Keithley DMM6500

Intro

This is my little Christmas endeavor into making my Keithley DMM6500 much more quiet.

I bought the instrument more than two years ago. I really like things to be quiet in my Lab so this new wonderful Keithley came to shame with its really loud fan. It was also very buggy, blue screens almost all the time. Some Firmware revisions later, 1.03, and it was usable.

Due to the fan it became a dust collector, just using it occasionally for some special measurements and not as my every day companion in the lab.

Some weeks ago when turning the instrument on the dates where reset back to 1970. Digging into this it became clear that Keithley had made a mistake draining the backup battery to quickly and there was also a new FW that should correct it to some extent.

This battery issue became the start of the modification. To summarize:

- Change of Battery. (Broke the battery holder, had to make a special solution).
- Update to latest Firmware (FW). Not pain free, but almost.
- Ventilation holes in lid.
- Move the original Fan and modify it with a diode in series to slow it down.
    - It could probably have been run Fan-less, see measurements and links at the end.

Sorry to say but Keithley seem to have cut corners in this design, especially around the power supply, thereby wasting a lot of power into heat.

- They have used two transformers in parallel with low primary inductance's making the standby power more than 6 W. So yes, have a switch turning the instrument of completely!
- Used linear regulation for the analogue parts with very large voltage margins.

N.B ! Disclaimer. If you do this you do it at your own risk. I can't be held responsible in any way!

// Per, 2021-01-02

Keithley DMM6500

https://www.tek.com/tektronix-and-keithley-digital-multimeter/dmm6500

Power - Measured with Power Meter

Power Off (Standby) 6.6 W, Current = 0.185 mA, Power factor = 12% (0.12)
Power On (Idle) 22.8 W (24.8 peak), Current = 0.195 mA, Power factor = 49% (0.49)

PF = Real(W)/Apparent(VA)

Fluke 87 V

Idle current, not turned on = 192 mArms -> 230 * 0.192 = 44.2 W (Apparent Power)
Turned on, 0.201 Arms → 46.2 W

Inputs, Front

Input	HI, RED
	LO, Black
Sense	HI, Yellow
	LO, Gray

Logg

- 2020-12-23
    - Change of battery.
        - Looked at this video: https://www.youtube.com/watch?v=feCA5vQYVpU
        - When removing the battery I am not careful enough and break two of the plastic clip edges that hold the battery. Have to invent a metal clip with some tape to hold the battery in place. So be gentle when changing the battery.
- 2020-12-23

    Upgrade of FW from 1.03 to 1.7.3

    I see in FW notes for 1.7.3 why my battery has been drained. Software bug.

    Get error: "Update DMM Analaog2" failed ...or something similar.
    Does seem to go through with the update after all.

    Have Error 1150, AMICRO initialization failure after the upgrade.

