xDevs.com English (en)

HP 3458A 8.5-digit metrology-grade DMM restoration

- Intro
- Disclaimer
- Initial inspection and basic disassembly
- Manuals references
  - Service notes
- Repair workflow
  - Boards condition check
  - A7 Front panel
  - A6 Outguard power supply assembly
  - A5 Outguard Controller
    - Digital board versions
    - Repair for A5 board
  - A4 Inguard power supply
    - Repair for A4 board
  - A1 DC Board
  - A2 AC/TRMS board
  - A3 ADC Board
  - A9 DC reference PCBA
  - A10 Front/rear switch board
- Chassis repair
- Diagnostics
- Repair for HARDWARE FAILURE — SLAVE TEST: CONVERGENCE
- Repair for DCI ranges 100nA, 1µA, 10µA, 100µA
- Repair for SYSTEM ERROR 114 — multislope rundown convergence
- Repair for ERROR 204: Hardware Failure: Level DAC Convergence
- Firmware
- Other possible 3458A issues, reported by community
- Tweaks and tricks
  - Adding extra memory option
  - Improving long-term stability of LTZ1000A voltage reference module
  - Improving long-term stability for resistance measurement
  - Improving long-term stability for current measurement
- Calibration
- Performance verification
- Restoration summary

Intro

Hewlett-Packard was a big name in 20th century for electronics and test equipment. They designed and manufactured many equipment which works and not too shady even by modern standards today, 25 years after. Later, in 1999 HP's Test and Measurement Division spun off into Agilent. Today electronics test instrumentation part become further split and is known by brand **Keysight Technologies**.

One of spectacular instruments which survived thru decades and three brands is metrology-grade 8½-digit Model 3458A multimeter, with its famous ultra-linear ADC. This meter is still selling and supported on market, with brand new cost reaching over $9500 USD, in base configuration. It was introduced back in 1989 with MSRP $6000 USD.

For those who are not familiar with 3458A, some very useful operation details and features are covered in **this HP Journal 1989, dedicated for 3458A release**. Journal sourced from **HP Labs journal archive**.

3458A have so impressive performance, that even competitors took it as platform, such as improved **FLUKE HP 3458A/HFL Special Laboratory Digital Multimeter** variant, prior to their acquisition of Wavetek Datron in 2000 and release of their own long-scale 8½-digit DMM, Fluke 8508A.

But today we will look on old unit, still wearing HP logo, manufactured somewhat in 1996. It was purchased as "parts, non-functional" piece for $750 USD, which is below market price, even for broken meters. Perhaps you thinking "this guy is nuts, paying that money for 20 year old broken machine". But think for a second, metrology-grade instrumentation market is very conservative. There are only 11 (eleven, that's right) 8½-digit DMM models in the world, all vendors combined.

Here's a complete list 8½-digit long-scale meters:

Manufacturer	Model	Type	Status	DCV accuracy	Resistance accuracy	DCI accuracy
Advantest/ADCMT	**R6581D**	DMM	No longer available for sale	±5ppm + ±0.2ppm	±8ppm + ±0.2ppm	±20ppm + ±20ppm
Datron	**1281/1271**	DMM	No longer available for sale	±3.1ppm	±6ppm	±25ppm
HP	3458A	DMM	Current model			
Fluke	8508A	DMM	Current model			
Keithley	**2002**	DMM	Current model			
PREMA	**6048**	DMM	No longer available for sale	±5ppm + ± 1ppm	±7ppm + ±5ppm	±30ppm + ±10ppm
Solartron	7081	DMM	No longer available for sale			
Transmille	8080	DMM	Current model			
Transmille	8081	DMM/Electrometer	Current model			
Transmille	8881	DMM	Current model			
ZIP Nauchpribor KM300	**KM300**	DCV/Res/Calibrator				

It does take tremendous amount of time and effort to test, validate and prove stability and performance of such machines, where no detail is insignificant. Performance is a key point of these designs, and even now many engineers trust their measurements from 3458A's. Old, but not obsolete. Hope this giving you idea

how much it can go as today, even for broken meter with unknown condition, and why is it so. It's also troublesome for international shipping, with weight about 15kg and large size (~2U height with full-size 19" rack depth and width).

Let's see what we have to do to get unit back to operational state. My plan for this project is to perform full component level repair, and perform overall study of instrument's internal construction, as repair advances. This means we will not be doing expensive boards swap unless absolutely unavoidable.

As usual, all photos are clickable for high-resolution version.

> If you thinking that buying broken 3458A for good price and fixing it would be easy way of getting good 8½ DMM, consider many hidden costs of doing so. If unit stated as "untested/unknown" and not to have shown self-test result, it could have hardware failures. Paid cost for such a unit **WITH** proper repair can easily exceed cost of buying a fully tested unit. If unit's photo shows it as powered up but you can see "ERR" on display, it also means there is fault detected. Keysight have standard 3458A repair + recalibration cost at $2660 USD. Calibration alone of fully functional unit is likely to be over $1000 USD. Also old units manufactured earlier than 2005, would have Dallas NVRAM batteries already near end of life, with risk of losing calibration data any day. So even if you buy meter for 1000$, you can be easily be held back by 2000-3000$ more to fix it and get calibrated.

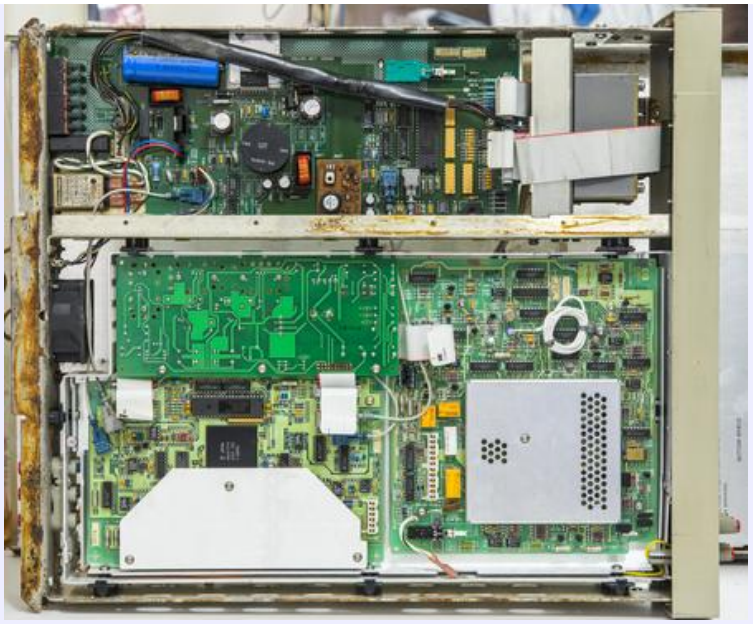
There are also special versions of 3458A with options, such as:

3458A-001	Extended memory option
3458A-002	Improved DC reference stability 4 ppm/year
3458A-H01	Special 1000 Vrms ac maximum input voltage
3458A-H52	US Air Force NSN
3458A-OGC	Precision calibration, intended for metrology use only

Disclaimer

If you willing to contribute or add your experience regarding HP/Agilent/Keysight instruments repairs or provide extra information, you can do so **following these simple instructions**

Initial inspection and basic disassembly

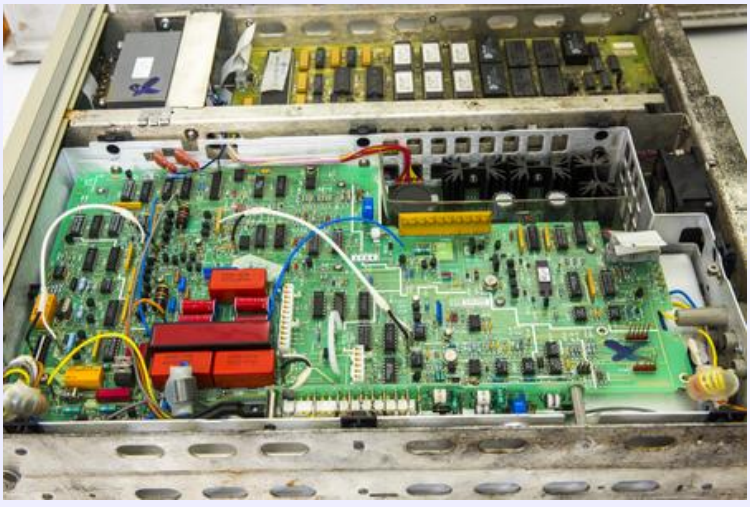


Damaged parts (and current status):

- U100 processor MC68HC000P8 had paper sticker BAD (A5 board manufactured 1990) No problems found
- Missing button cap on power switch, guard switch and front/rear switch.
- Missing fuse binding post for amps on front panel Replaced
- Rust on steel chassis. Fixed
- Mark “X” on mains power transformer. Replaced
- Mark “X” on analog board 66501 (manufactured 1996)
- Error message **RAM 1 LOW** stated by seller. Fixed
- Missing voltage reference board (so calibration is meaningless, even if it’s still intact in 1990 year DS1220).. Fixed, bought replacement A9 PCBA.
- Missing fuse holder for mains Replaced with another fuse socket
- Damaged plastic rear panel Replaced
- No legs Fixed
- Dodgy soldering on A1 PCBA
- Broken fan Replaced
- Rusty GPIB connector on A5 PCBA Replaced
- Old electrolytic capacitors on A6,A4 PCBs Replaced
- Prone to explosions Schaffner FN 323-3/05 EMI/mains filter Replaced
- **ISOLATOR FAILURE** error message Fixed
- 100nA,1uA,10uA,100uA ranges on DCI not working, zero reading Fixed, replaced RP200
- **SLAVE TEST : CONVERGENCE** error message Fixed, install jumper P100 2-5 on A1 PCBA
- **SYSTEM ERROR — multislope rundown convergence** failure Fixed, replaced A3 PCBA
- Front/rear switch is damaged and not locking Replaced

Unit covers are very dirty overall, with lots of rust on rear part of steel chassis. Good thing is, that analog boards looking very clean, so it does not look that meter was flooded/observed direct water damage. That would be a major disaster for repair, if such happen.

All sensitive analog boards are enclosed in separate insulated aluminum cage, held by plastic standoffs. This is called “Inguard” by HP terminology, because this cage is kept under guard voltage potential to isolate sensitive analog circuits from external signals, EMI and RFI.



Pay attention to mains voltage selection switches, located near mains IEC connector. Using incorrect voltage setting (e.g. 120VAC with 220VAC mains) will likely to destroy transformer, as it is linear type and directly wired to mains! This is likely what happened to my unit by

> previous owner, and was a root cause of damage. New transformer cost is $337 USD + tax, so was rather pricey mistake.

Manuals references

- **A User's Guide to Keysight 3458A Front Panel Operation**
- **3458A Multimeter User's Guide, Edition 7**
- **Keysight 3458A Multimeter datasheet**
- **Agilent 3458A : Quick Reference Guide, Edition 2, Dec 2000**
- **3458A Multimeter Calibration Manual, Edition 7**
- **3458A Multimeter Calibration Manual, Edition 6**

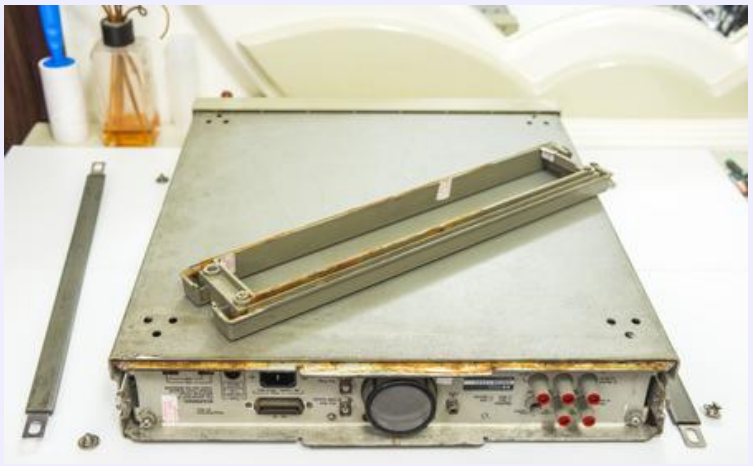
Service notes

There is also number of service notes/engineering changes were published during years of 3458A's lifecycle. If your unit is old, worth to check if any of them required to do.

- **Service note 3458-01C : A/D Linearity Improvement**
- **Service note 3458-04A : Apparent failure at turn-on or when given a "RESET" command**
- **Service note 3458-06A : Modification to Fix Hardware Error, "ac offset DAC 10mV invalid cal value: 184"**
- **Service note 3458-07B : Modification to Fix Intermittent Error "Multislope Rundown Conversion"**
- **Service note 3458-08A : Incorrectly Labeled Line Voltage Switches May Cause Switch Setting Confusion**
- **Service note 3458-10A : 3458A Documentation Available As "On-Line" Files**
- **Service note 3458-11A : Reduction of AC Noise When Measuring ACV and Using Twisted Shielded Pair Cables**
- **Service note 3458-12B : Outguard Firmware Upgrade: Enhancements, Fixes, & Changes**
- **Service note 3458-12C : Outguard Firmware Upgrade: Enhancements, Fixes, & Changes**
- **Service note 3458-13A : GPIB Communication Failures Using the 3458A**
- **Service note 3458-14B : Calibration Error After Power "On" or After an "ACAL"**
- **Service note 3458-15D : CAL RAM Battery Preventative Maintenance for the Outguard Controller (A5) Assembly**
- **Service note 3458-16 : The original 3458A fan filter (3150-0300) is no longer available. The replacement fan filter uses three unique parts.**
- **Service note 3458-17 : Errors May Occur if ACAL AC is Initiated From the 4-Wire Ohms Function**
- **Service note 3458-18A : Some recently produced 3458As may be "out of DCV specifications" due to time drift issues.**
- **Service note 3458-19A : The original 3458A A5 (PC Assy-Outgard Controller) is no longer available. The replacement kit consists of two unique parts and an installation note.**
- **Service note 3458-20 : Bad SRAM causing Cal Ram batteries to fail prematurely**

Repair workflow

As usual, we have **project tracker, dedicated for 3458A repair** so any one can contribute, or track the progress.



Before starting any repair, good idea to read thru repair manuals, to get idea of board functions and purpose. HP has both assembly and component level repair manuals, which include full schematics and board assembly drawings. AFAIK it's the only 8½ DMM which have complete schematics. I still remember repair efforts and countless hours without schematics, deciphering circuitry in **Keithley 2001 DMM**.

3458A Multimeter Assembly Level Repair Manual, Edition 2

3458A Multimeter Component Level Repair Manual

Also worth to note requirement of adjustments/recalibration procedures, from repair manual, in case of board replacement/repair:

Ref Designator	Agilent Part Number	Assembly Description	Adjustments Needed
A1	03458-66501	Front panel	DC circuitry Offset, DC Gain,Resistance, and DC Current Adjustments
A2	03458-66502	AC converter	AC Adjustment
A3	03458-66503	A/D converter and Inguard logic	Offset, DC Gain,Resistance, DC Current,and AC Adjustments
A4	03458-66504	Inguard power supply	ACAL ALL
A5	03458-66505	Outguard Controller	Offset, DC Gain,Resistance, DC Current and AC Adjustments

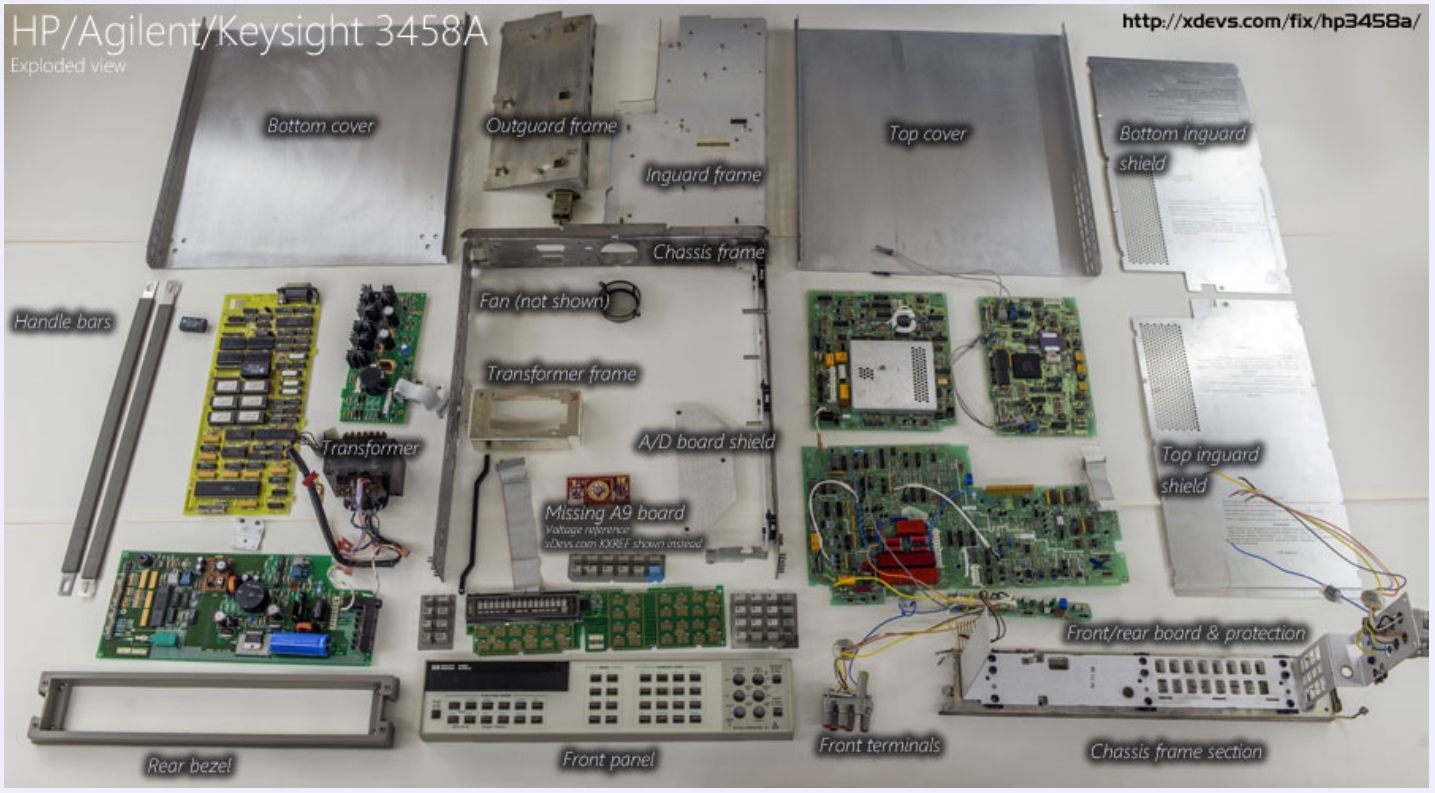
A5 (001)	03458-66515	Outguard Controller (Opt 001)	Offset, DC Gain,Resistance, DC Current, and AC Adjustments
A6	03458-66506	Outguard power supply	ACAL ALL
A7	03458-66507	Display logic	ACAL ALL
A9	03458-66509	DC reference	Offset, DC Gain,Resistance, and DC Current Adjustments
A9 (002)	03458-66519	DC reference (Opt 002)	Offset, DC Gain,Resistance, and DC Current Adjustments
A9 (HFL)	03458-66529	DC reference (Opt HFL)	Offset, DC Gain,Resistance, and DC Current Adjustments
A10	03458-66510	Front/rear switch	Offset Adjustments,ACAL ALL

Some parts are available for order from Keysight. **List of parts and cost from Keysight, Excel table**

As expected, most mechanical parts are affordable to allow minor repair, but when we start looking at PCBA level repair cost is quickly jumps to thousands of dollars, making whole project worthless.

> HP/Agilent/Keysight does not support users doing component-level repairs, so don't expect answers to questions like "I have problem A with my meter, found broken component R532 and U245, can you sell me new component?"

