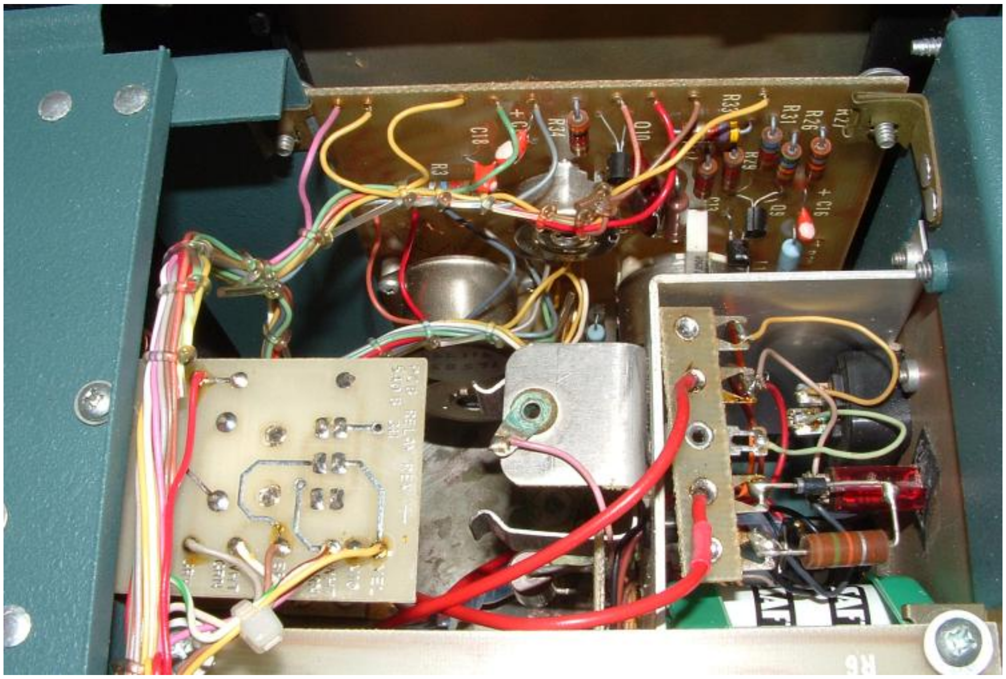
I've been looking for a very long time for a suitable, very low-drift replacement battery. Freshly charged batteries, for example, are terrible for this or, as always, constantly empty due to self-discharge. The size alone says nothing, the only decisive factor is the technology and generation used. After a long search I found a nice solution, the part is now wonderfully still. However, a few simple circuitry measures were necessary for this, which do not need to be mentioned here, I would be hacked up again for that with comments like: "it's still completely tight, you don't do something like that". I experienced this in a similar situation, I once just washed an amplifier with water and I didn't think anything of it, it caused an outcry on the internet that could hardly be described: "he's crazy" "lunatic" or something similar. I won't do that to myself again this time. If you still want to know, send me a photo of your 540B with an open bottle in front of it, made by a local drink manufacturer from your region or something original together with the standard, that's the ticket, and at least I'll get a few interesting photos on the side.



The white (attenuator) and the gray box (thermal high vacuum converter) should definitely not be opened, much to the benefit of the adjusted frequency response. The white one contains a lot of metal film resistors and mica capacitors, don't even bend them. Don't open the high vacuum thermocouple and transfer compensated attenuator, calibrated frequency response can be accidentally degraded easily. Many metal film resistors and Mica capacitors inside.



The left circuit board is an approx. 5 kHz oscillator and a synchronous demodulator. The device has a magnetic based modulator. The "Saft" can be seen in the bottom center, here it is NiCd batteries from the manufacturer Saft, which date back to 1979. Left hand PCB shows a 5 kHz oscillator and synchronous demodulator. Devices also operates with NiCd Battery.