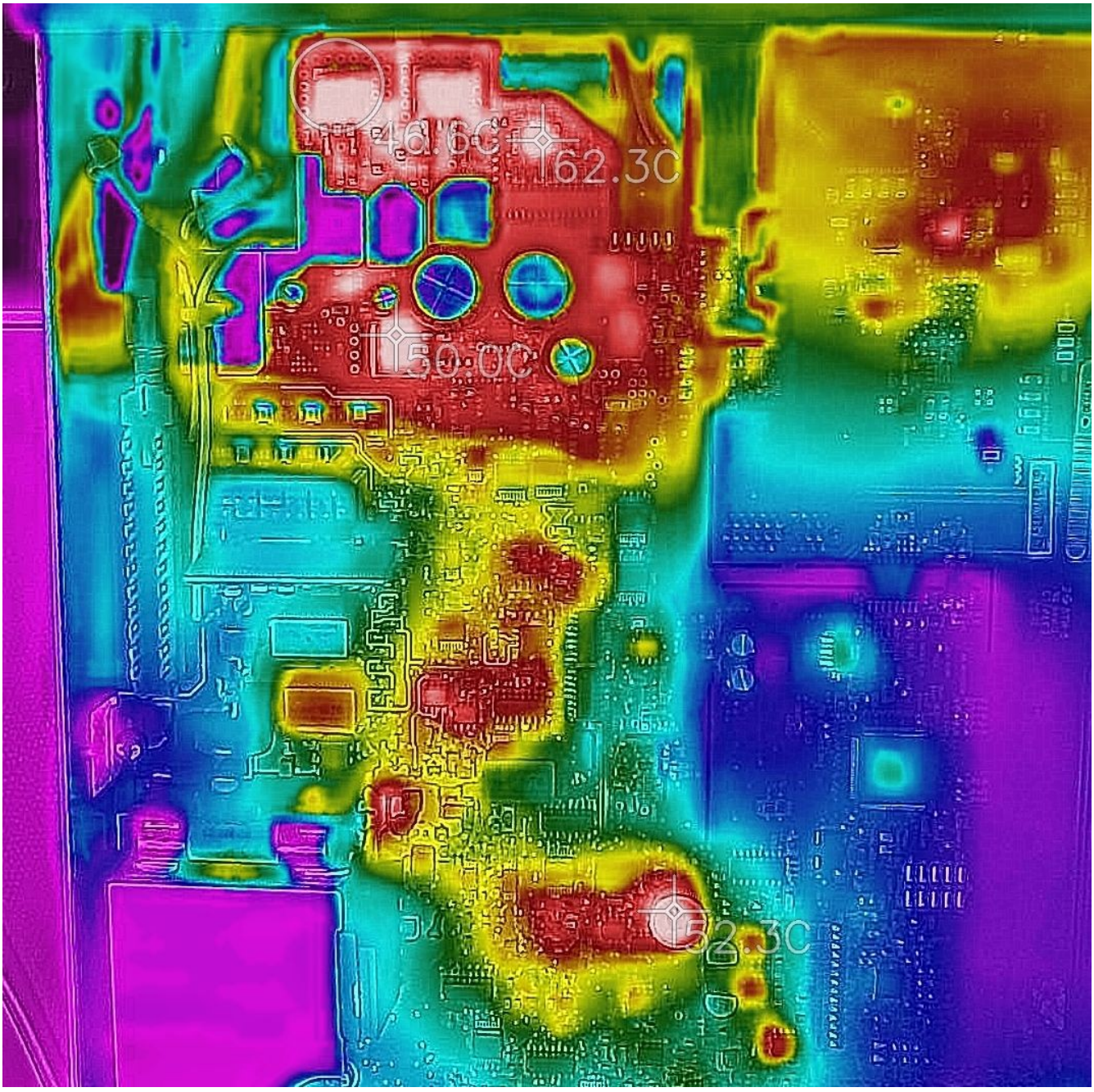
After upgrade to 1.7.3 and reboot the instrument is non working.
The instrument does not show any measurement figures and the terminals are stuck at REAR.

Do a Downgrade to get back to what i had (1.03) but instead the FW 1.7.3 is reloaded another time and this time it seems to work ! ?