Overall parts view:



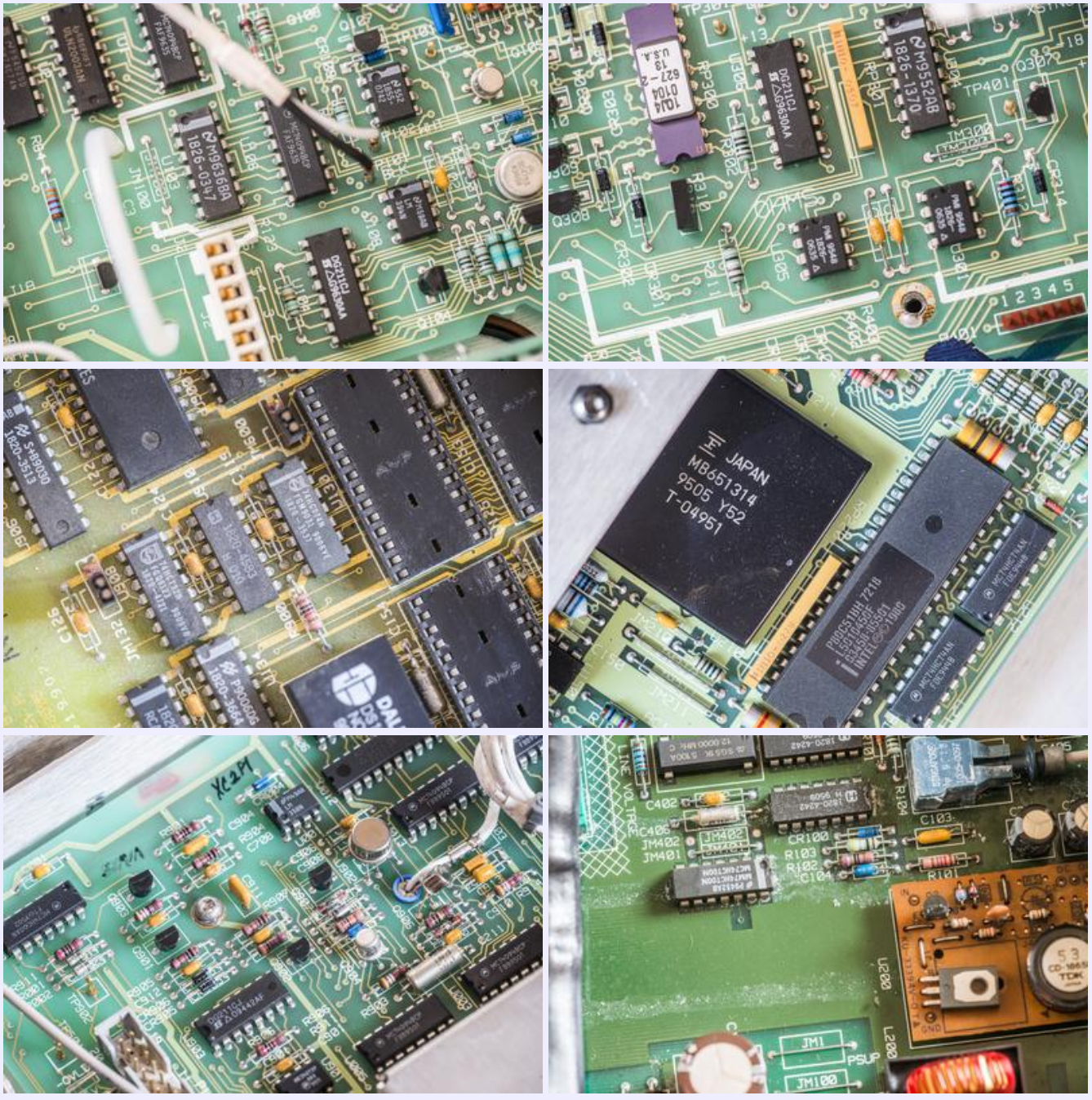
Except missing A9 DCV reference board, everything is there, no missing parts on boards. Vacuum-fluorescent display glass is not damaged (barium flash on glass from **getter** is shiny dark, if air leak into tube it would become white)

Boards condition check

Before doing any repairs or applying power, wise to check physical condition of components and boards inside instrument. Often this easy operation can spot obvious failures, such as blown MOSFETs, burnt resistors or missing parts, saving time for further repair.

Have a close look on electrolytic capacitors, especially if instrument's age is more than 10 years. If you see leaked electrolyte or bulging capacitors, do not apply power. Replace broken parts and clean board thoroughly, to avoid further damage. Often electrolyte soaks into PCB via's and eat copper tracks, so pay close attention to condition. If any visible discoloration found, use DMM to check connection resistances, and rewire broken nets, if needed.

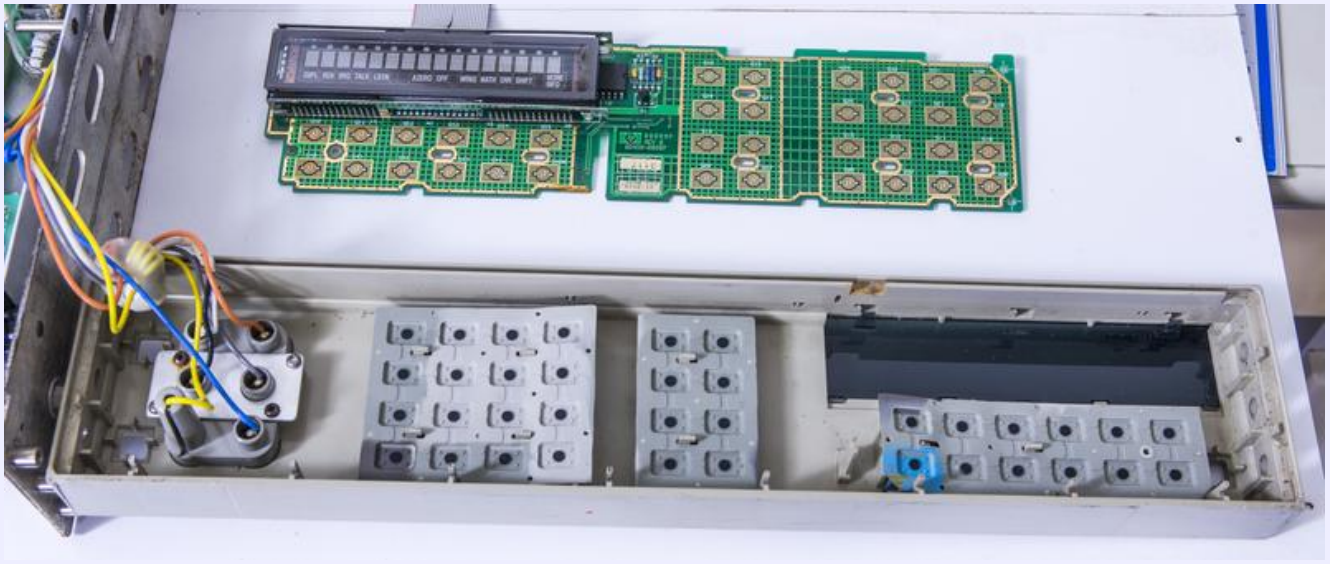
I usually replace old electrolytic aluminum capacitors to fresh ones even if they look okay. It does not cost much, but will save the question regarding if original ones are good or bad, or at borderline. Important to keep same voltage and capacitance rating, and ESR/ESL spec as original caps, unless you really know what you are doing.

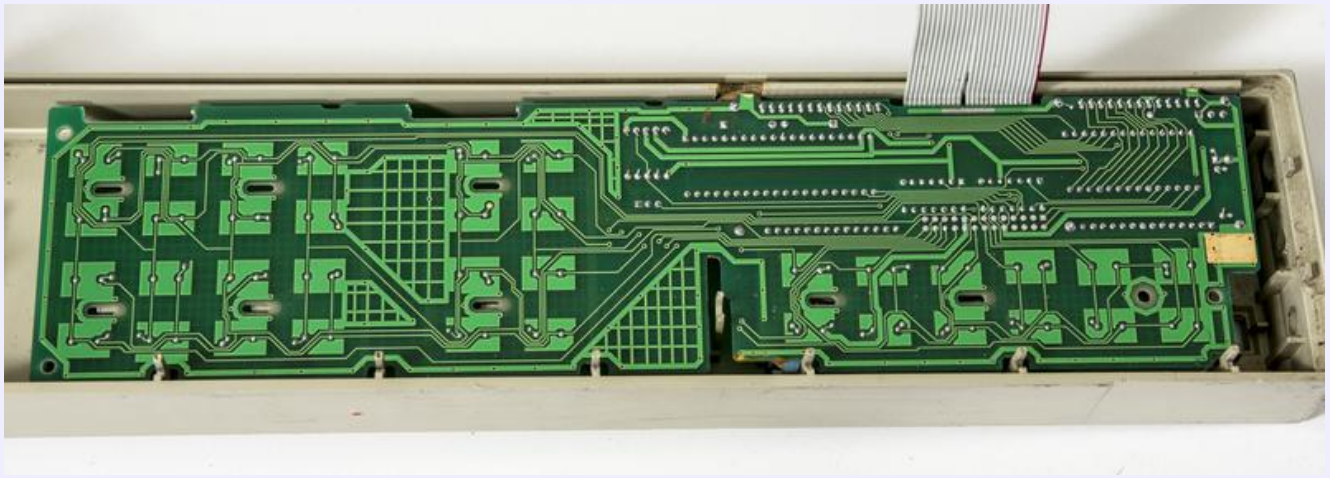


Now take a look on PCB and fix issues as we go. Order is

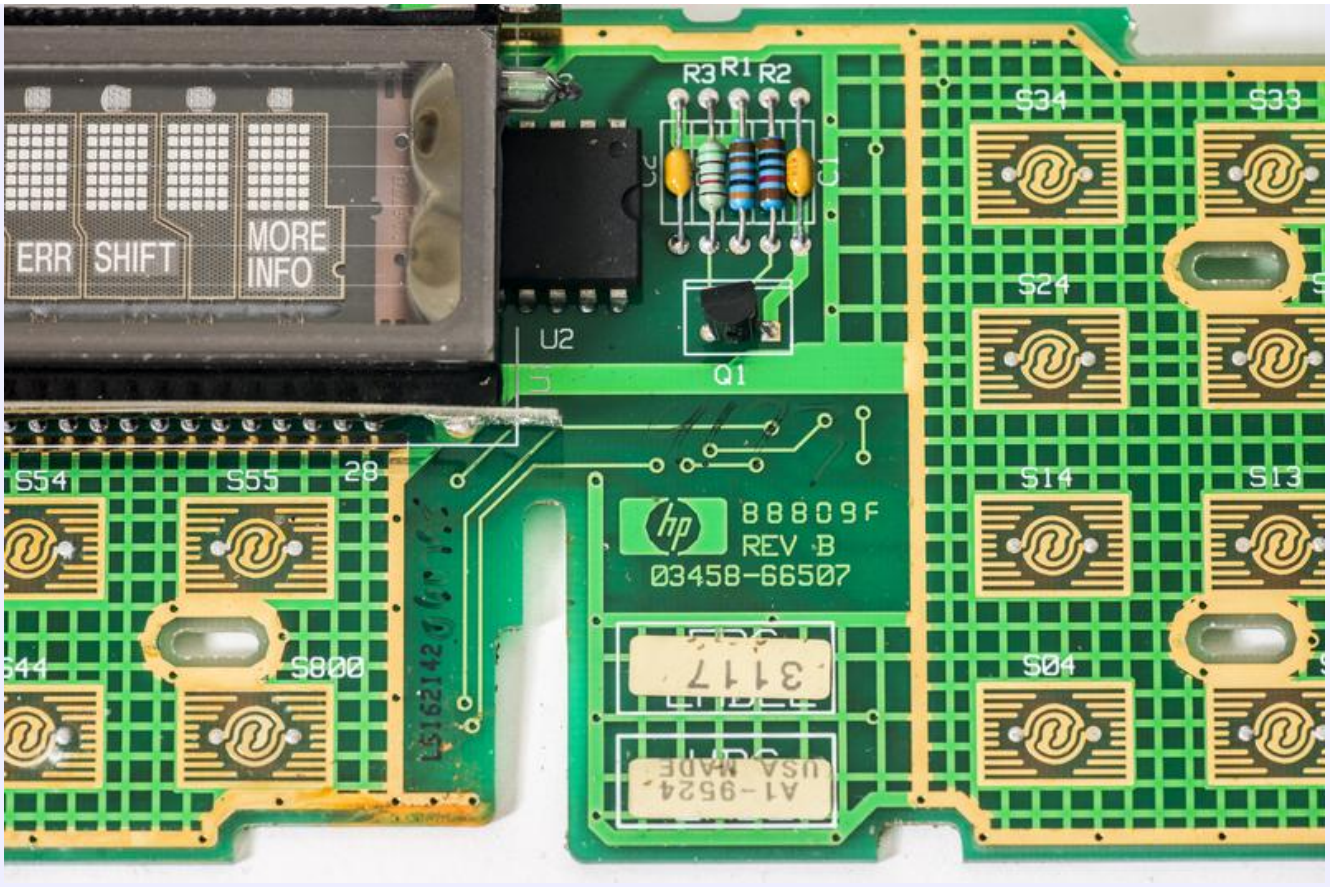
A7 Front panel

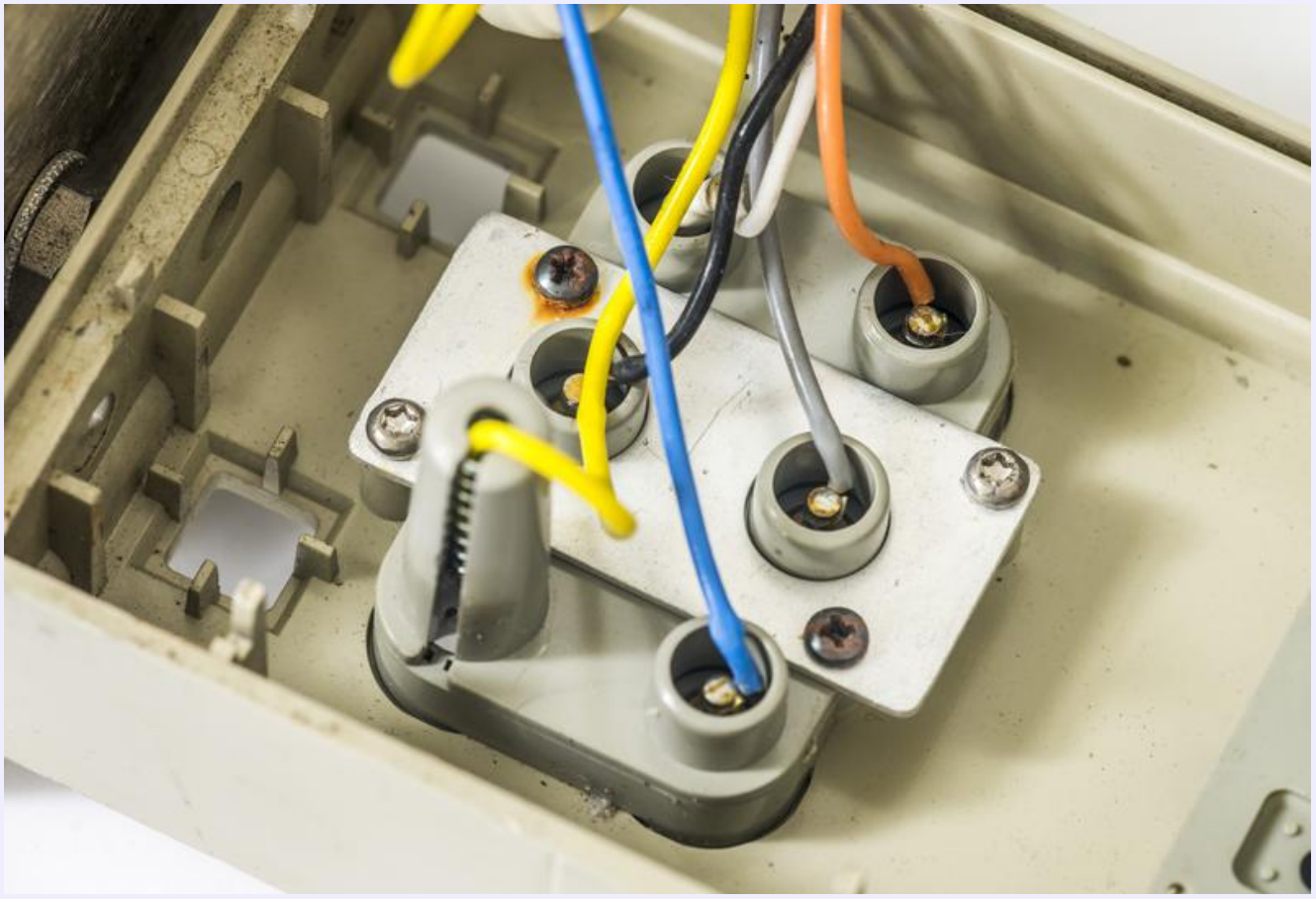
Front panel must be removed in order to remove mains transformer. To do so, lift right side of panel and release it from chassis frame. Be careful with front panel assembly, as vacuum display glass is fragile.





Looking good, just minor cleaning required..

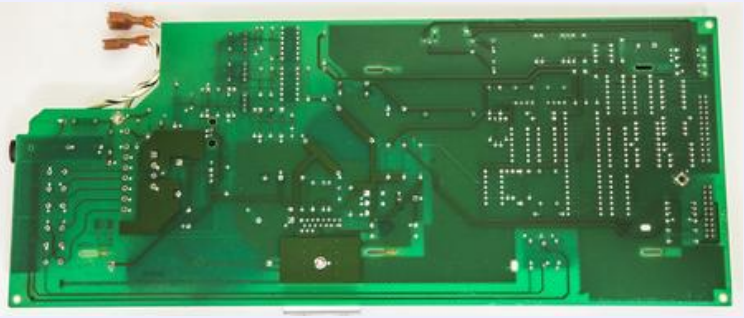




Front panel PCBA label and front binding post terminals.

A6 Outguard power supply assembly

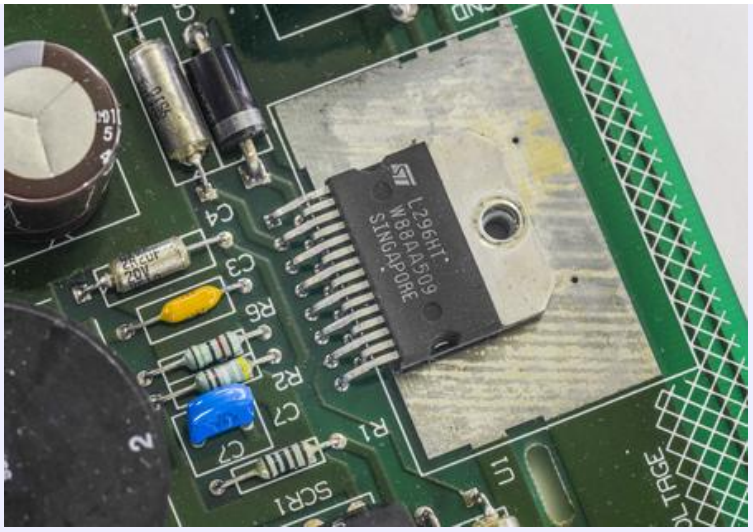
Let's deal with Outguard stuff first, as we cannot test or check anything on analog Inguard side, unless main processor, front panel and interface is fully operational.
It's wise to start from testing power supplies.