The top circuit board is the magnetic modulator. In the middle of the picture you can see the battery holder for a 1.35V mercury mono battery (not inserted). Easily recognizable by the corrosion of the contact, the condition was neglected. Of course, if the standard just stands there, its accuracy doesn't deteriorate, but later it always involves work until a new start-up is completely successful. Unfortunately, it is common, and in many cases has never been different, with all devices with internal batteries: they are often neglected and neglected, batteries and accumulators are deeply discharged or leaked, which means that the contacts have corroded over the long term and in most cases become unusable. The corrosion sometimes continues into the first few centimeters of the copper wires,

Little trip:

Multimeters also use the principle of first converting the AC voltage into a DC voltage. There are various methods for doing this, one of which is electronic precision rectification, for example. Many ready-made IC's are available for this. A special advantage of the thermal method is also a wide frequency insensitivity, with special devices the ranges in the high frequency can also be covered. An advantage of thermal methods that should not be underestimated is the dynamic range, the ability to process signals with a higher crest factor, many electronic methods reach their limits more quickly here, what crest factor the 540B can process is unknown to me, also plays less of a role, since it is sinusoidal signals in the calibration are the rule.3400A or 3403C , whose measurement inaccuracy compared to thermal transfer plays a minor role with non-sinusoidal signals. But there are also ICs that work thermally, for example the LT1088 (obsolete) from Linear Technology. It combines two heating circuits on one IC and can process higher frequencies and crest factors. The application examples for this component are worth reading.

Back to thermal transfer:

as you could see from the pictures, the standard was in a non-functional condition. The 1.35V reference battery was missing and the nickel cadmium batteries were already very old. The charging circuit still managed to get the batteries close to the NiCd end-of-charge voltage, but some individual cells were very weak and lost a lot of voltage after half an hour. A battery charge is usually sufficient for approx. 100 hours, the reference cell was given with approx. 2000 hours of operation. A battery charge should last about 16 hours.

Normally, with proper care and storage, NiCd batteries are a very reliable and long-lasting battery technology, but the specimens shown have been denied proper treatment in recent years. They were already deeply discharged and were probably stored in this unfavorable state of charge for a long time. To be fair, however, it must also be said that the batteries are already 28 years old. In such a case, new ones should be used.

The NiCd batteries are two blocks of ten cells each in series. The built-in size is Sub-C, a size found almost exclusively in industrial devices, but less often in commercial ones. The price of this design is higher compared to the usual sizes, and Sub-C cannot be bought on every corner. What now?

I really wanted to switch to standard sizes. Mignon-size cells would easily fit into the available space, but their capacity was too small for me. Baby cells would have a higher capacity, but they no longer fit into the original battery compartment without modification. NiCd or NiMH batteries would also have the advantage that you could use the original charging circuit, but they have two major disadvantages:

- NiCd and NiMH batteries quickly lose their capacity through self-discharge, which is unpleasant for this application. It may be that such a standard is only used every few months, the problem with that - the batteries would always be empty exactly when you need them. NiMH normally self-discharge even faster than NiCd.
- NiCd and NiMH of higher capacity and quality were a little too expensive for me and involved a lot of soldering and packing, but there is another way:

In particular, mercury oxide, NiCd and lead-acid batteries should be disposed of professionally, as they contain heavy metals that are harmful to the environment. The old 540B batteries were therefore disposed of at a collection point.

The good old lead-acid accumulator

If treated, stored and charged correctly, lead-gel batteries are very durable and reliable energy storage devices and are also inexpensive. The specimens shown in the following pictures are of high quality, more recent years of construction and even come from an inexpensive electronic mail order company, de-facto free compared to NiCd or NiMH, and with a brute capacity that can otherwise only be achieved with high-quality mono cells is. Twenty good NiCd mono cells cost a multiple compared to lead gel batteries. With a capacity of 7.2Ah, measurements can be taken for a very long time, and the voltage is also stable.

The specified self-discharge rate of this 12V/7.2Ah lead-gel battery is around:

after 3 months 80% @27°C
after 7 months 50% @27°C

after 3 months 90% @16°C
after 7 months 75% @16°C
after 13 months 50% @16°C

You can live with this self-discharge rate, the built-in batteries are recharged every 2 months anyway via an external modern special lead-acid battery charger, so they are always ready for use and should hopefully last a long time. A fully charged battery has an open-circuit voltage of approx. 12.9 volts when it is idle (after it has been fully charged and has been waiting for approx. 2 hours). Basically, lead-acid batteries should not be stored below 12.6V for a longer period of time, they can of course also be discharged below 12.6V during use, but should be recharged as soon as possible. There is plenty of information about lead-acid batteries, but you have to sift through this mess of numbers from a wide variety of sources for a long time to recognize the essentials for this application.

Modification of the housing

Of course, the lead-acid batteries no longer fit into the housing, so the housing has to be moved to the outside, said and done:

Shows the original charging circuit, which has already been slightly modified here. The battery holder remains unused. The yellow capacitors were installed and the rectifier diodes disconnected, since they are no longer needed and would only load the batteries with reverse currents (minimum, rather ridiculously little). The Sub-C batteries were in the green plastic shells. Shielded connection cables for the batteries were laid through the hole in the former mains fuse. The shield is not live, it is at the housing potential, recognizable by the copper eyelets.