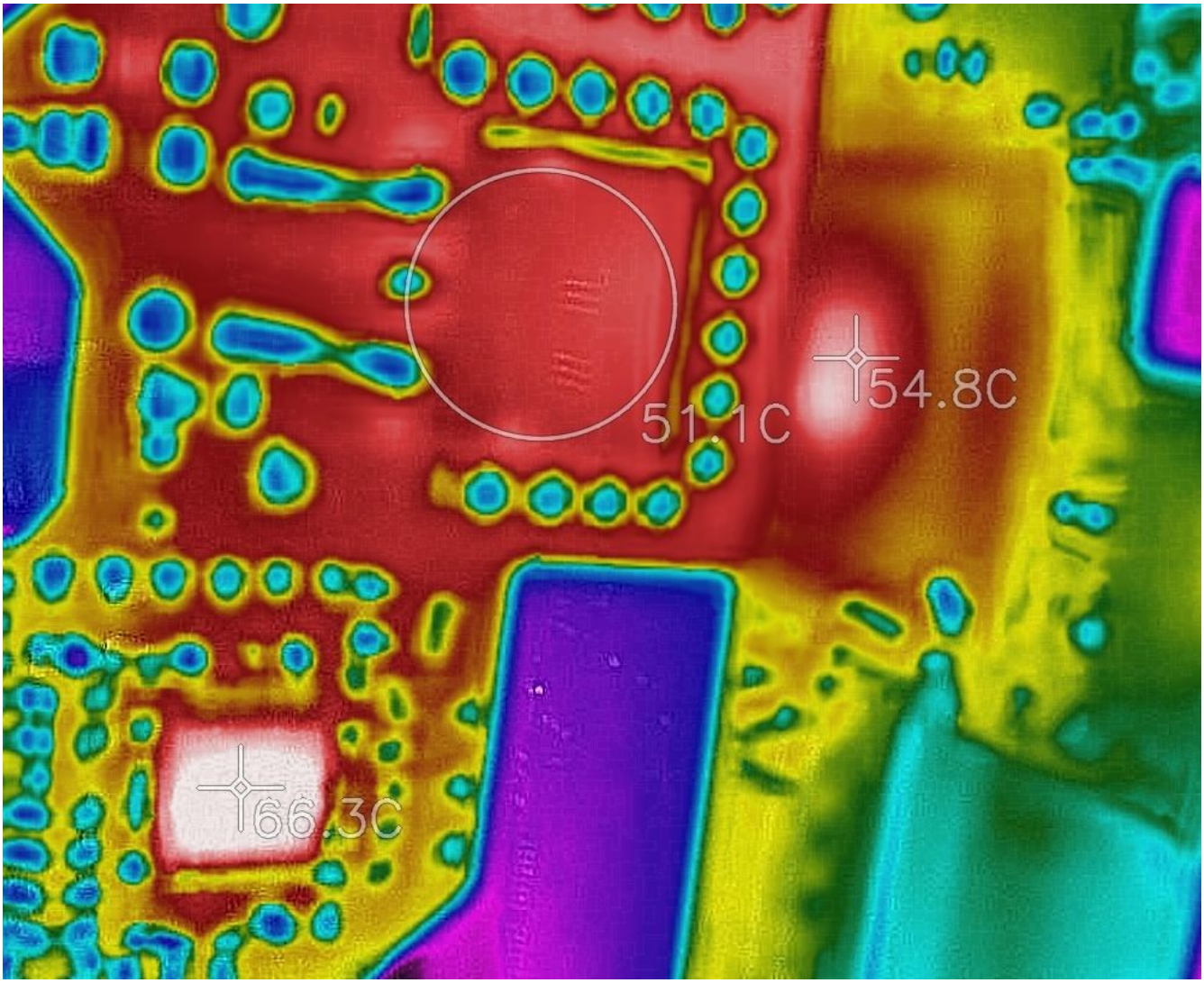
APPS -> DMM6500 Intro. Ending the Intro locks the instrument... something about script ending error ?
Restart of instrument works.

- 2020-12-24
  - Picking the instrument apart also removing the main PCB to be able to get to the Fan.
    - 3 screws to remove. One of them in the back left corner holding a rectifier bridge to the chassis.
    - 2 plastic clips to be pressed together and vertically lift the PCB as there is a connector connecting to the expansion slot. You can see the connector looking into the box with the Front removed.
    - 3 connectors to remove.
      - Front Transformer, 5 pole connector.
      - Back left corner (Brown).
      - Rear Output Terminals. Two screws.
    - There are two ’protrusions’ in the sheet metal that to some extent guides the PCB. Take it gently to not get stuck there.
- 2020-12-25
  - Temperature measurements with FLIR and Fluke. See Temperature measurements.
  - Modify the lid with 62 holes, 3.3 mm in diameter. See Picture elsewhere.
  - Moving the Fan. Diode in series.