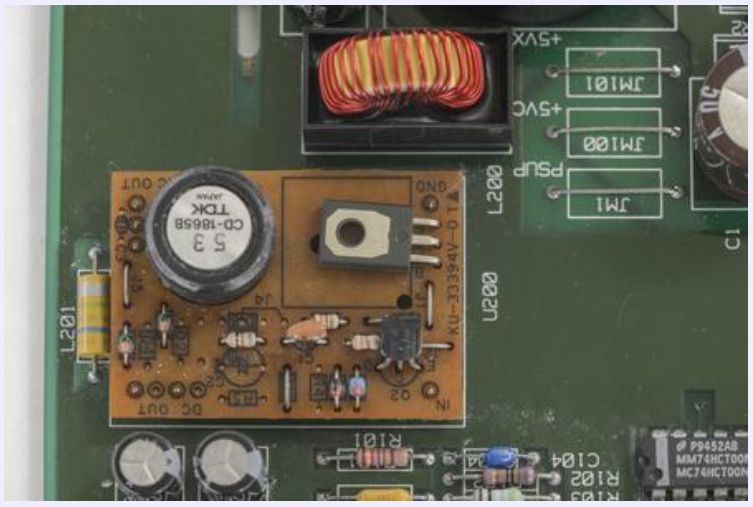


After installing fuse, meter digital section can now power on, giving short beep and displaying error message on VFD.

Display looks bright and nice, it's great news, as old VFD segments often fade badly if being operated for long periods of time.

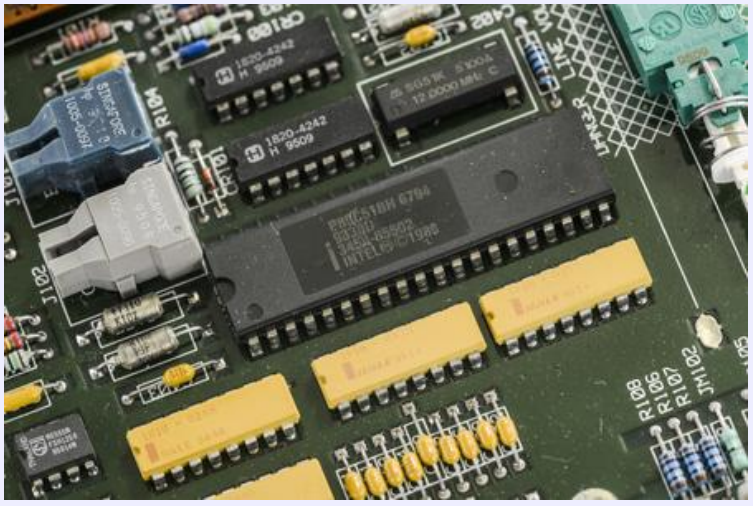
Error message **RAM TEST 1 LOW** meaning there is fault with digital board. So let's troubleshoot digital section first, which is board A5. We will get into it later, let's finish up with A6 supply first.

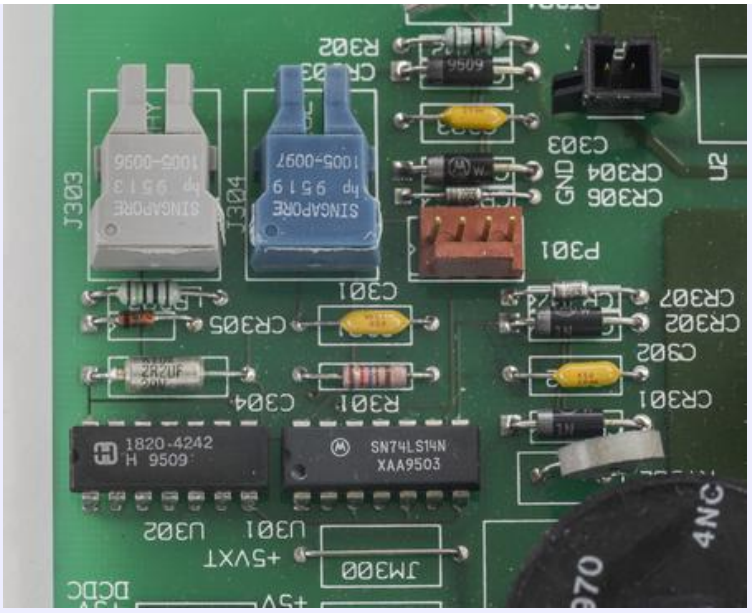




This board is host for two main supplies, high-current +5V supply for digital controller board, front panel board, display and fan. Main power convertor is based around switching **ST L296**, which is capable of supplying up to 4 amps of current.

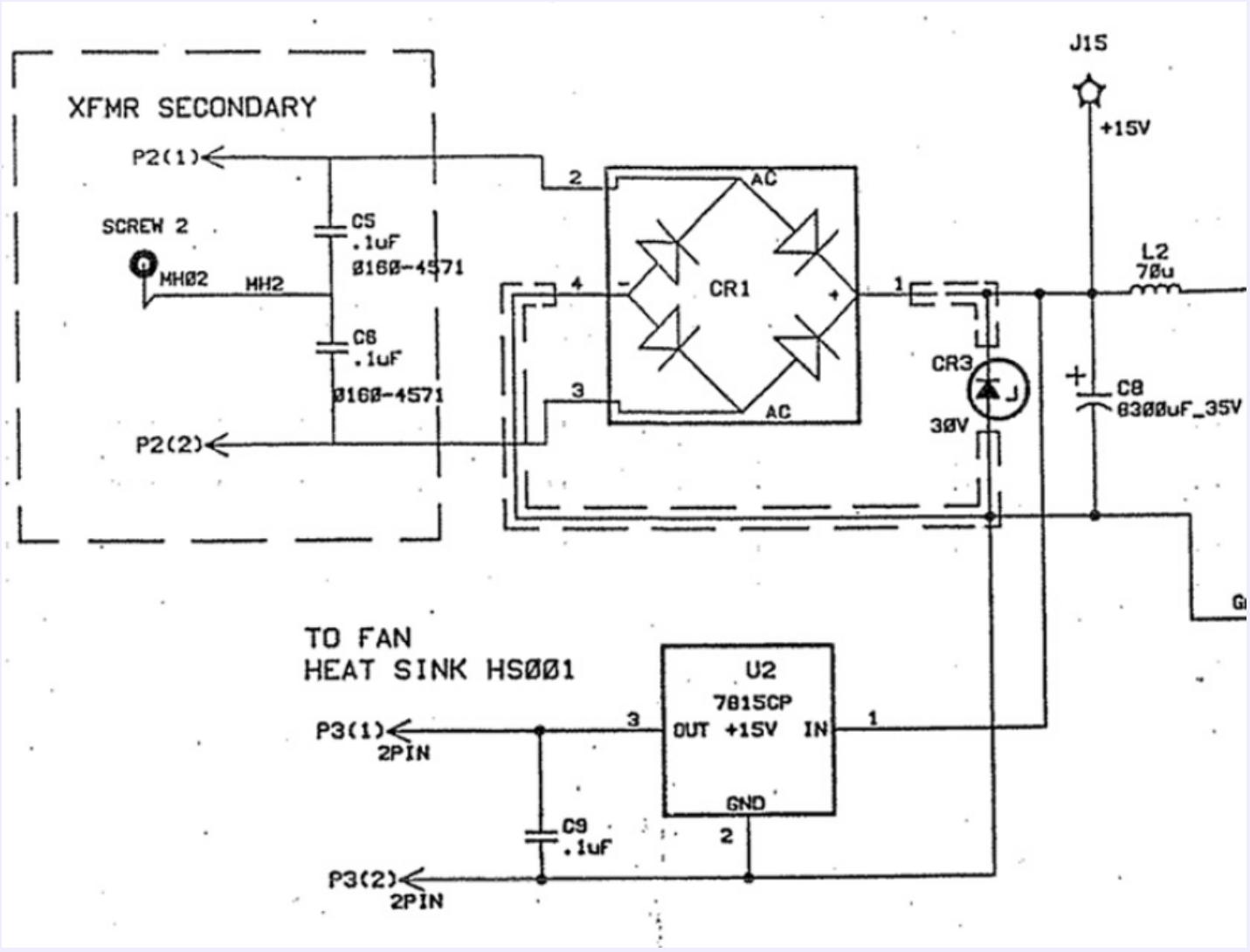
Small board with U200 refdes features simple DC-DC/AC to provide alternating voltage to front panel vacuum-fluorescent display filament and +60VDC to its segments.





Big chip in DIP package is **Intel's 8051 microcontroller**, preprogrammed with 03458-85502 mask firmware. This controller handles buttons, buzzer and display operations. NE555 nearby provides tone signal to buzzer.

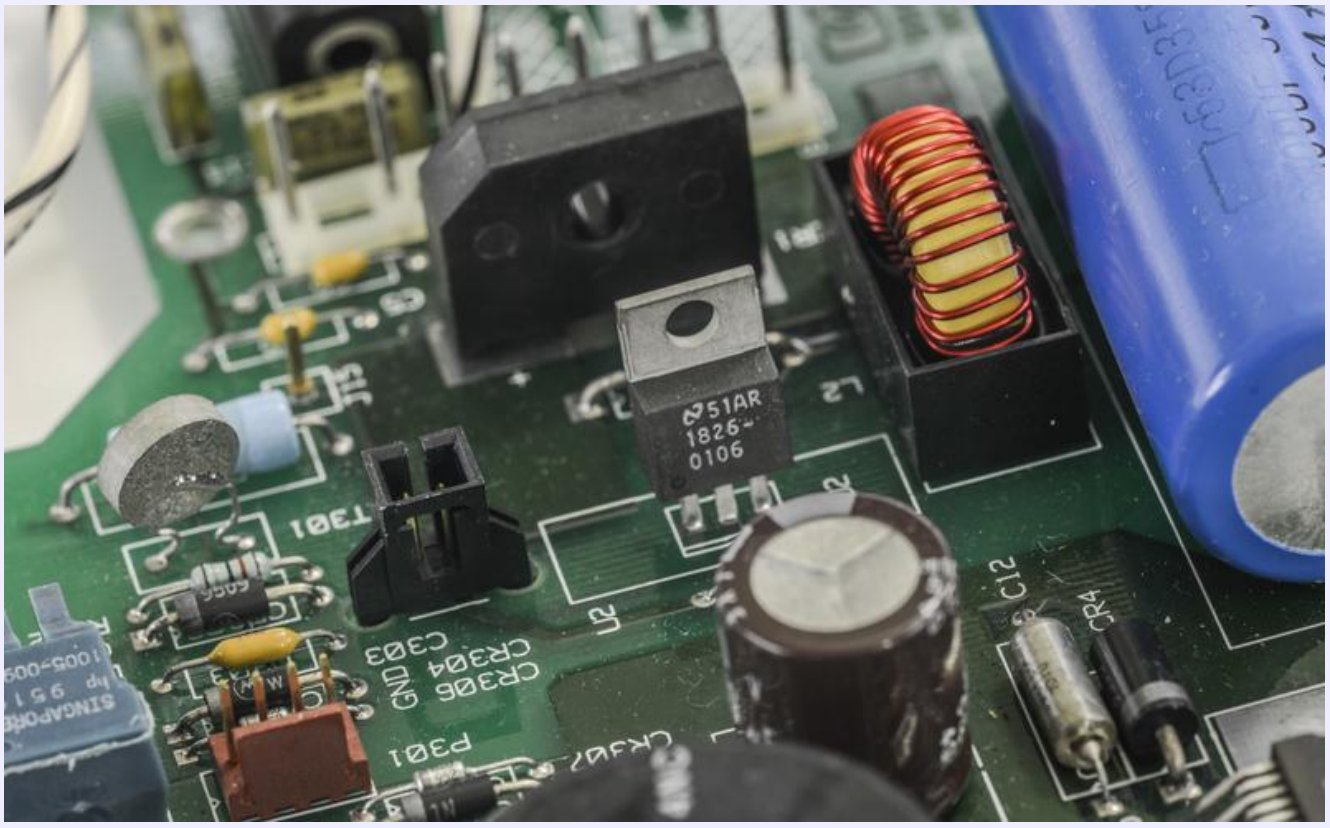
Let's take a look on system fan. First, it's supply:



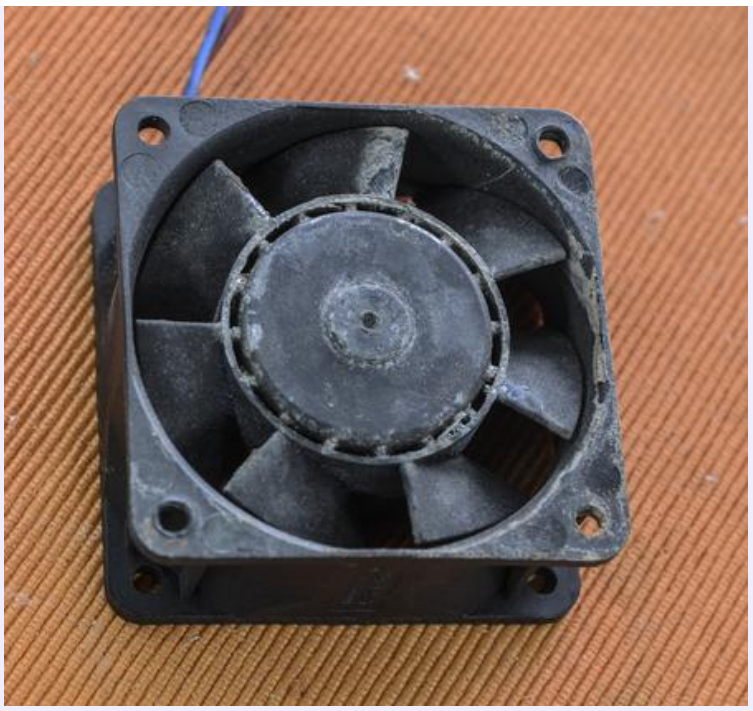
It's little confusing, if taking into consideration +15V marking and 7815 LDO after diode bridge. Had measured actual voltage going to fan, it is indeed +15.1 VDC.

Fan 7815 linear regulator have little clip heatsink, and bearing HP custom code marking.

According to CLIP's BOM list its regular MC7815CT linear regulator in TO220 package, designed to provide 14.4/15.6 VDC output.



Black 2-pin connector at left of regulator is fan header. Fan in my unit is completely stuck and blocked by gunk, so instead of wasting time on fan cleaning, I'll just replace it with same specced new one from NMB.

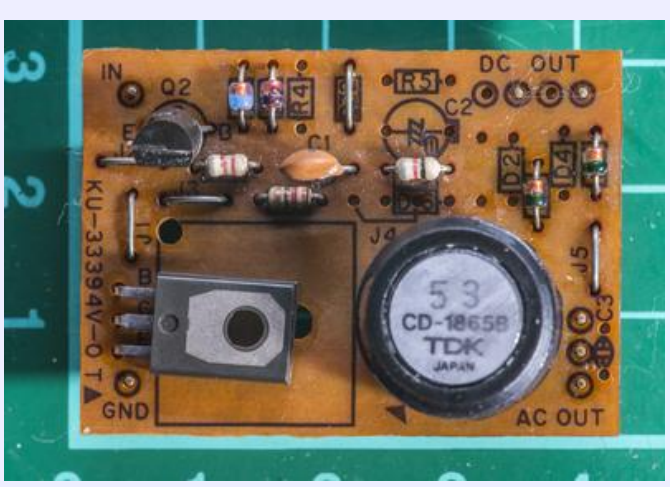


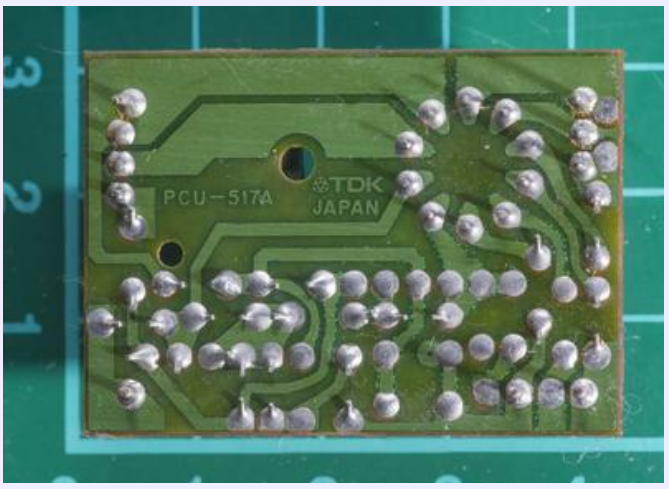
Original fan is 60×60×25mm sized, DC type with just two wires. Made in Germany by respectable manufacturer, PAPST. Interesting to see, that fan is actually rated from 6 to 15VDC, while most of similar small DC fans are usually 5, or 12 or 24 VDC.

My favorite destructive analysis reveals fan support with dual ball-bearings. Lubricant was long gone, resulting metal-type dirt and specs in motor.
I desoldered original fan wire, so I'll use it with new fan, saving trouble with cable length and connector matching to A6 board.

I also ordered some capacitors from DigiKey to replace all electrolytes on this board. You can call me paranoid and insane, but I would not trust 20 year old electrolyte capacitors, even if they are made by 1st tier manufacturers.

Removing VFD supply board as well to clean:

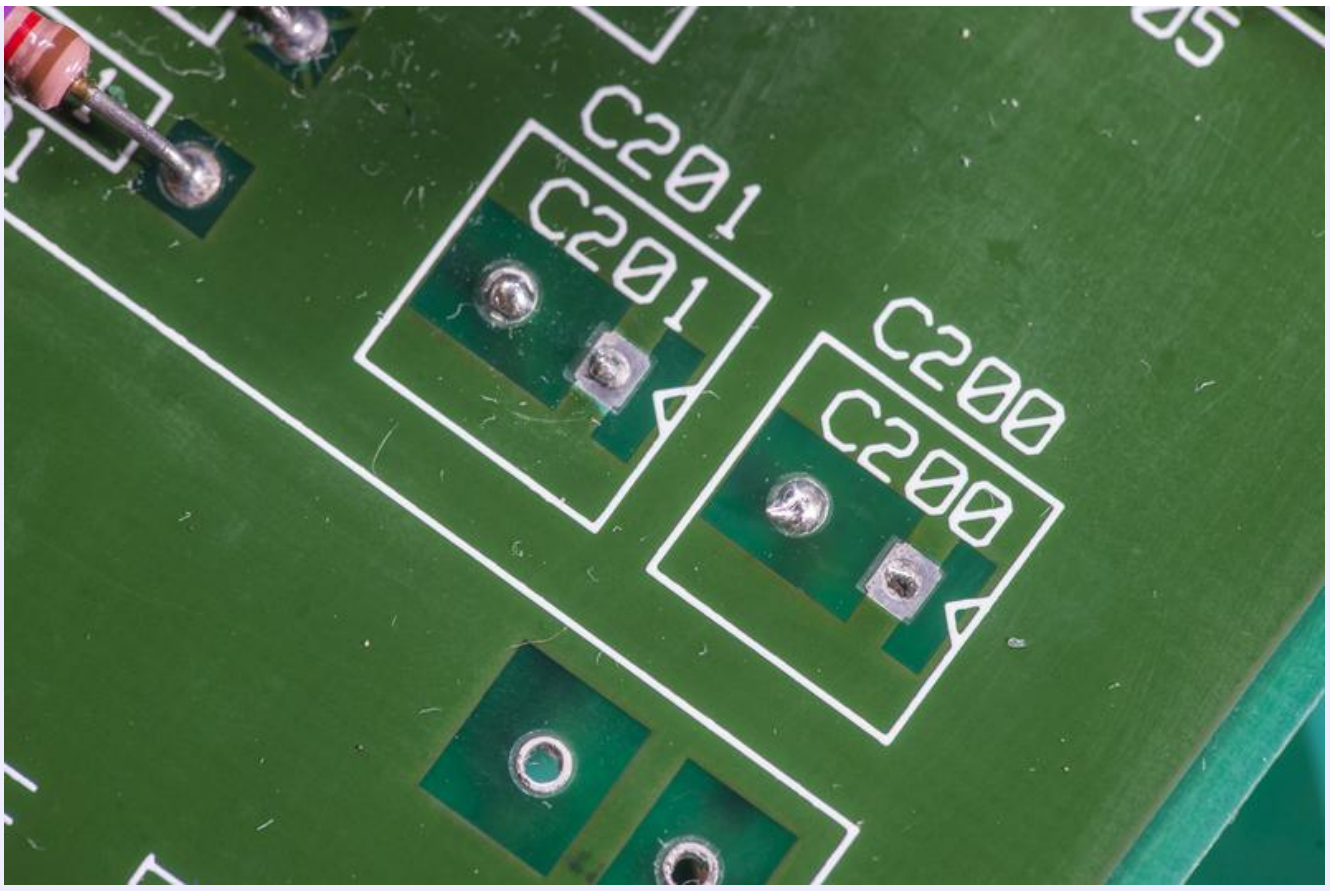




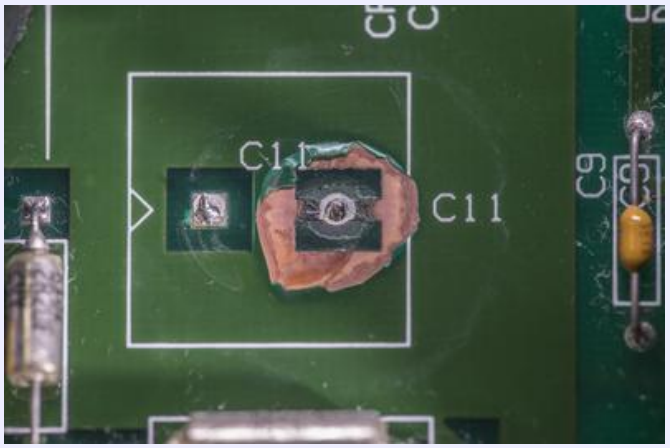
It's a **TDK-CD1865B DC-DC/DC-AC module**. It takes +5VDC input and generate +50VDC and VAC voltage for filament.