Here the battery connection lines were brought out and fastened accordingly. The lower frame made of copper circuit boards and the aluminum brackets forms the carrying frame for the batteries. The frame is supported by two additional rubber feet underneath.

To get straight to the point, this is what the housing looks like in the finished state. Closed all around with a two-sided copper circuit board, together with the shielded cables, a beautiful shielding cage is created, I didn't want to leave the batteries lying around openly. For optical reasons, the copper surface was lightly polished and then coated with clear lacquer.

Shows the battery pack for the galvanometer circuit. The reference cell is located to the right in the small box. The long, insulated M6 screws in the cover fix the battery in place when the cover is mounted and prevent it from slipping. The reference cell is firmly screwed on, an old medicine box served as the base; another example of how even rubbish can be excellently combined with the highest quality measurement technology. The sticker "intended for immediate use" also comes from the medication, which of course has nothing to do with the cell.

Same on the right half of the case as on the left. Only this time the batteries for the Search Amplifier can be seen. These are two 6V batteries connected in series. The circuit requires a center tap. All batteries leading to the outside received an additional fuse as fire protection for unforeseen things, you never know.

There is a charging socket on each side of the housing for connecting the battery chargers. A high-quality and stable 180 degree DIN panel jack was used. Two corresponding mating plugs were mounted on the two existing chargers. All my measuring devices with an internal 12V battery supply have the same charging socket and pin assignment on the outside. In practice, this method is extremely useful, two chargers for everything. If necessary, simply plug it in and plug the charger into the socket, just wait for the green LED to indicate the end of charging on the charger - done -. The low batt display has been readjusted to the lead batteries.

The nice thing about these modern chargers is that you can sometimes forget to disconnect them again, they automatically switch to trickle charging. Forgetting to disconnect again is an operating condition almost born for lead-acid batteries.

A NiCd battery, on the other hand, charged in the conventional old way, as intended by the original charging circuit, should be disconnected from the mains after 72 hours at the latest. The original charging circuit for the original Sub-C has no limit switch or similar, to be fair you also have to look at the time of the device development at that time, back then there was no charging controller IC like there is today.

The gain in convenience through lead-acid batteries in combination with charging technology from the 21st century is a nice thing. In this way, I charge my entire battery-operated measuring device park without stress, fear, forgetfulness and fiddling, the charging sockets were deliberately given the same pin assignment on all devices.

The entire case is easily removed so one would get access to the innards of the Standard again. It is only screwed to the top and bottom of the device and can simply be pulled off to the rear. It really took a nice while to oversubscribe what a useful battery mount could look like, some other solutions were discarded. The construction of the box and the wiring really took time, you can't necessarily do something like that in a single day.

There is a second 540B that will also be put into service, but this time I won't do all the work to build a nice shiny box again. The second device is used to verify the measurement results of the first.

Here is the picture of the second device. This version is a little older than the one previously shown. The device was also operated on batteries by the previous owner, he placed them outside, unfortunately the seven connection wires of the batteries were simply cut off and no one knows which wire goes to which battery anymore, making a mistake when reconnecting it would be fatal. So I had no choice but to cut open the beautiful wiring harness and see where what went and to think about what went where. The manual is of course helpful for this. Unfortunately, the wire color was completely different than in the newer model - copying it - didn't work. Figured everything out, tied the wiring harness back together and connected the batteries. The batteries are charged with this charger, but they are taken out for this purpose.

That's the hard work that always takes a lot of time, but what do you want to do? no other choice and still keep your nerve and not make a mistake. On the back there are two unspectacular 10 mignon batteries screwed into a battery holder on the back wall.

It compares very pleasantly and comfortably with these standards, it's really fun with it.

A reader picture sent by email at Christmas 2013:

Hi Ralf,

you always wanted a "something different" Fluke540B picture for your website.....at least that's what you wrote in your article....

Unusual enough? I call it "mini nerd at the transfer normal"

I'm sooooooo proud of our little one and his good taste :-))

The young boy on the way to becoming an early master,
he has guaranteed the best support from the "manufacturer".

Congratulations

(I won't say who took the picture, data protection.)

works quite well as a 1.35V battery replacement

HOME miscellaneous gallery MAIN GALLERY