Temperature Measurements



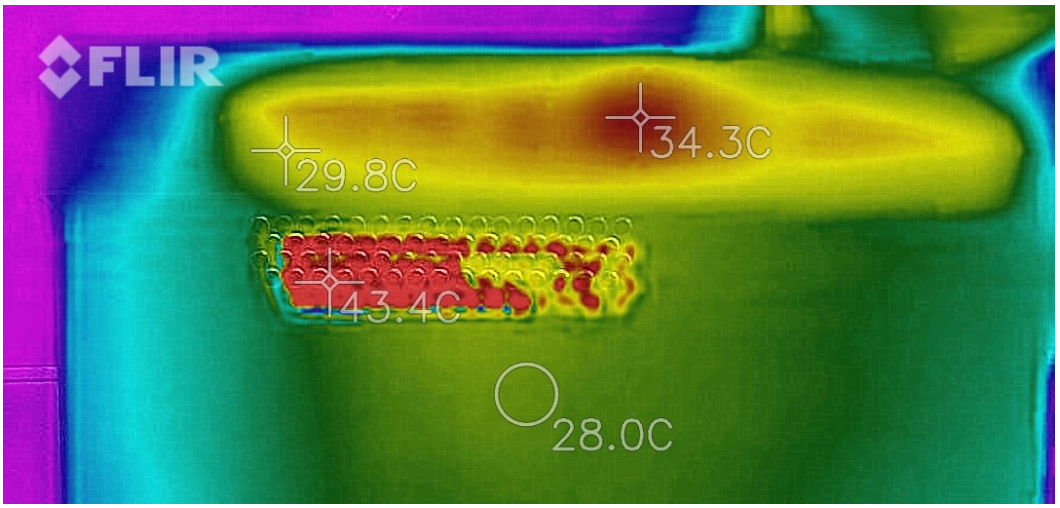
Open box, lid off and after 2 hours using a Flir One Pro. Highest temperature is 62C.



This is a bit hard to see but the left part is the Main PCB with the analogue voltage regulation section, 66.3C and 51.1C. To the right is the Front PCB with CPU etc. where one spot is reading 54.8C.

Lid ventilation

Modified the lid with 62 holes 3.3 mm. See picture. Could probably have made it bigger.



Natural convection with new ventilation.

Fluke

My Flir One Pro goes dead here !

After 2 hours with Fluke Thermocouple. Lid Closed, ventilation in lid.
Thermocouple measurements with Fluke 87 V.

No Fan at all.	**New Fan = New placement of Fan.**
• Inductances Digital DC/DC, approx. 50 C	New Fan → 46C, 44C
• The hottest chip 68-70C (Earlier with FLIR, open box approx. 62-64C)	New Fan → 53C
• Transistors, regulators, DPAK approx. 60C	New Fan → 43-44C
• Large electrolytic capacitors, 57C	New Fan → 40C

The Fan

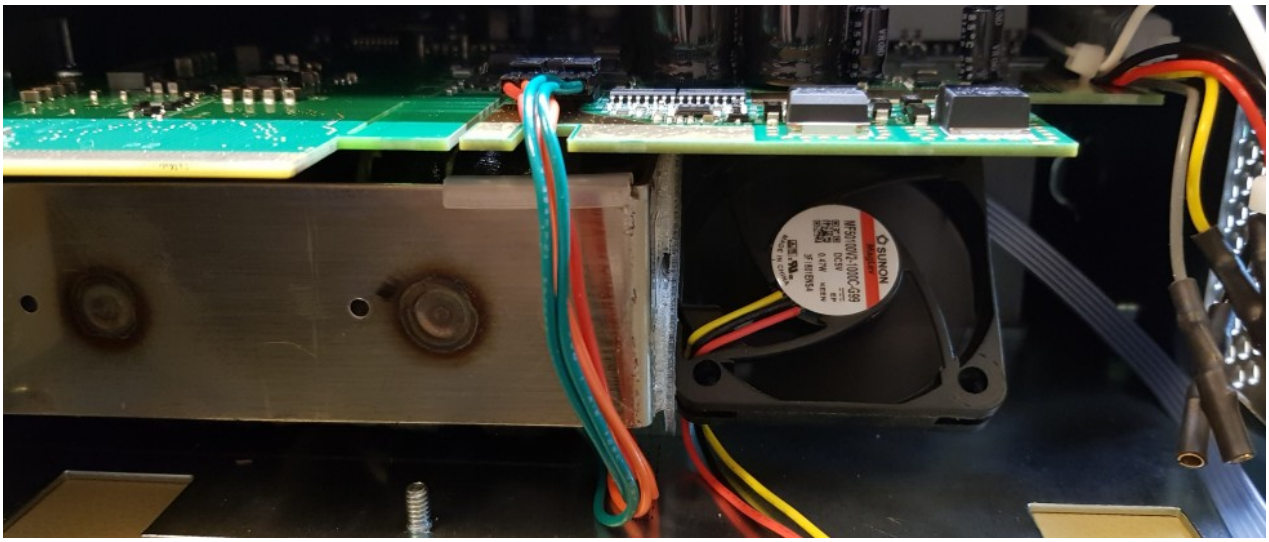
The Fan is pulling 83 mA @ 5 V, i.e. R = 60 Ohm. Lowering the current to 30 mA and the fan gets very quiet but is still blowing a descent amount of air.