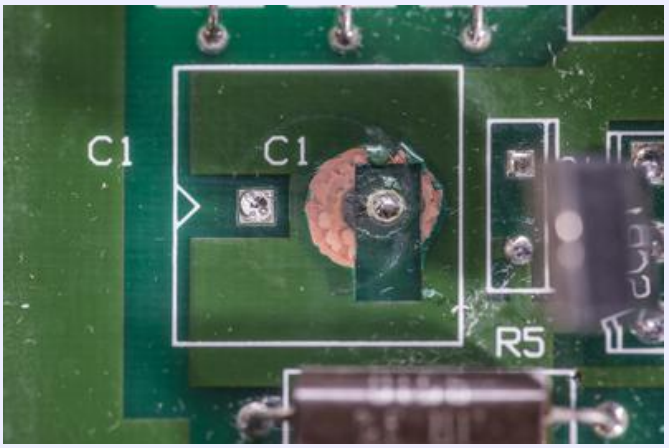
Electrolytic capacitors looked alright, so most of people would think – *Hey, those caps probably okay, don't waste your time?* . No, better be safe than sorry… Take them out, and say thank you later.

Now it's visible. Electrolyte got already out and started its destruction activities. Green pieces are actual PCB's solder mask.



Small ones did not do any damage (yet), but bigger ones…





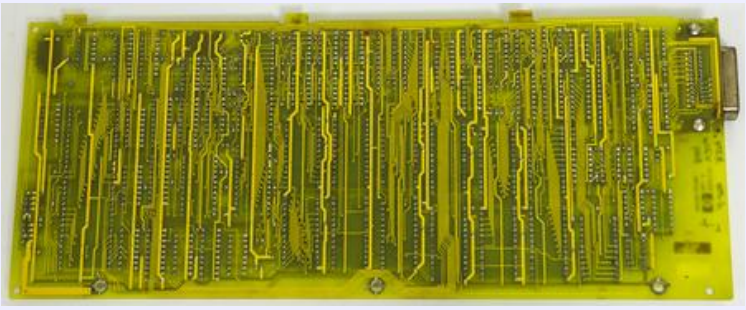
Now I am really glad that we did not cut corners here, and removed them. And it's nice to have HP 3458A with only 2-layer PCBs, no risk of inner damages. I'll just clean it to shiny copper, add layer polyurethane enamel film around pins , just to be future-proof. Caps I bought from DigiKey are long-life, rated for +105°C, and so should work a treat for many years after replacement.

I was wondering and measured old caps too, for series capacitance and resistance, with help of repaired **HP 4263B**



It's a good lesson, capacitors are only getting bad with age, not better as voltage references. 10 years passed? Replace them **now**!

A5 Outguard Controller

Meter digital brain, firmware, calibration ROM and digital interface circuits are located on this dual-layer board. We have older board version with all thru hole components, while newer meters usually have smaller SMT-type A5 controller.

Main processor is infamous 16-bit Motorola **MC68HC000P8**, 8MHz RISC

Processor's RAM consist of pair non-volatile **Dallas (today it's MAXIM) DS1235**, high and low bytes separately. If these NVRAM become bad, meter during power-on selftest will throw error **RAM TEST 1 LOW** or **RAM TEST 1 HIGH** depends on which IC died and lockup further operation.

It's fully compatible and can be replaced with **Dallas (today it's MAXIM) DS1230Y** chips. Original RAM chips are soldered down directly to PCB, so it's wise to remove old RAMs and solder good quality collet-socket for easy replacement in future.

Calibration data stored in separate NVRAM, Dallas DS1220. I expect that RAM chip dead too, as it's same age as main RAM.

If your meter still contains valid calibration data, there is a way to read calibration constants back, given that meter can power up and enter operation mode. **This message** in volt-nut maillist have some details regarding using GPIB commands to readout NVRAM contents.

DS1230 and DS1220 NVRAM is still in production, as can be bought from **MAXIM** or can replace battery-backed NVSRAMs with Ferroelectric RAM (FRAM) such as **Cypress FM18W08** and **FM16W08** which does not require battery power to retain its data. Only drawback, that these production FRAM provided only in SOIC package, while obsolete older FM1808 and FM1608 chips had drop-in DIP package version too.

Digital board versions (A5 Outguard Controller)

There are multiple revisions of A5 board assembly in 3458A units over its 25 year lifetime.

PCBA Version SKU	03458-66505	03458-66515	03458-66547	03458-66548
				
First released	1988			
Option variant	None	001	None	001
RAM type	2 x DS1235, for low and high bytes			
Calibration RAM type	1 x DS1220, for calibration data			
User-replaceable batteries	No		Yes	

Older units with 66505/66515 boards can be retrofitted with the newer version A5 PCBA by ordering Agilent/Keysight Update Kit p/n 03458-80047 (around $600 USD) or extended memory Kit p/n 03458-80048 (around $1000 USD). There is **Service note 3458A-19A** covering this upgrade.

Repair for A5 board

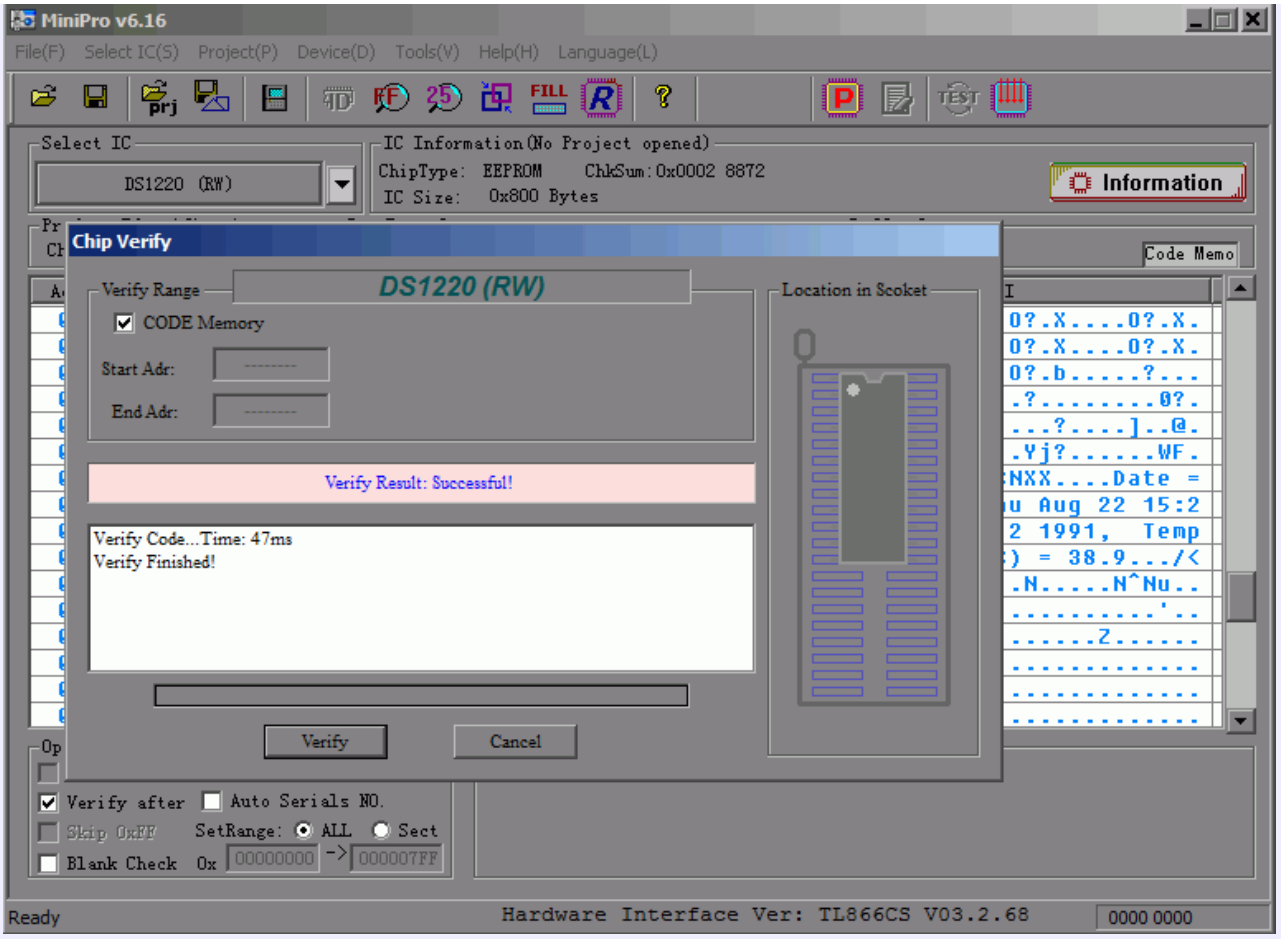
STEP 1. NVSRAM

As described earlier, failure of main memory NVRAM chips will instantly generate **RAM TEST 1 LOW** or **RAM TEST 1 HIGH**, so that is exact problem we have in our case.

I used copper solder wick to suck solder from NVRAM pins and remove faulty chips from PCB. Instead of soldering new chips in place, I opted to solder good quality gold-plated collet sockets, so in future soldering would not be required.

Same did for calibration NVRAM chip, DS1220, position U132, as that one is also very old. After meter repair and calibration, data stored in that chip will be critical. You don't want risk losing those constants after expensive calibration.

Tested original chip from board and was surprised that actually it does have correct-looking data and pass read/verify tests on my MiniPro TL866 programmer.



Date of calibration recorded in plain ASCII, saying 1991 year. This makes it rather useless, as in 24 years resistors and parts in meter drifted more than such old data could be used, as original DC reference board is missing. But since we have nothing better, I will copy this data into new Dallas DS1220 so we can use it as starting point.

After replacement of Dallas NVRAM, and powering up only A5,A6 and front panel I can see it passing RAM test, checksum test and display now shows **ISOLATION FAILURE** message, just after few seconds of running **HARDWARE TESTING**. Of course, that is due we have nothing else connected, and processor expects data from analog side.

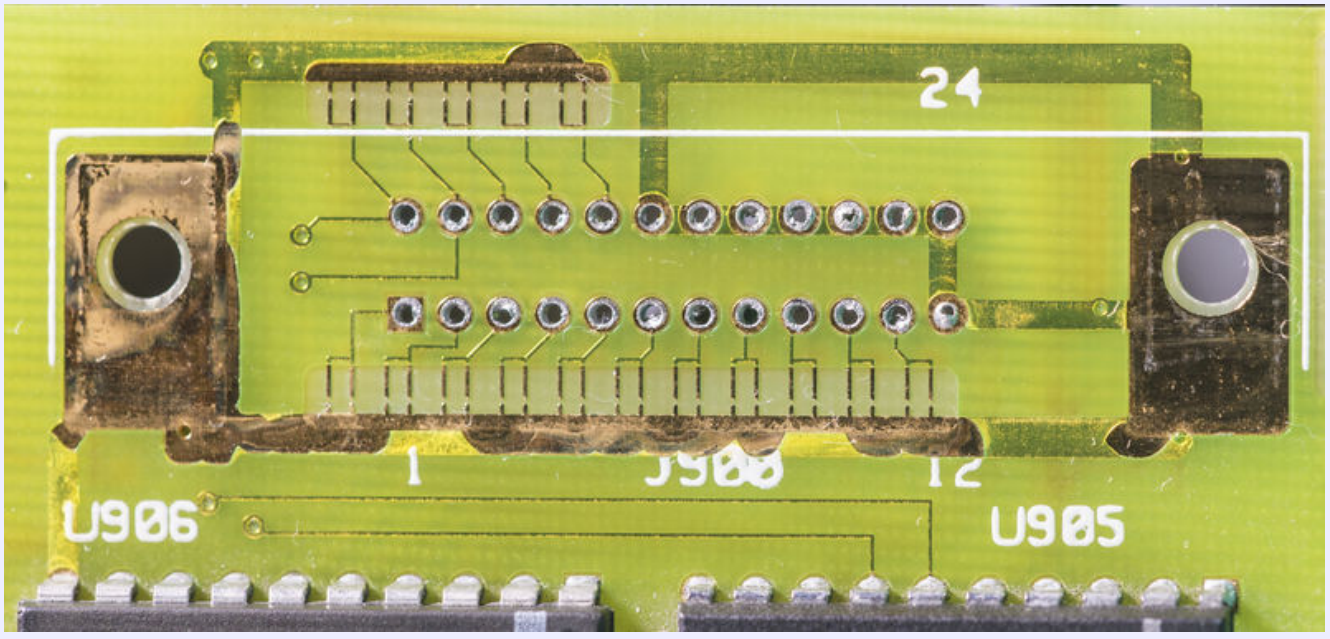
STEP 2. GPIB port

My board also fall within range of **Service note 3458-13A : GPIB Communication Failures Using the 3458A**, so I will add jumpwire for better ground on GPIB connector. There is interesting open connection routing with open mask on top side of PCB, just near connector pins.

I also replaced GPIB connector, as original one is really rusty. New GPIB connector was used from **broken HP 33120A PCB**.

Since I bet all of you already tired watching multimegabyte photos, let's do something different this time around:

5 hours worth timelapse, one shot every minute, 4K resolution, using my **repaired Nikon D3**. 526 photos, total.



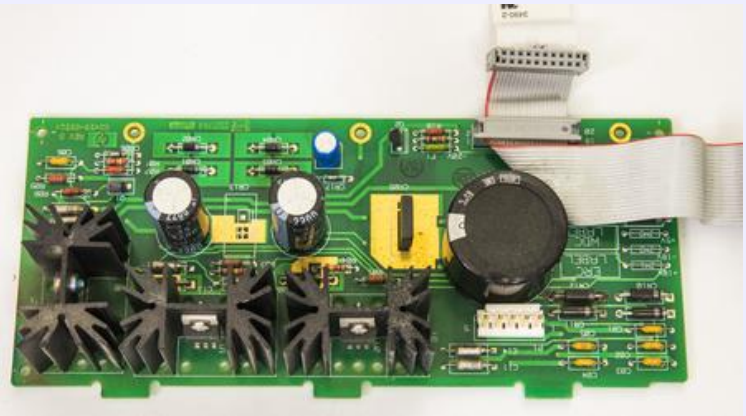
Quiz for readers : what are those funny traces with cutout do? :-/O

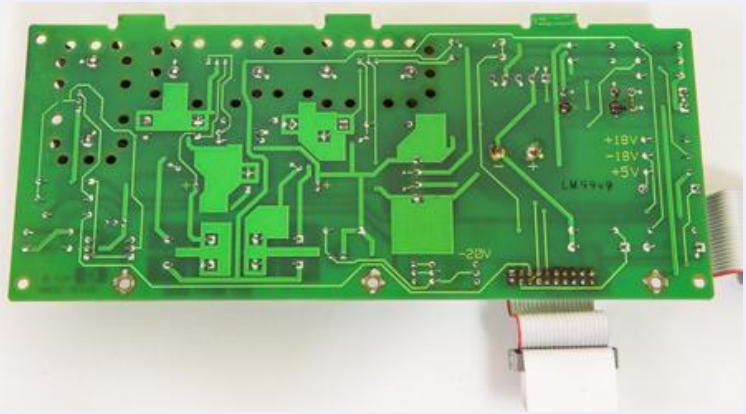
After connector replacement (had to saw it a bit, as it's mounted to PCB using rivets!). No, I don't have a drill, so used hand mill instead.

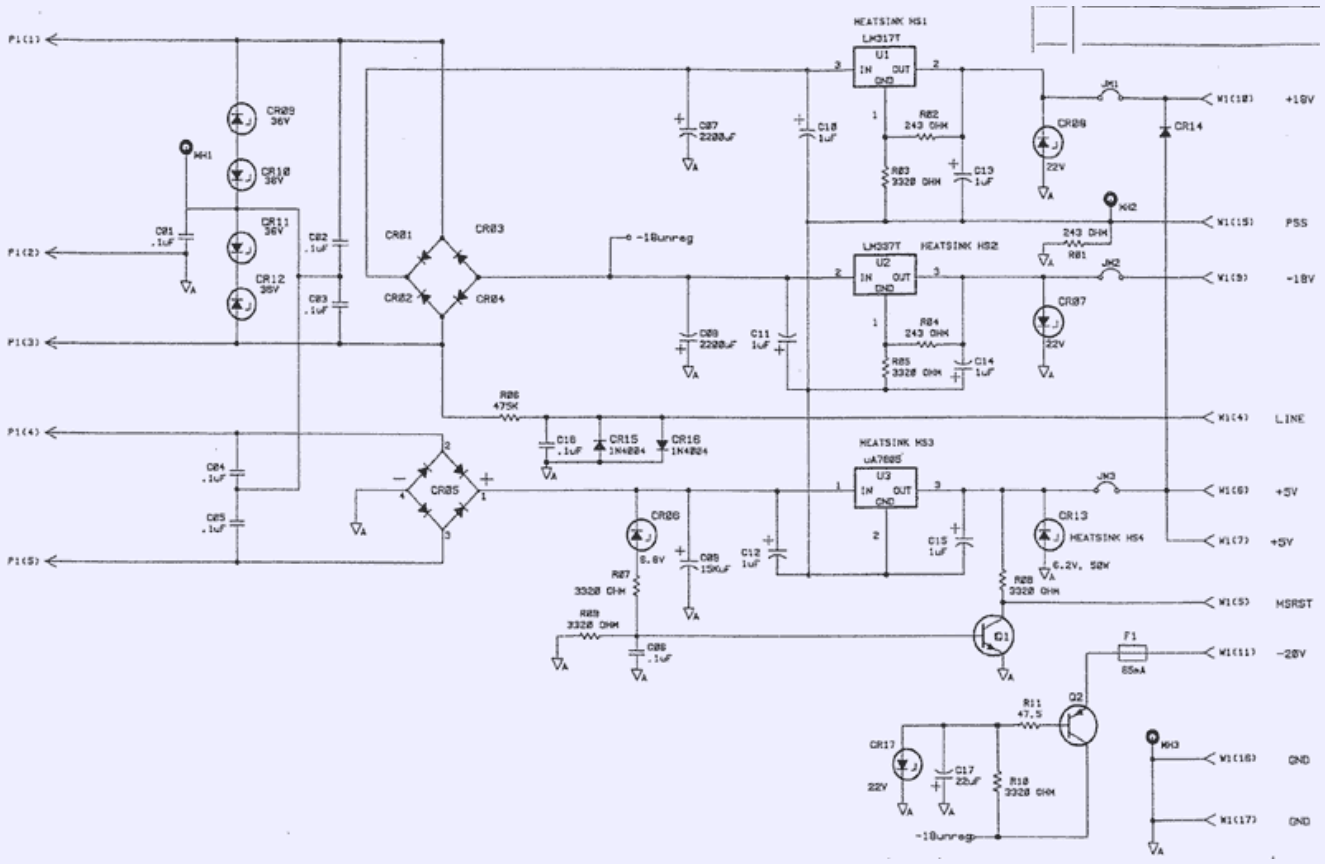
Then boring part, water+IPA bath for PCBA:

A4 Inguard power supply

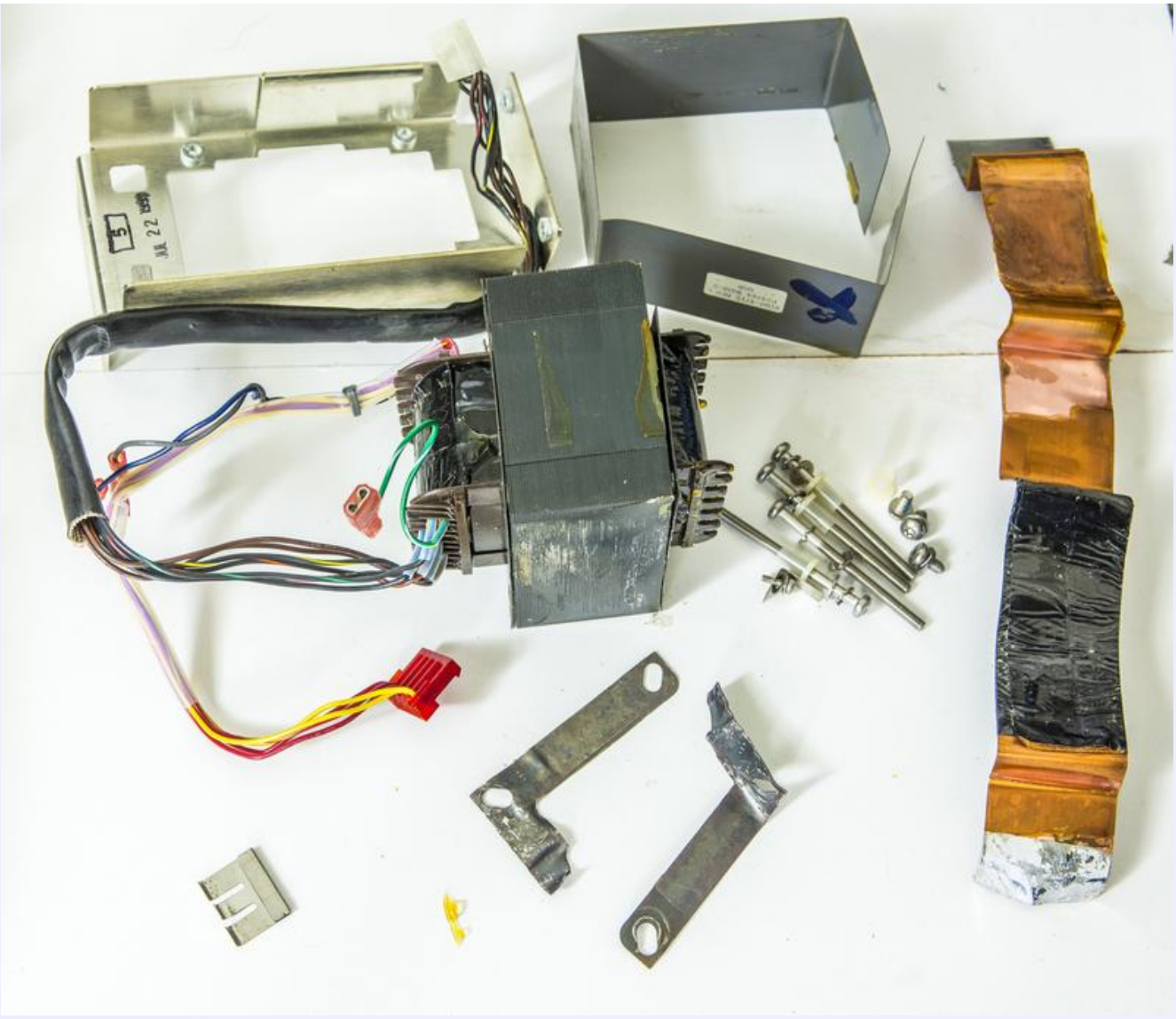
This board rectify secondary voltages from main transformer T1 connected via 5-contact P1 into DC voltages for analog board's power.







Let's look on transformer first.

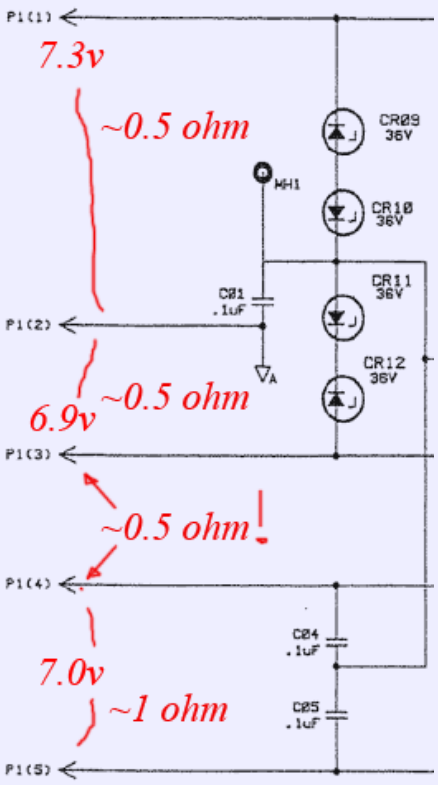


Transformer have winding sections, with separate two bobbins, primary with secondary Outguard +5V rail (goes to digital board and front panel, so that's working).

Second section for Inguard supply is inner bobbin with two secondary windings (one with center tap to generate +18/-18 and second for +5V analog supply).
Each winding have its own metal inner shield to reduce leakage and coupling between different transformer sections. Each of those shields have separate wire connected to different locations at Outguard and Inguard chassis frame points.

Windings in my transformer are shorted together, which is clear from simple DMM resistance check!

> ⚠ This could be a result of 220 VAC is applied, while rear line voltage selection switches are set for 120 VAC.

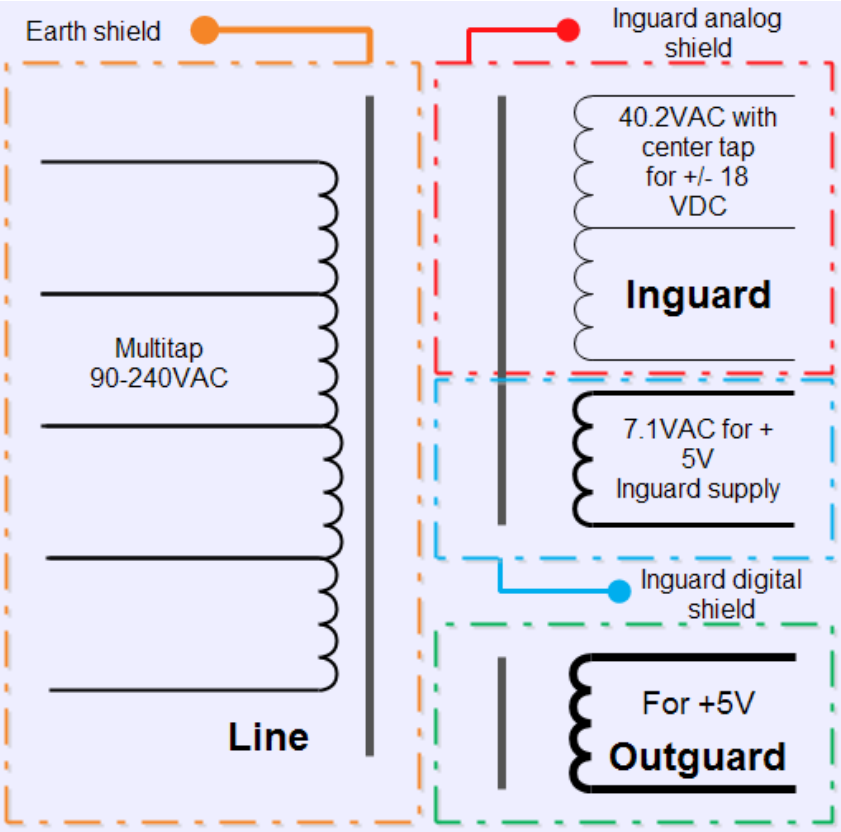


I would not trust repaired/rewinded transformer in such an instrument anyway, so we going to make Keysight richer for $337. That's new transformer cost.

2 weeks later…

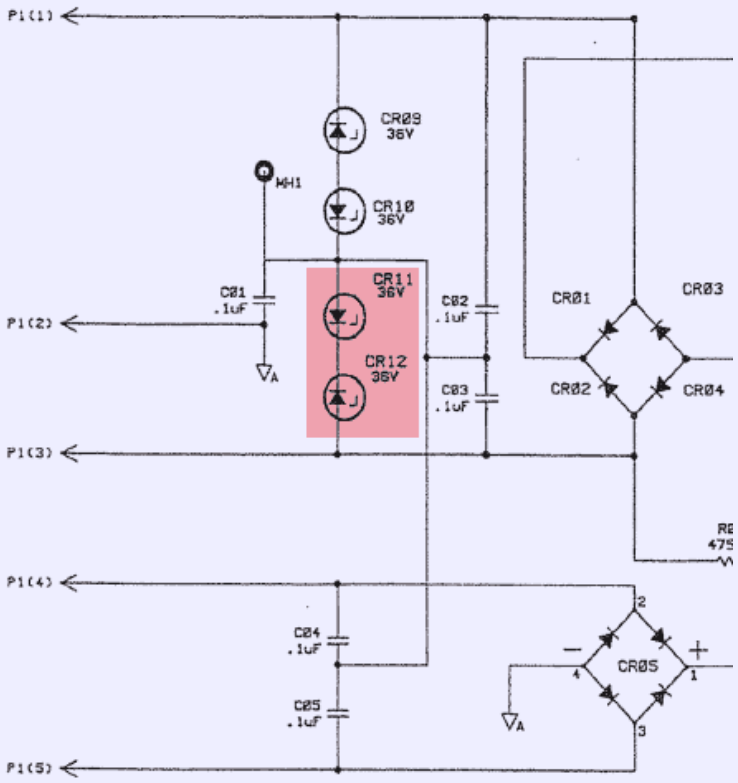
Now, new transformer arrived and we can measure both failed old one and new to provide comparison measurements, so this will help owners of dead 3458A's to diagnose theirs units.

Voltage rail name	Nominal spec	Regulator	Bad transformer in our unit	New good transformer winding
+18V	+18VDC	U1, LM317T	Vmeas : 7.3 VAC, 0.5 Ω	Vmeas : 20.1VAC, 1.42 Ω
-18V	-18VDC	U2, LM337T	Vmeas : 6.9 VAC, 0.5 Ω	Vmeas : 20.1VAC 1.42 Ω
PSS	return for +-18VDC		Vmeas : 14.2 VAC, 1.0 Ω	Vmeas : 40.1VAC 2.88 Ω
Resistance between ±18V winding and +5V			0.5 Ω	>10 GΩ
-18unreg		CR01-CR04 diode bridge		
+5V	+5VDC	U3, UA7805	Vmeas : 7.0 VAC, 1.0 Ω	Vmeas : 9.1 VAC
-20V	-20VDC	CR17 zener + Pass PNP Q2		
Resistance between ±18V winding and secondary shield			0.8 Ω Shorted!	>10 GΩ
Resistance between ±18V winding and secondary 5V shield			>10 GΩ	>10 GΩ



Repair for A4 board

Now we can look on A4 PCBA, and quickly spot visible damage occurred on zener diode CR11. Quick measurement indicated that diode is dead shorted, as well as CR12. These **IN5365B 36V Zeners** rated for 0.4W power and function as overvoltage protection clamps before linear regulators.



In case of voltage presence over rated zener's 36V, diode will start conducting, directing current flow into ground, and limiting voltage on protected rail.

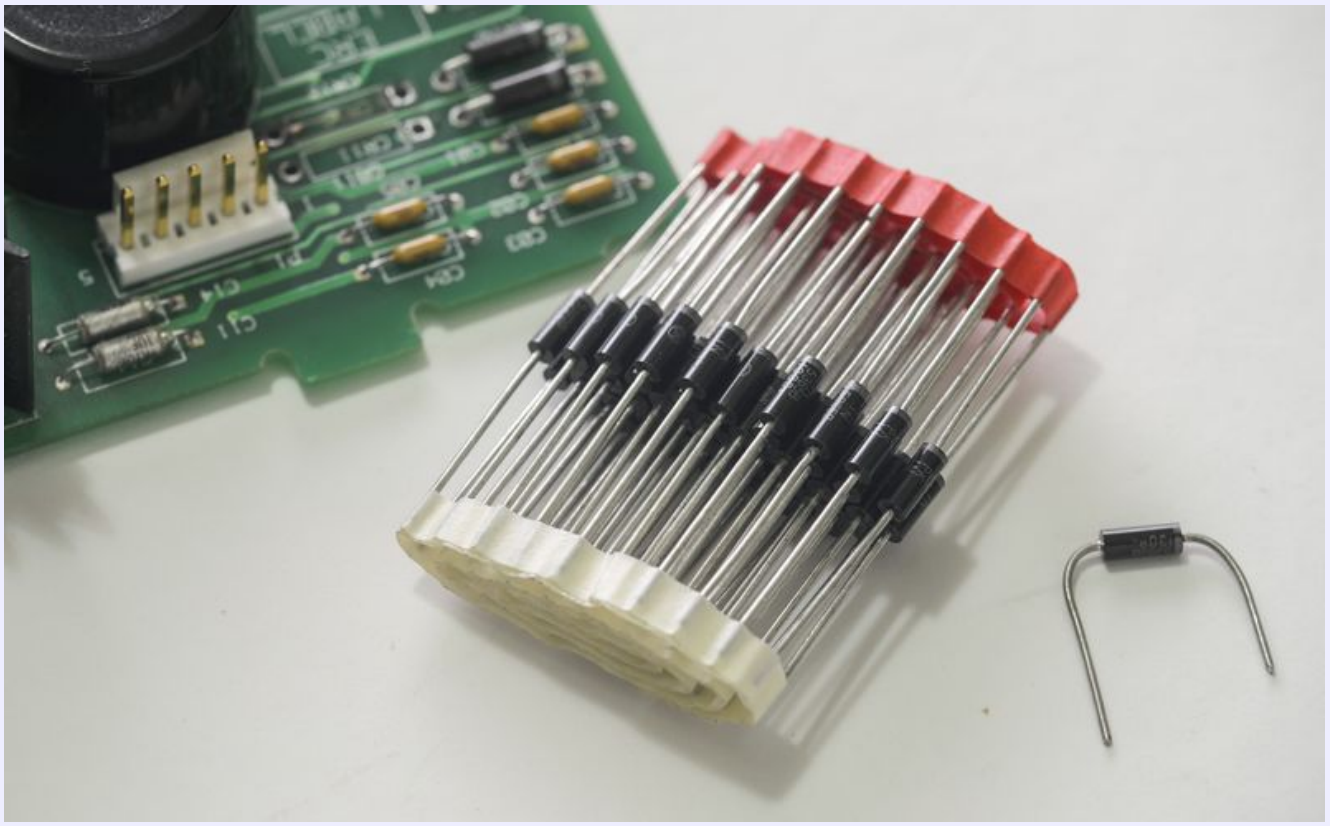
Zener's are connected back-to-back, to limit both sine wave sides, forming variant of **TVS device**. It is nice to

see these protection parts in design, instead of hoping that transformer will never supply unexpected higher voltage. A thing to learn for young engineers generation ;-)

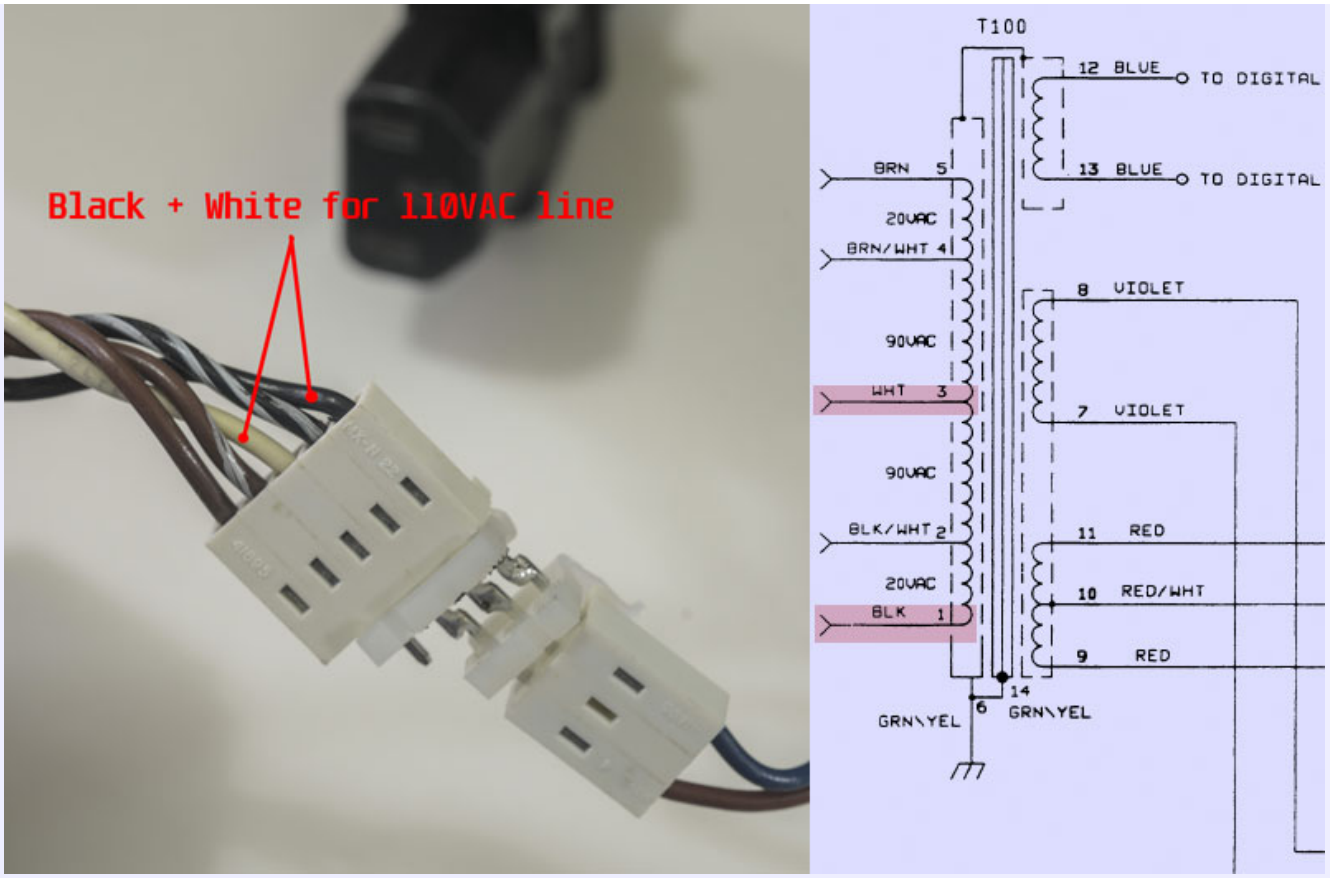
There are also output zener protection and CR06 for +5V supply. These diodes are OK.