The voltage in the instrument at the Fan terminal is **2.9 VDC.**

A serial resistor to slow the Fan down is a bad idea. You loose too much power and the Fan stalls.

Voltage control is better. The Fan starts, stalls at 1.8 V and at 2 V the fan is pulling approx. 30 mA.

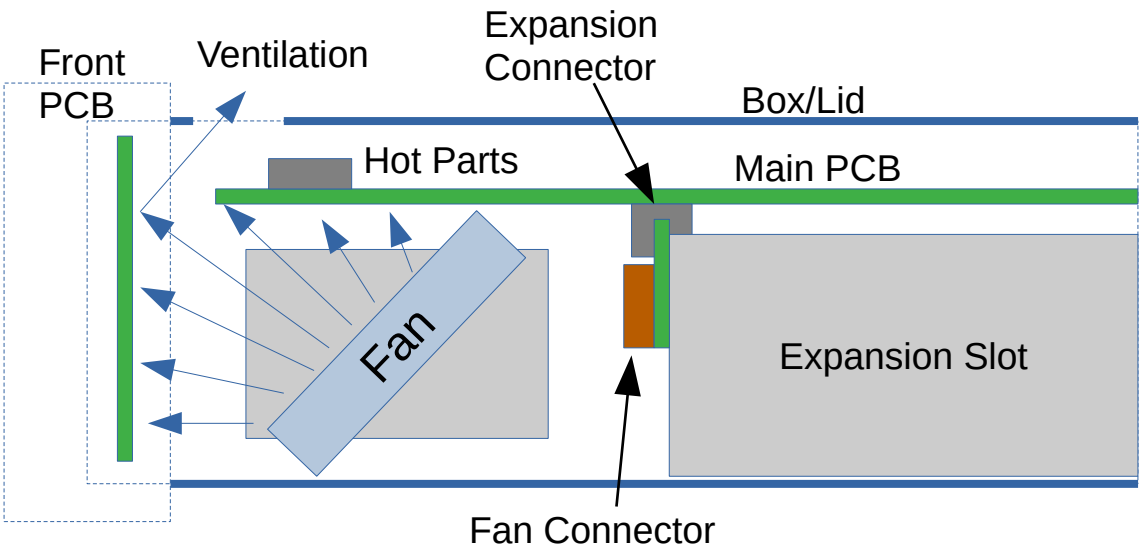
The final solution is a diode in series with the Fan dropping approx. 0.5 V. The Fan is now quiet enough.



New mounting of original Fan at the end of the dual transformer pack using 3M Dual Lock.

Mounting

Below is a side view sketch of the new mounting of the fan. The Fan is now blowing on the hottest parts of the design, i.e. the bottom side of the main PCB on the analogue voltage regulators and on the front PCB with at the digital electronics, CPU etc. These parts get quite hot as well.