Now, since we still wait for new transformer to arrive, how can we test Inguard supply to confirm it's OK? Glad you ask, I have a solution. From previous Keithley Model 2001 repair projects I have one extra power transformer, which happen to have same voltage outputs, as HP one, just at lower power rating. But since we connect only Inguard supply A4 board, we don't need full power to check LDO's operation. Let's replace blown zeners and test A4 PCBA with properly wired Keithley mains TR-280 transformer. Never know which parts could ever come handy, eh?

But first, replaced original CR11,CR12 with fresh zeners (got 50pcs from eBay, just few dollars with free shipping).

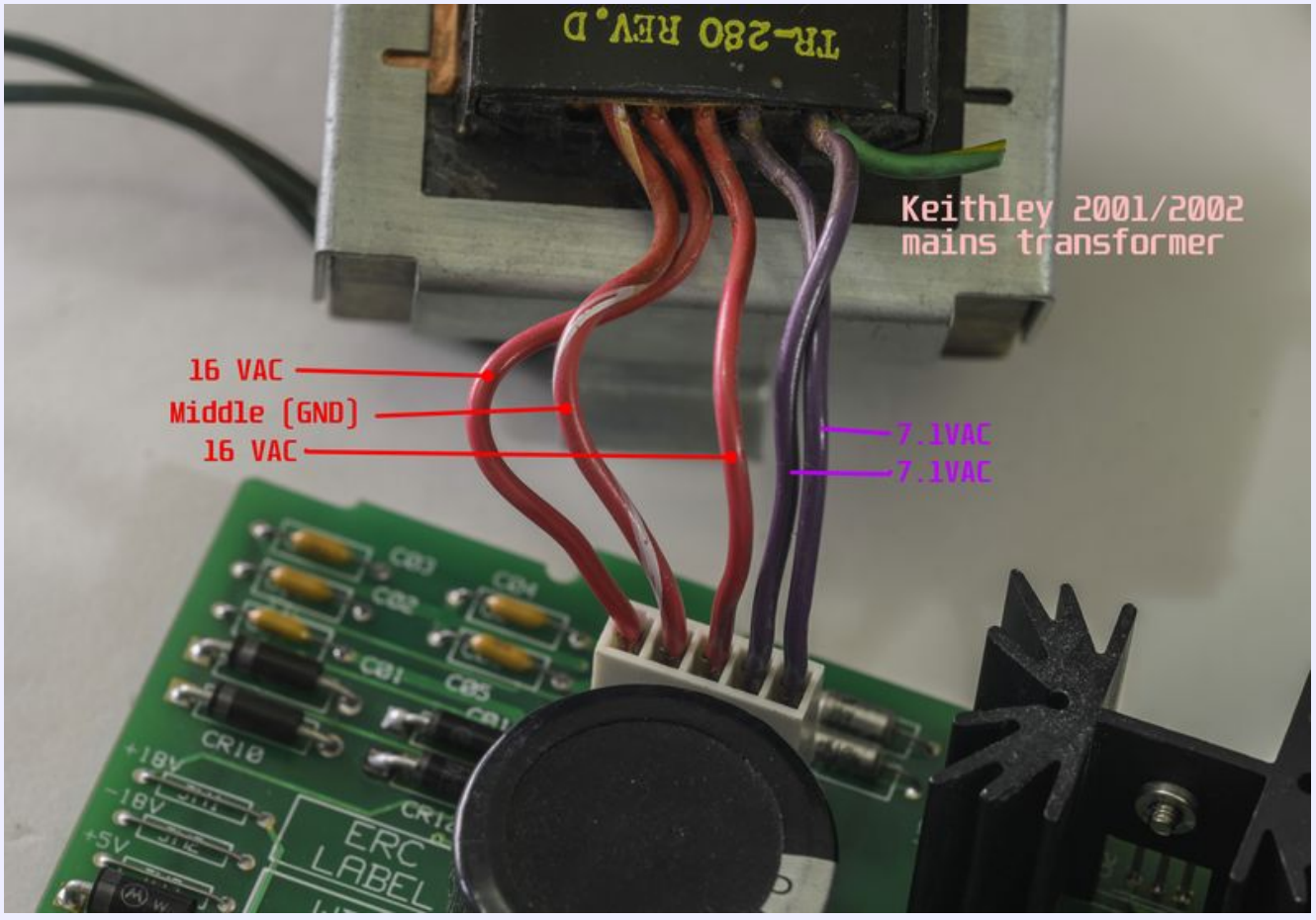


Cleaned board both sides, everything else look intact and good.

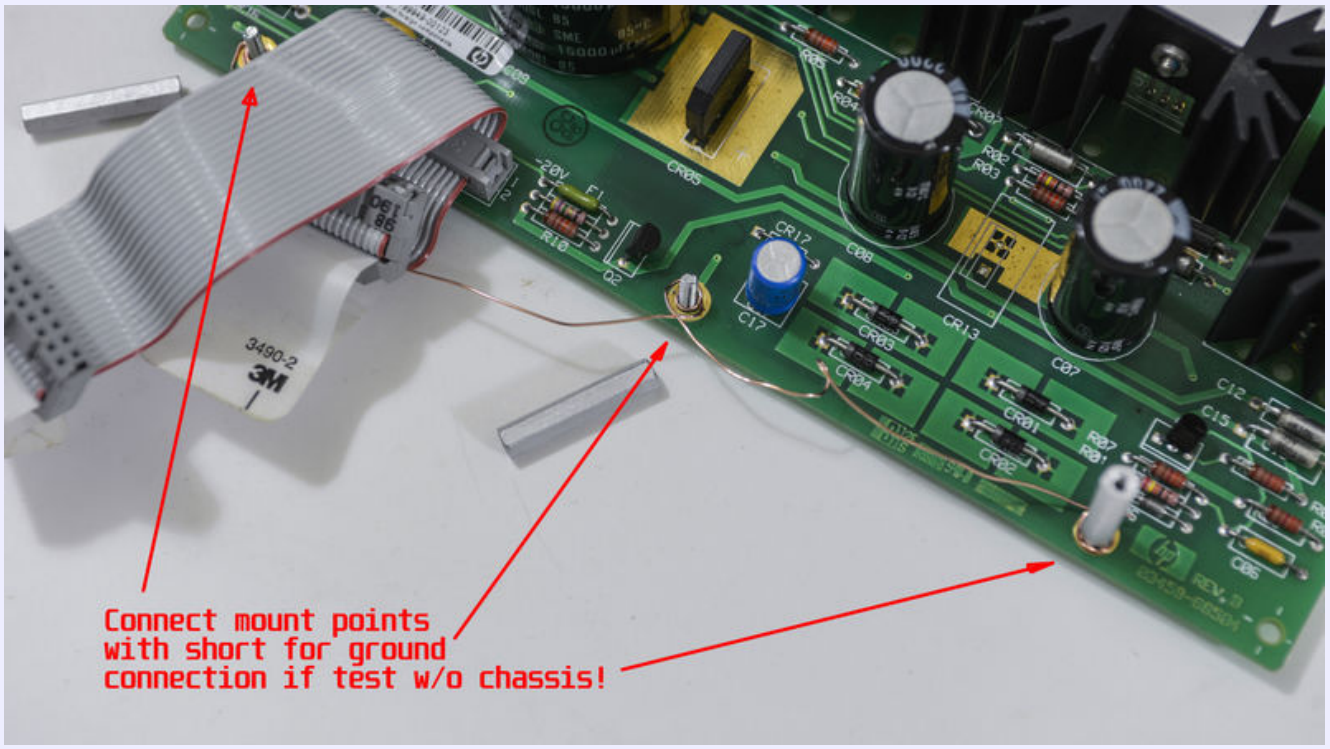


> ⚠ Warning! These procedures involve working with line mains voltage, so be careful and pay attention of what you doing, to avoid electric shock!

Now we can connect input IEC plug socket to transformer's primary (since I need 110VAC, I used WHITE + BLACK wires).

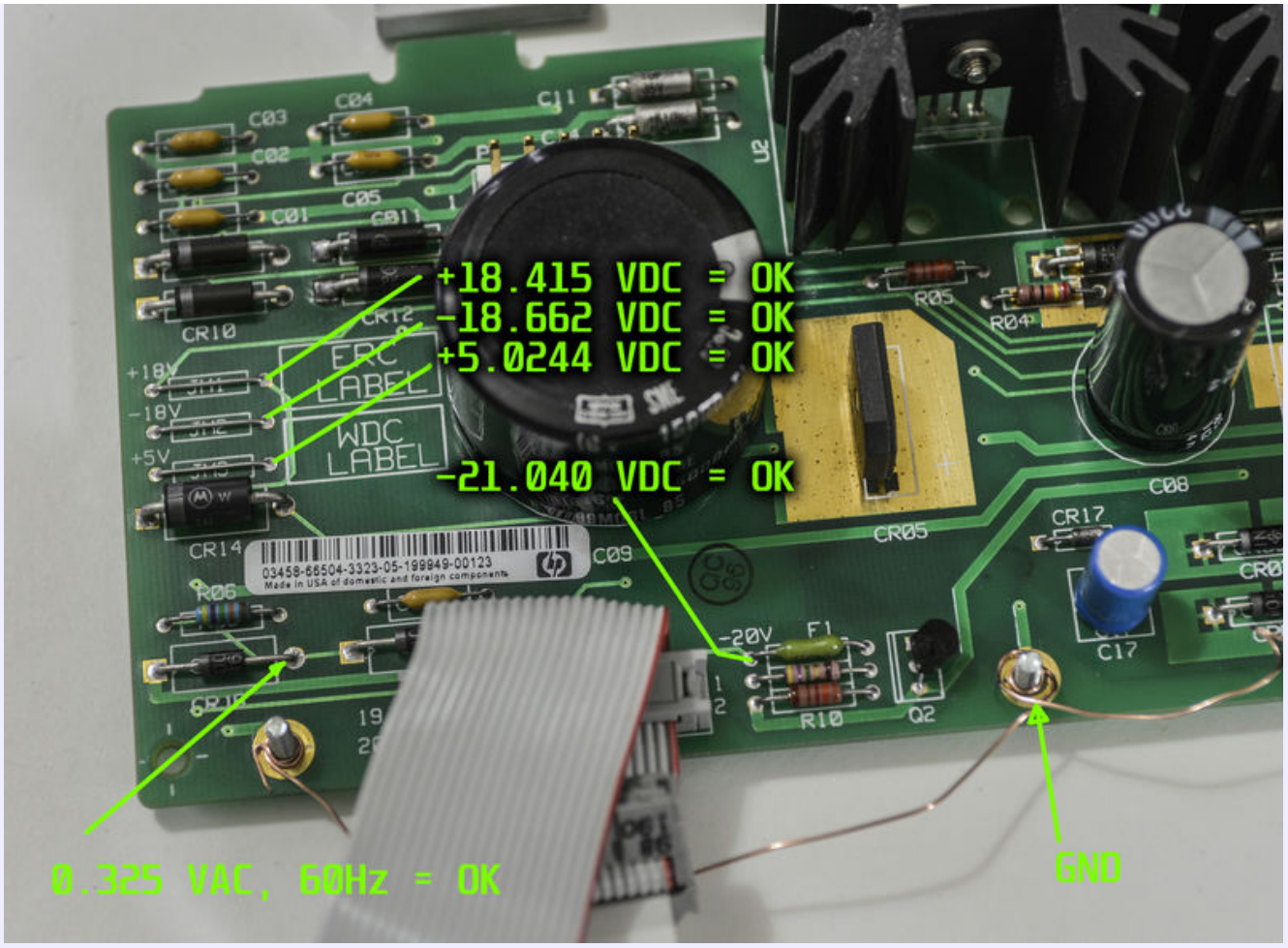


Keithley used same type of 5-pin connector, but with different pin out. Secondary connector need rewiring as on photo above. I powered transformer separately and measured VAC voltages on secondary, without A4 board connected, to make sure all voltages correct.



If you see schematics of A4 board above, you may notice MH1, MH2, MH3 connections. These are connected directly to guard frame in 3458A's chassis, which is acting as Mecca star point for GND potential. Since I testing board separately, not mounted to chassis, I needed to connect these MH* points together with copper wire. This will be our ground point for measurements as well.

Apply power to transformer, and if nothing smokes, test output DC voltage.



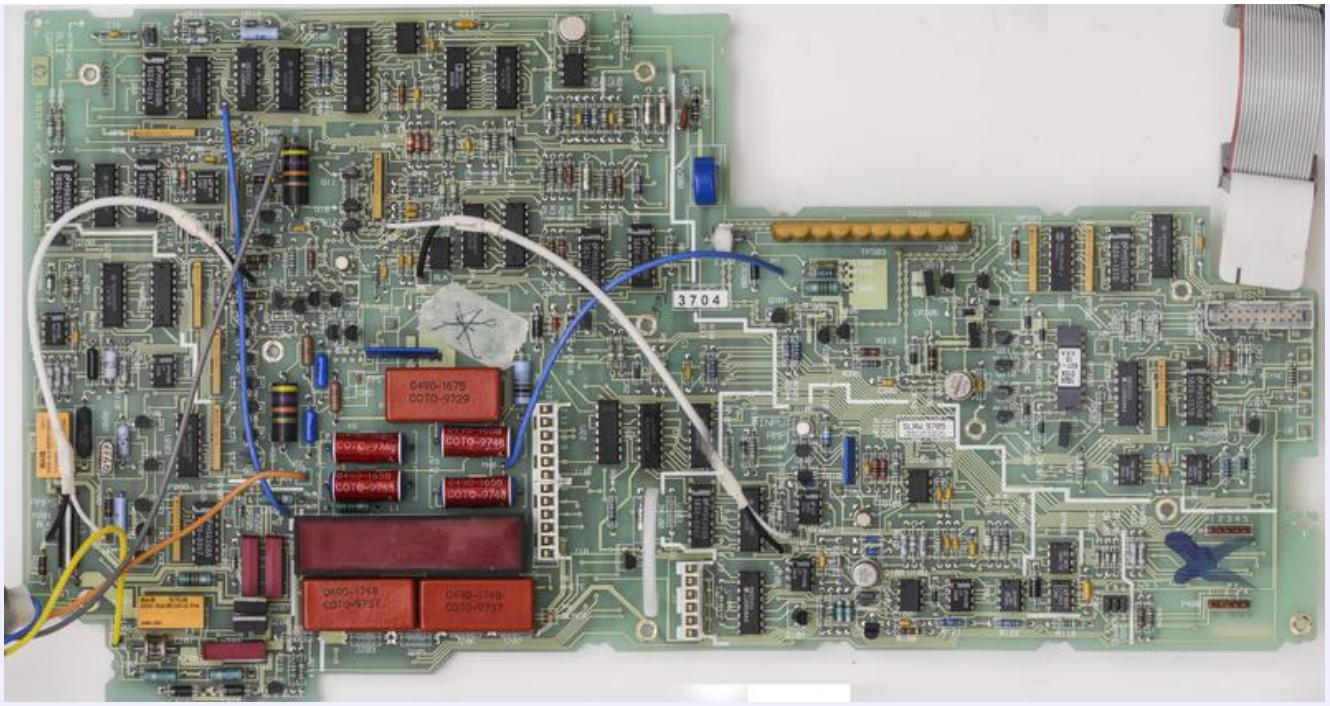
There are nice labels near test points, telling us voltage test points location.

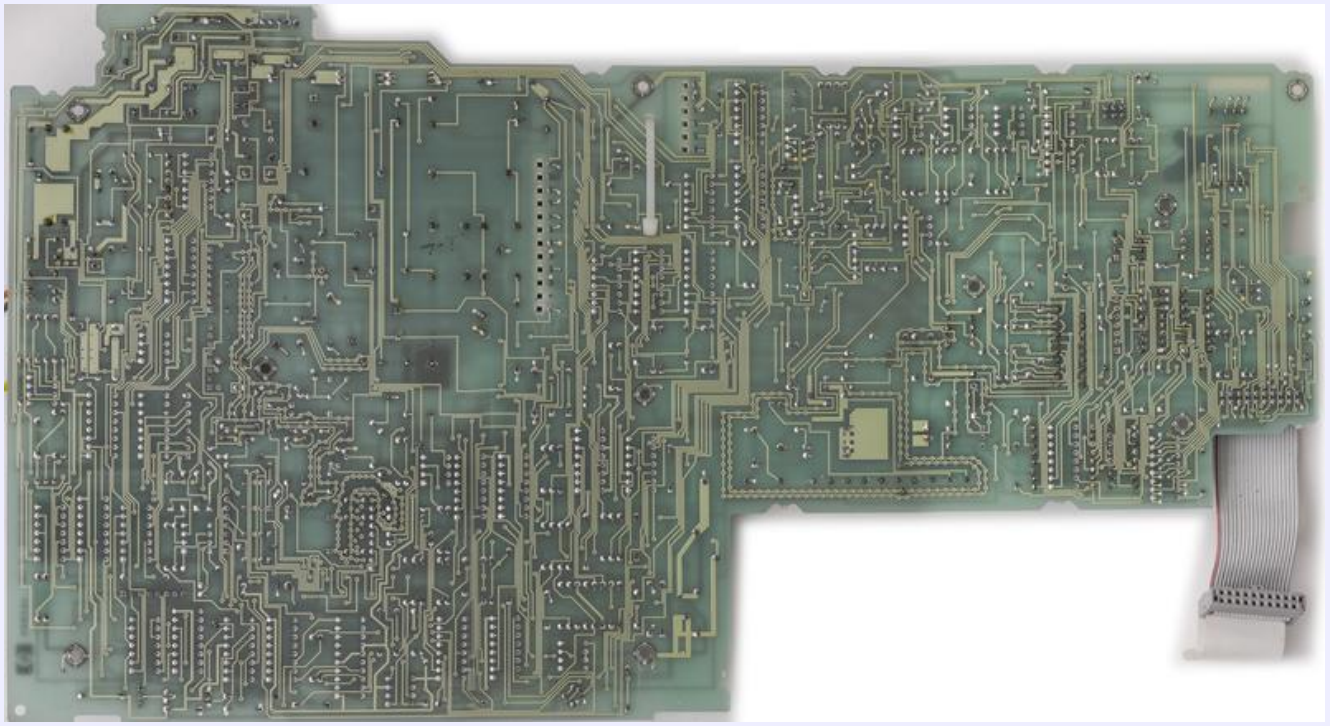
All voltages are OK, also 0.325VAC 60Hz signal to read mains frequency is OK too.

I also replaced 2200MFD 35V and 15000MFD 16V electrolytic capacitors to 2200MFD 35V & 27000MFD 35V (did not find stock of 15000MFD in proper size).