Power Supply - Voltages

Measured with Power Meter

Power Off	6.6 W, Current = 0.185 mA, Power factor = 12% (0.12)
Power On (Idle)	22.8 W (24.8 peak), Current = 0.195 mA, Power factor = 49% (0.49)

PF = Real(W)/Apparent(VA)

Voltages

There is a clear marking for Analogue GND and test points with markings for the voltages.

They use LM313, LM337 as regulators and 7805 for 5V etc.

Input: 234 VAC to dual transformers, one for Analogue and one for Digital.

5 wires from Transformer input connector. One higher voltage (HV) centre tapped secondary and one lower voltage (LV) winding. Primary winding resistance = 44 Ohms.

Red	HV- Centre Tap	(Rectified +/- 22.6 V below)
Orange	HV1	
Orange	HV2	
Green	LV1	(Rectified 9.5 V below)
Green	LV2	

Analog

Marking	Measured	
+5 VA	+5.03 V	
-5 VA	-5.05 V	
+18 VA	+22.5 V	
-18 VA	-22.7 V	
+15 VA	+16.7 V	Where they lossing too much power in the LM317 ?
-15 VA	-15.2 V	
+6 VA	+9.5 V	

Chips (Around the Transformer input):

- LM313, LM337, 7805,
- T074 77K(G4) AQKV (Marking,TI) - This is the hottest chip in the design.
  - TL074CDBR ? Quad Low-Noise JFET-Input General-Purpose Operational Amplifier. Is this really true ? Have I found the right chip ?
- C6040SD (Marking)

    - Diodes, 60V COMPLEMENTARY PAIR ENHANCEMENT MODE MOSFET
- 74HCT4051D
    - Nexperia, 8-channel analogue multiplexer/demultiplexer

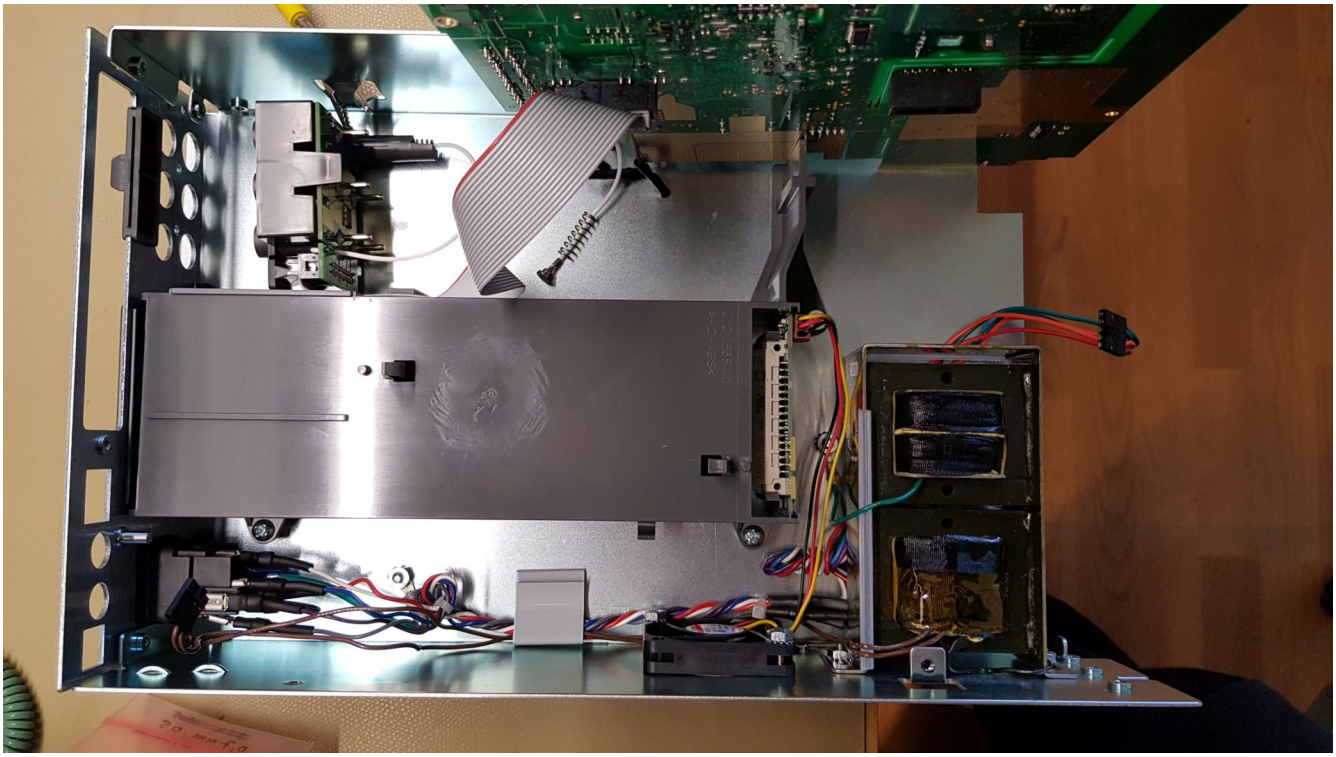
Digital

Input 9 Vrms from Transformer

Marking	Measured
6VD	9.7 V
5VD	4.99 V
3.3VD	3.37 V
1.8VD	

Chips: 3 times TJ 8PD (Marking, Brand ?)

Pictures



Main PCB removed. The big Gray box is the Expansion Slot with the two clips holding the Main PCB. Lower right, Dual Transformers One for the Digital Section and one for the Analogue section.

Links

Change of battery

---
https://www.youtube.com/watch?v=feCA5vQYVpU

DMM-thread on EEVblog
https://www.eevblog.com/forum/testgear/new-keithley-dmm6500/425/

Brad O (Keithley)

It might? The box isn't supposed to be opened at all, that's what the calibration is counting on realistically, the calibration probably wouldn't change that much. If you care about the calibration though you're probably sending it in once a year so they could just change the battery then if it dies.

All you need to do to replace that battery is pull off the front panel panel and put another CR2032 battery in, it's in a holder right behind the display. The battery will drain whenever the unit isn't on, even if it's connected to mains. But, the ONLY thing that battery powers is the real time

clock which has such a low drain that it's basically the same as the charge leakage of the battery. Really, you're limited by the battery's shelf life minus a couple months maybe.
Also, it doesn't affect measurements at all, so if it dies you might not have any need to replace it, the date of the instrument would just be wrong whenever you turn it on.

Fan Noise

FAN – according to Brad O. from Keithley it should not be a problem to turn off the fan completely.

https://www.eevblog.com/forum/testgear/new-keithley-dmm6500/775/

For the fan air - you could try blocking the vents with a breathable fabric. If placed loosely nearby it should still allow some air exchange while reducing the audible noise. If it is completely blocked off, the internal temp will rise and after some time, you may see measurements have drifted.
A good test is turn autozero OFF then block up your airflow.. after 30 minutes see how much drift has occurred (in addition to the normal spec) - it might be perfectly acceptable to your application.
This kind of operation wasn't characterized very much.

https://www.eevblog.com/forum/testgear/new-keithley-dmm6500/900/
Saw pictures that it is a Sunon Maglev MF50100V2-1000C- (50mmx50mmx10mm 5V 25.6dbA 11CFM 0.11inchH2O). Too bad noctua doesn't yet produce their 50mm slim a series fan.

Brad O, page 17

https://www.eevblog.com/forum/testgear/new-keithley-dmm6500/400/
Unfortunately that's not possible with the current design. Firmware can tell the fan to be on High or Low (It's on Low all the time right now), but there isn't any method that would allow the fan to be turned off completely, it would require, I'm told, a significant amount of work. Believe me, we know people don't like fans, and we have these instruments on our desks all day too (you should hear the fan required for the original 4200!). The fan was actually added pretty late in development, the team thought the DMM wouldn't need it at first, but when it wasn't meeting specs a fan had to be added.

Another, less invasive but maybe more risky method would be to stick a paper clip or something in the fan port and jam it. The fan is currently operating just above its stall speed so it *probably* would take quite some time to burn up, if at all. More likely is the fan would just have reduced life (the unit itself would be fine, only the fan would have a reduced life).