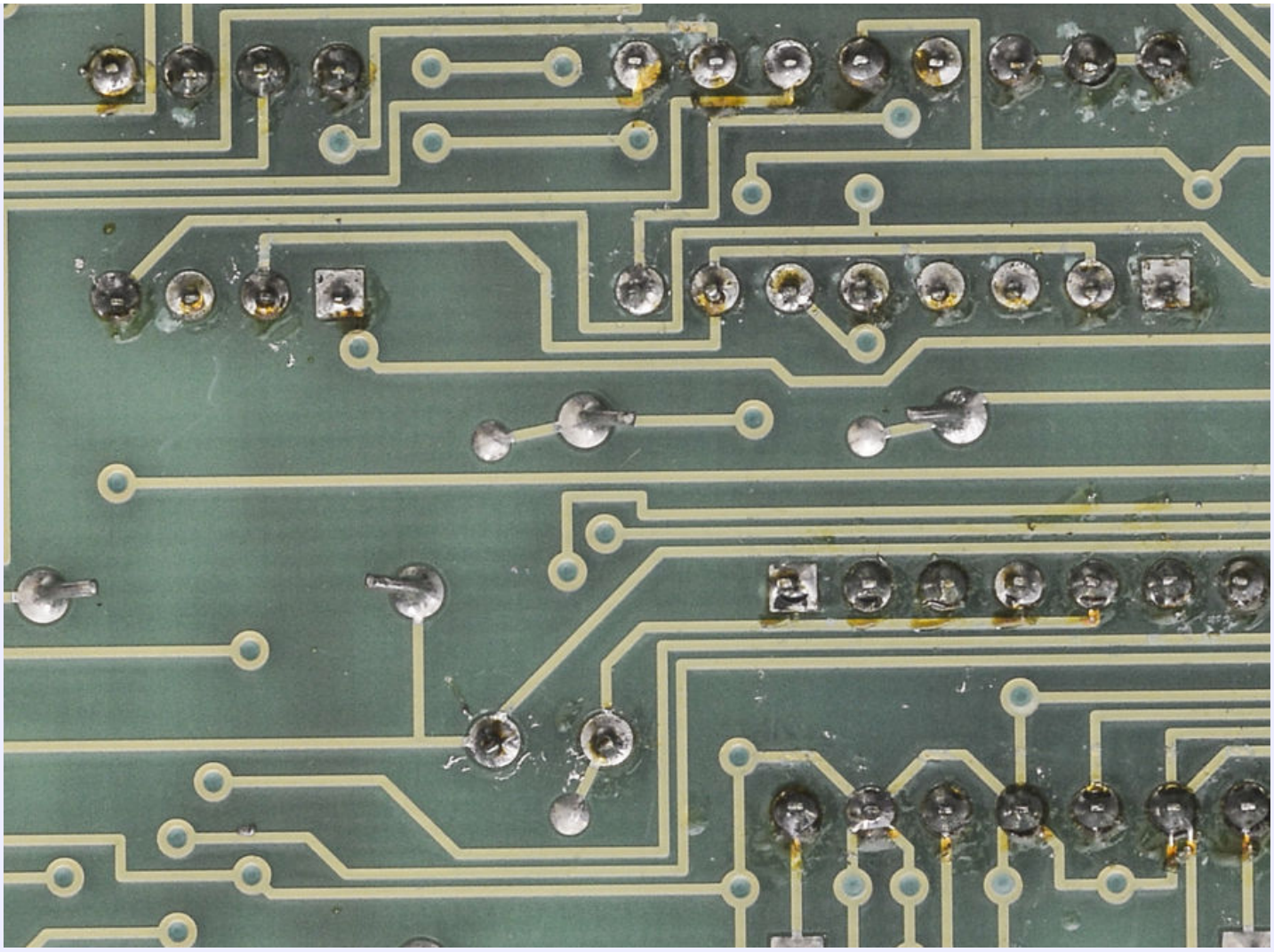
Repair of A4 Inguard power supply now complete.

A1 DC Board



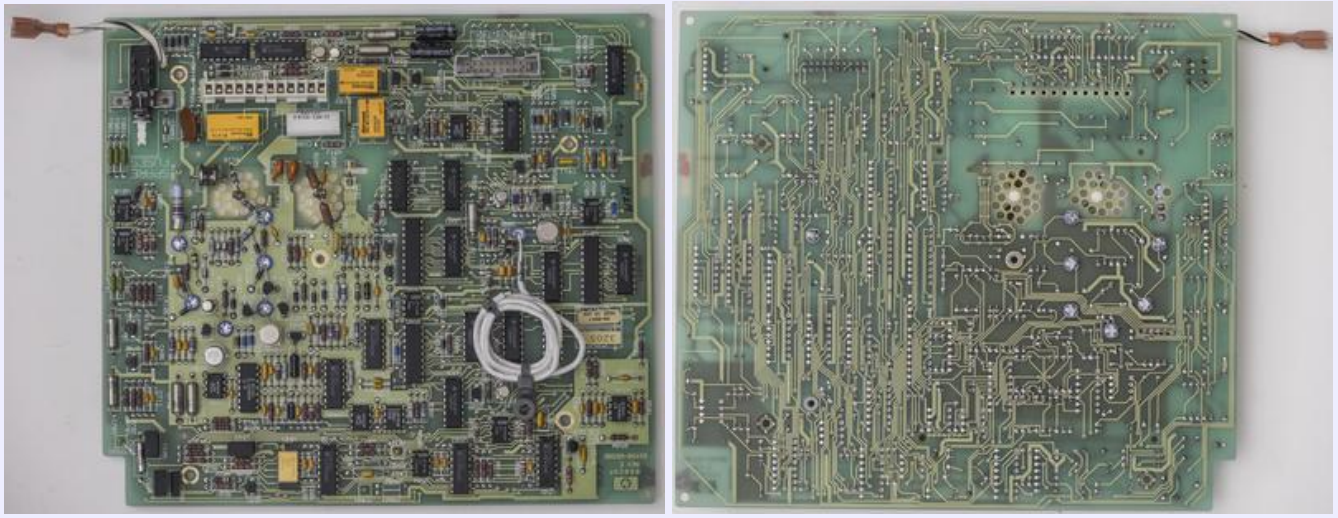


This board also have mark “X” around reference header, also paper tape sticker “X” in center of board near RP7 resistor network. Visual inspection shows ugly soldering and flux around parts U300, U305, U301, RP300, U304, U306, RP301, U303, RP302, RP303, R308, R307, R310, RP200 and around all relays (K1, K2, K3, K4, K5, K6, K7, K9, K200, K201, K202, K203, and K204). Relays have date codes from 1997, while rest of the board IC’s dated 1995-1996. Previous owner tried to fix board by replacing relays?

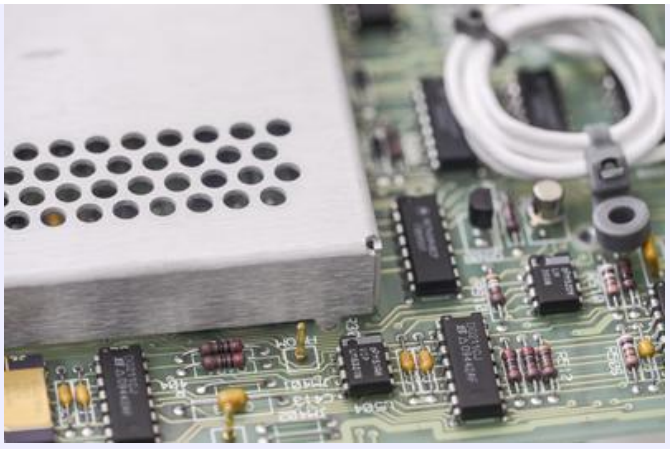


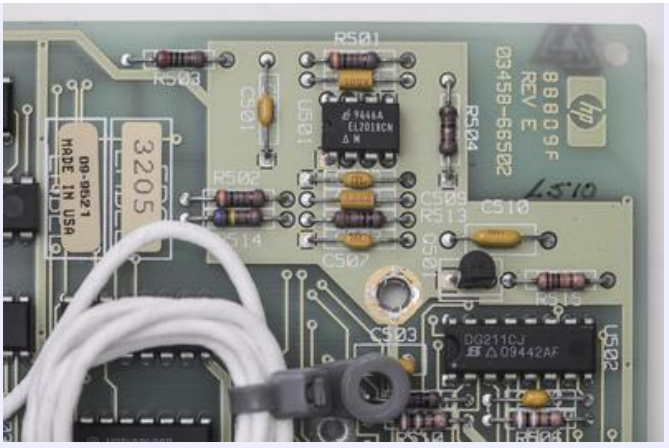
Looking not good, if you ask me. That's why even broken gear sold by inexperienced owner, without attempts of non-qualified repair is easier to restore than hardware which looks mint externally, but have solder bodges and flux all over the field inside. Oh well, let's continue.

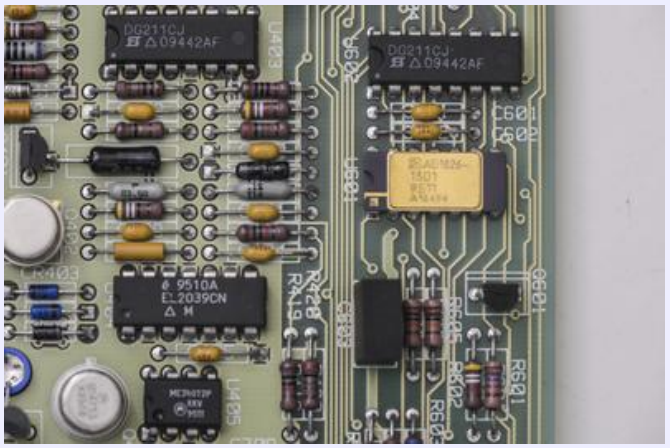
A2 AC/TRMS board

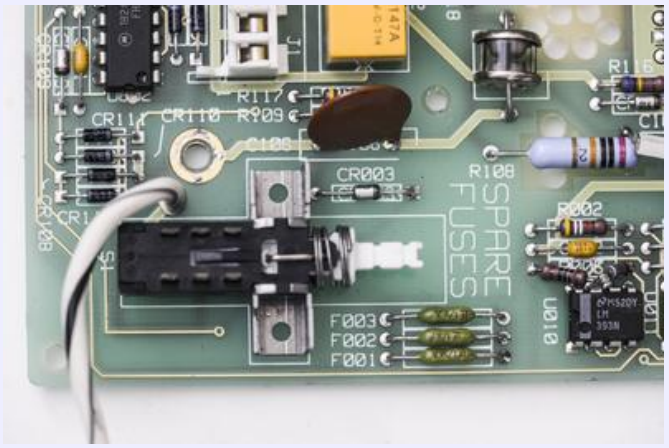


My board have ERC (Engineering Revision Code) over 3108, so modification covered in **Service note 3458-06A : Modification to Fix Hardware Error, "ac offset DAC 10mV invalid cal value: 184"** is not required.

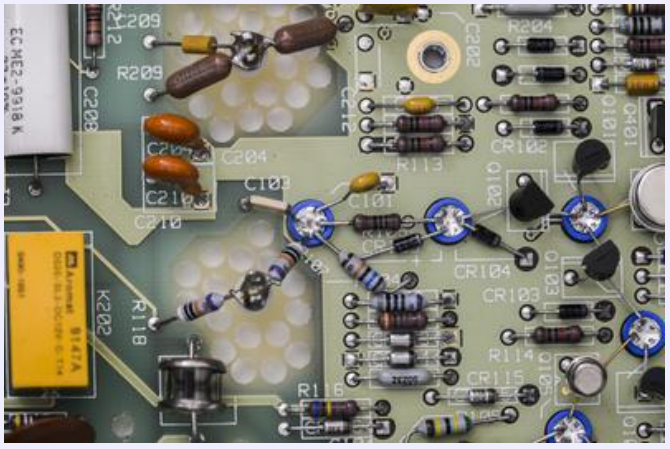


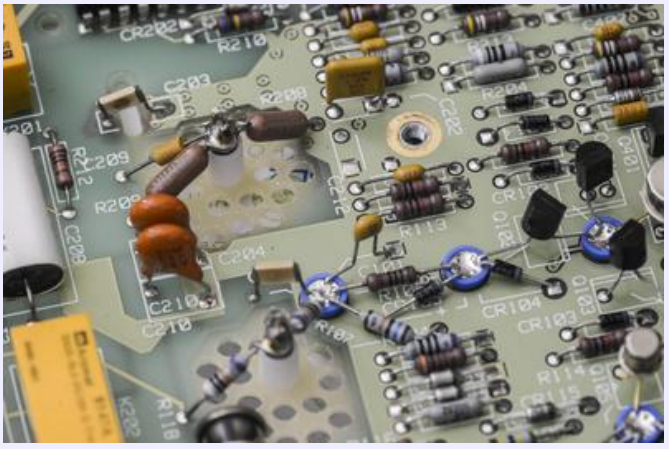


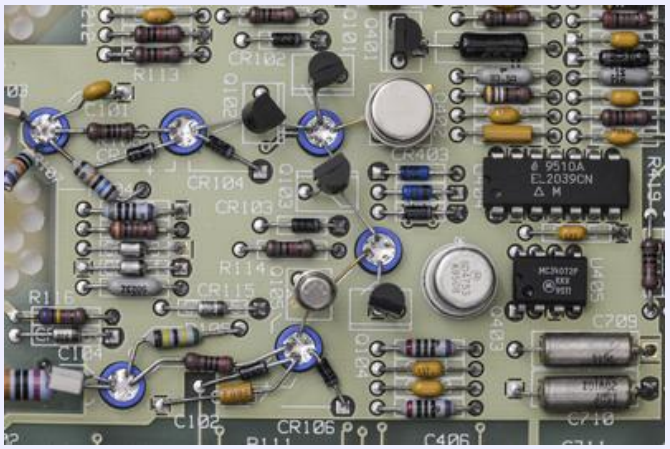


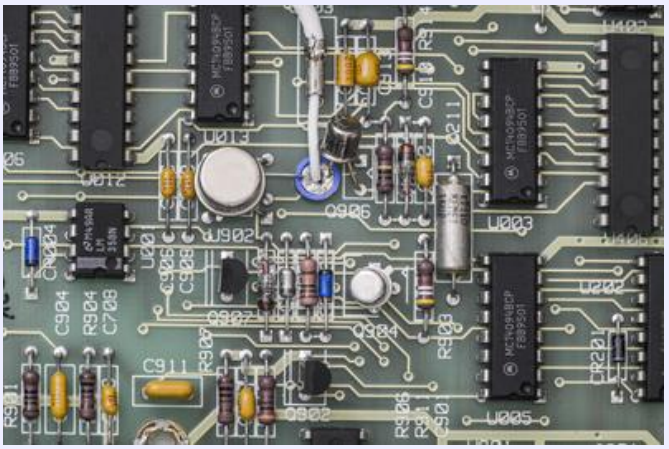


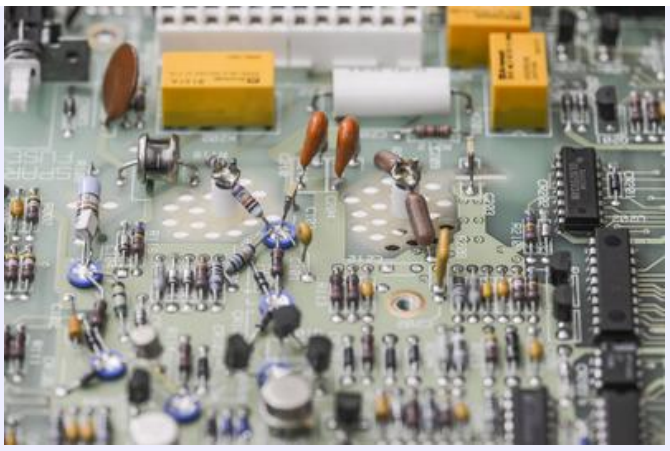
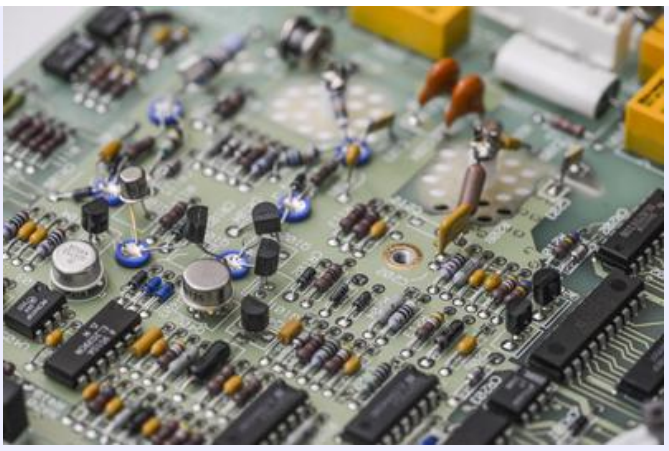
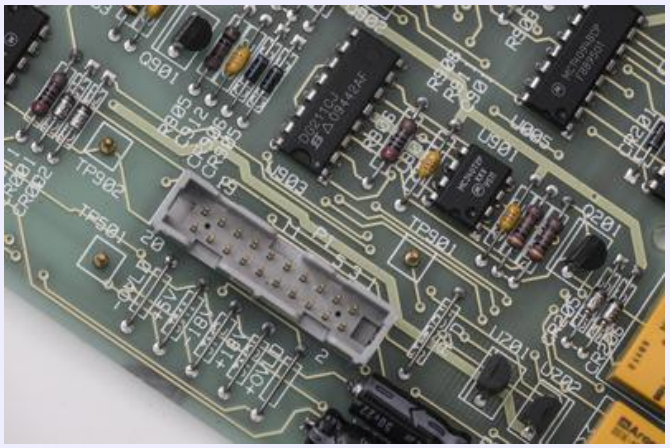
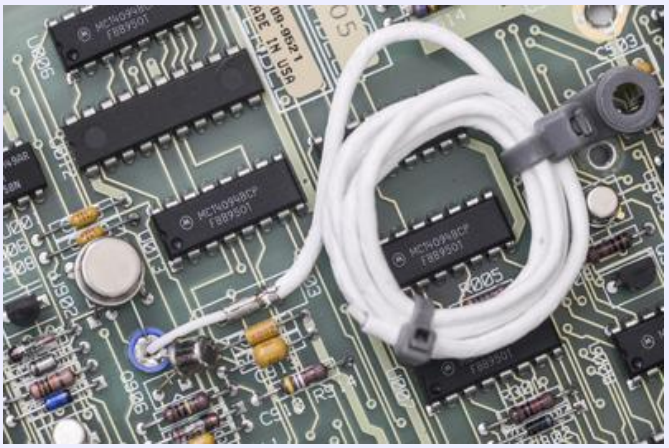
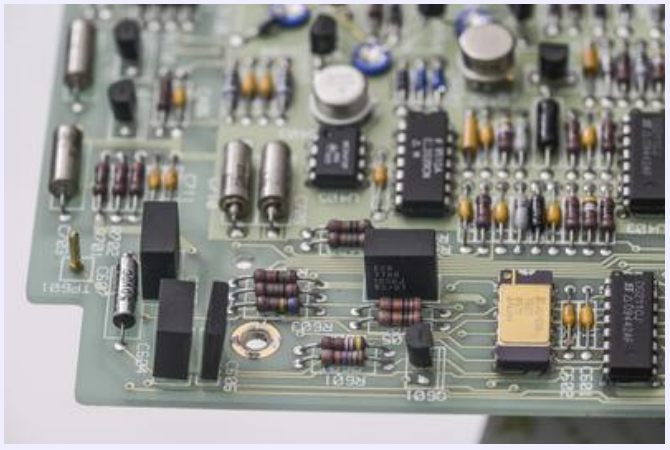
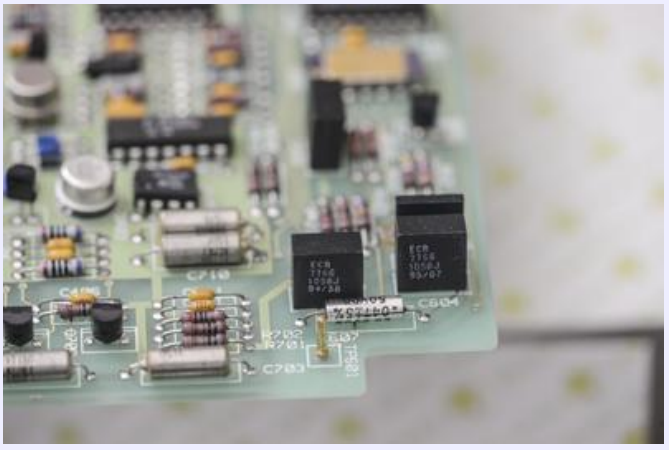
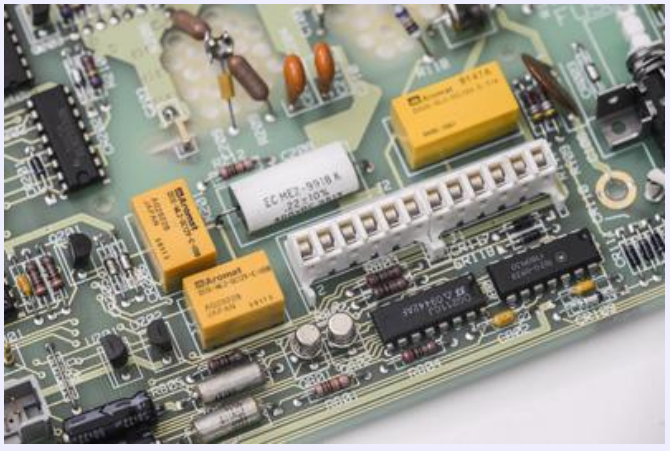
Teflon standoffs and “wires-in-the-air” mounting was used to avoid PCB surface leakage into sensitive nodes and signal nets.







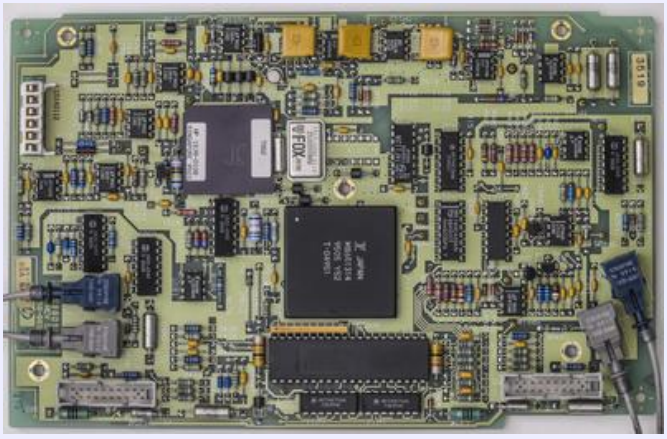
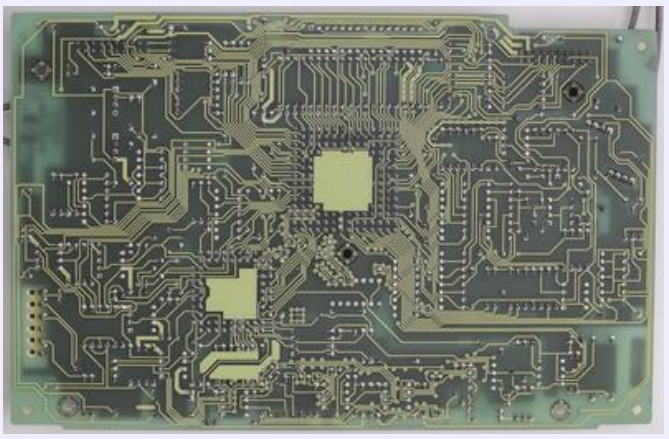


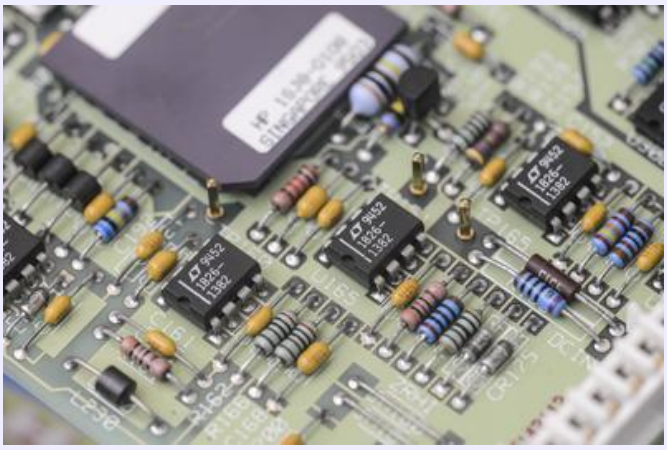
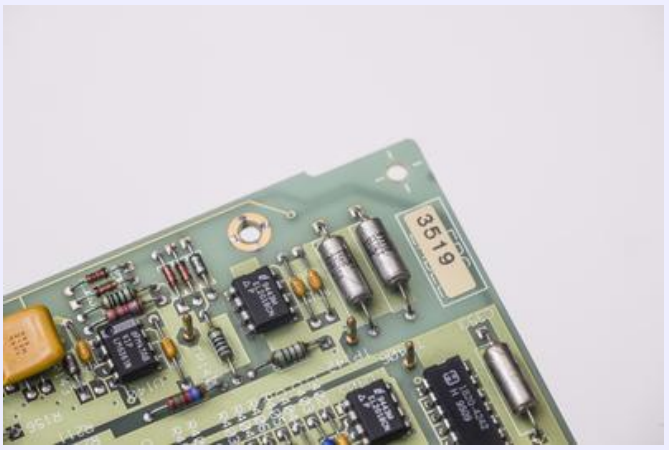

A3 ADC Board

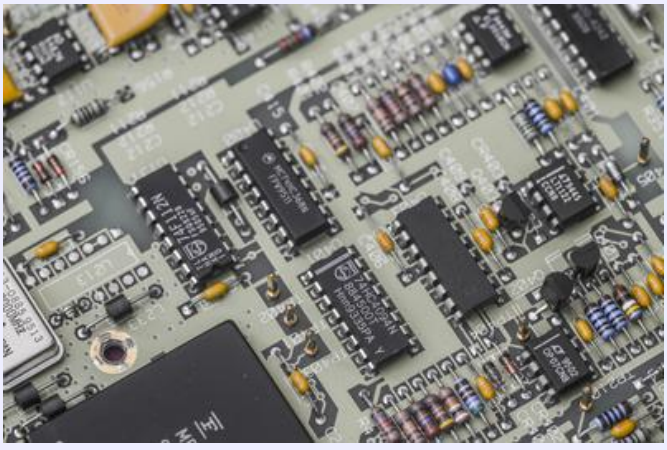
A/D Converter board is heart of instrument popularity and performance. It's capable of performing 16bit (corresponding to 4½-digit resolution) conversions at 100kSPS speed or full 28bit (8½-digit mode)

conversion at 6SPS, with <0.1ppm linearity.

Close-ups on PCBA components

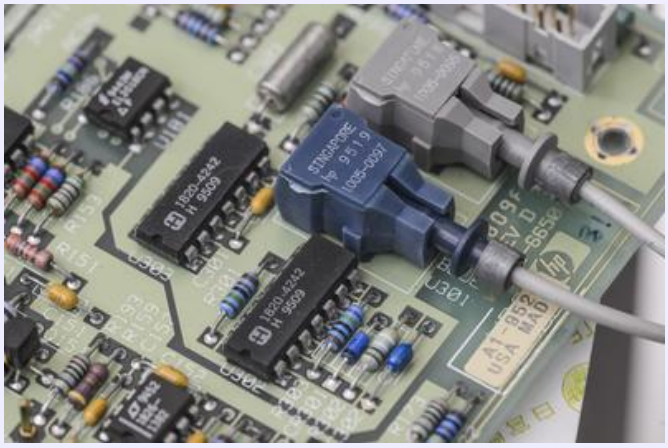




This board also features its own **Intel 8051 microcontroller**, with mask firmware 03458-85501. This MCU is

orderable from Keysight.

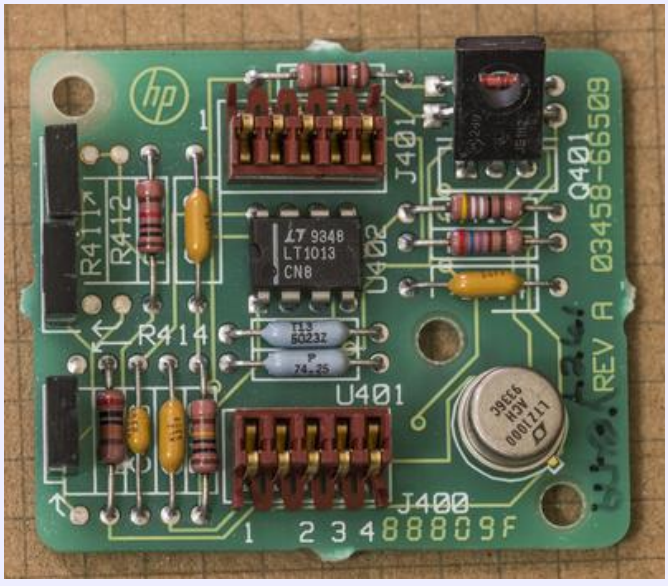
ADC board interfaces to Outguard main processor thru 2Mbit bidirectional UART optical link, using fiber Avago's **Versatile Link** cables. HP have related **PDF-document** covering this application as well.

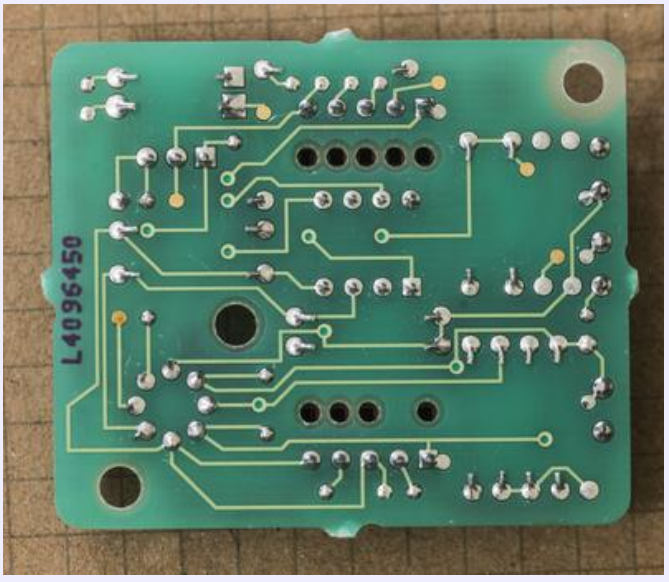


Since our unit have S/N later than 2823A00700 and also ERC is 3519 we don't need modification covered in **Service note 3458-01C**, my board have mentioned capacitors 15uF 10VDC. There is **installation manual** available for A3 board replacement.

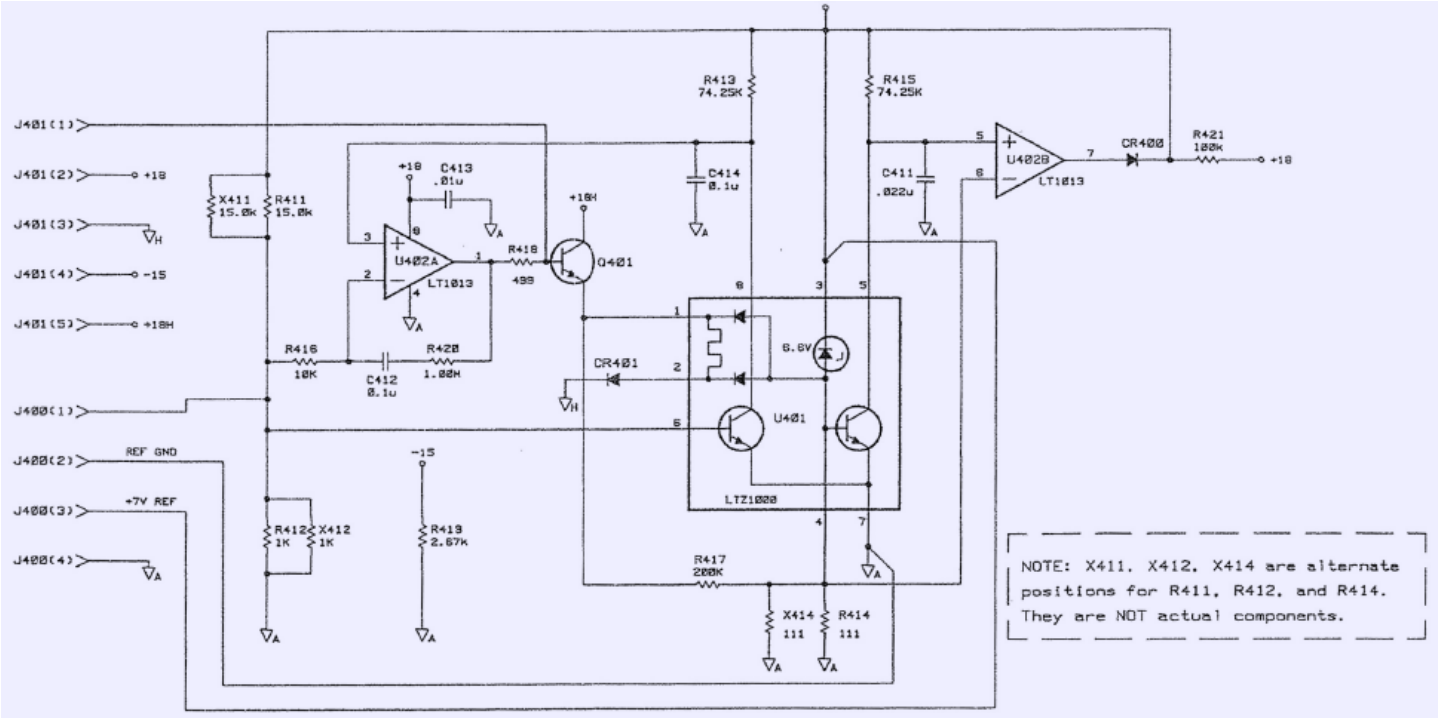
A9 DCV reference board

This board was missing, so I had to buy replacement from secondary market. It's often possible, because famous reference board from 3458A often on sale on auctions and from precision enthusiasts. I got mine, standard variant for little over $130 USD, shipping included.

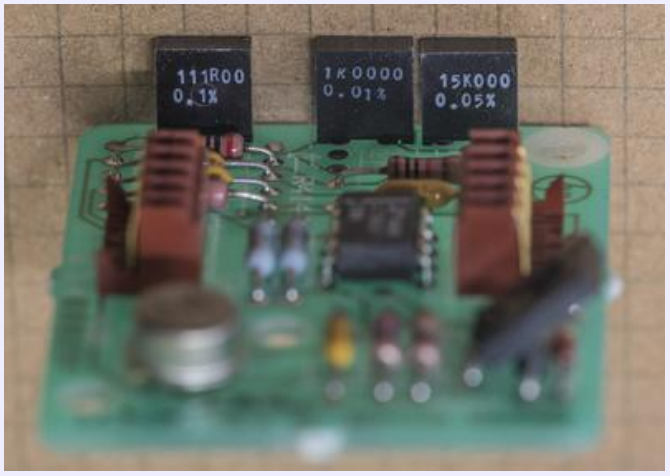


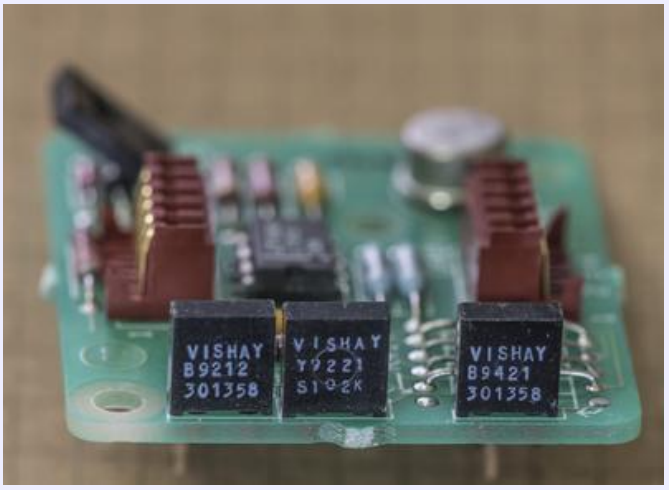


Little module is almost exact copy of LTZ1000A's datasheet reference schematics from Linear.



Heart of the reference is **Linear Technology LTZ1000A Super-Zener** with integrated temperature sensor and oven heater. It's most stable commercially available reference, even today, providing temperature coefficient below 0.05 ppm/K and very low noise and long-term drift rate. With proper support circuitry this chip can deliver stability less than 1 ppm per year.





One of the common difficulties of LTZ-based references is extreme requirements for setpoint resistors stability. It is not rare to see literally hundreds of dollars worth resistors around LTZ1000A, which itself cost 54$, directly from LT.

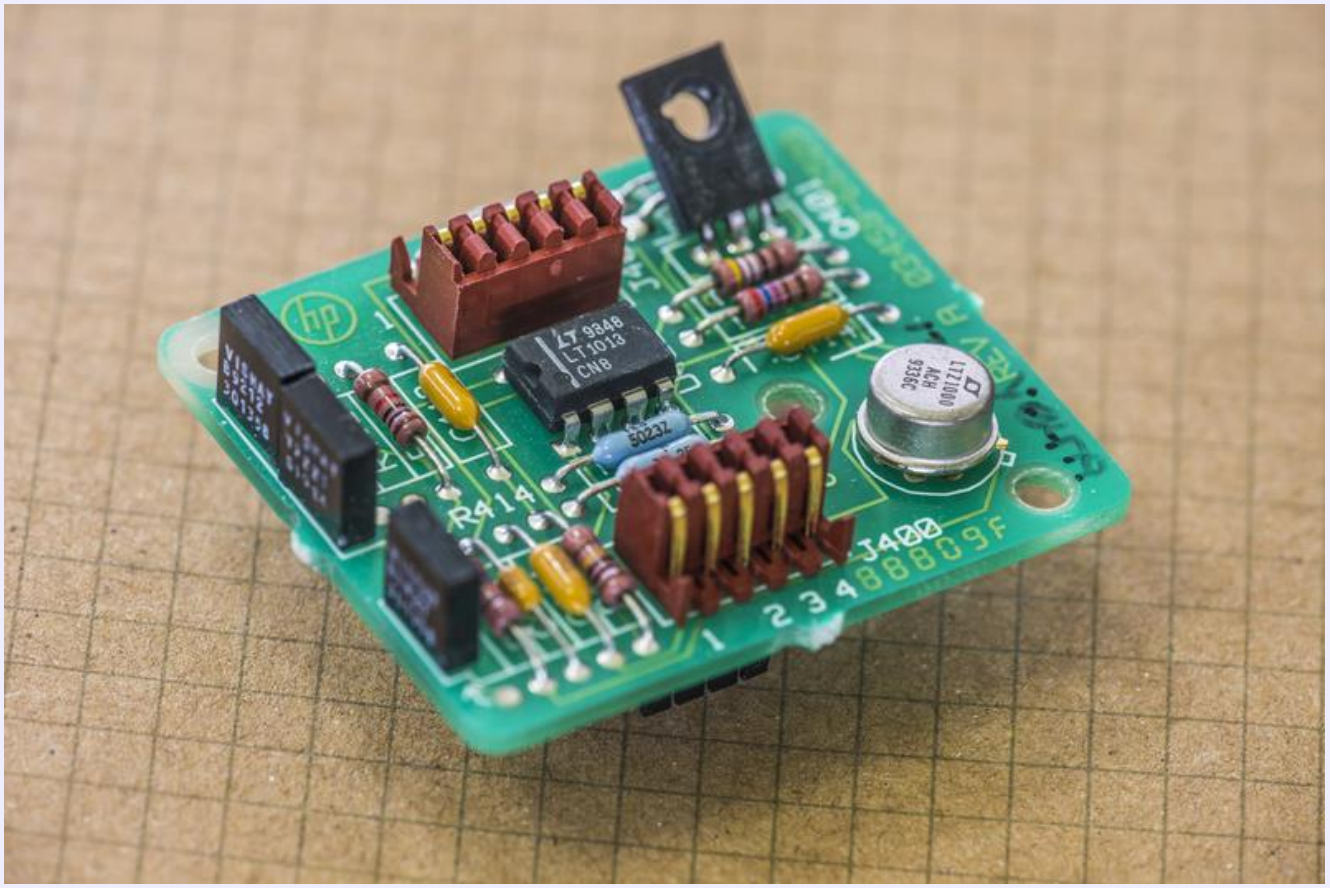
There is strong community discussing this interesting chip and related designs, such as **here**.

Its obvious today for experienced engineers, that design team did not set target of making HP's LTZ1000A reference most stable, given both used components, PCB layout approach and official specification of "only" 8 ppm/K. Perhaps it was done so due to cost, time and market demands back then. Below is resistor specs used in STD version of A9 board.

RefDes	Resistance	Abs.Tolerance	Temperature coefficient	Type	Spec
R414	111 Ω	±0.1%	±1.3 ppm/K	Vishay metal foil	Custom, type 301358
				Vishay metal	

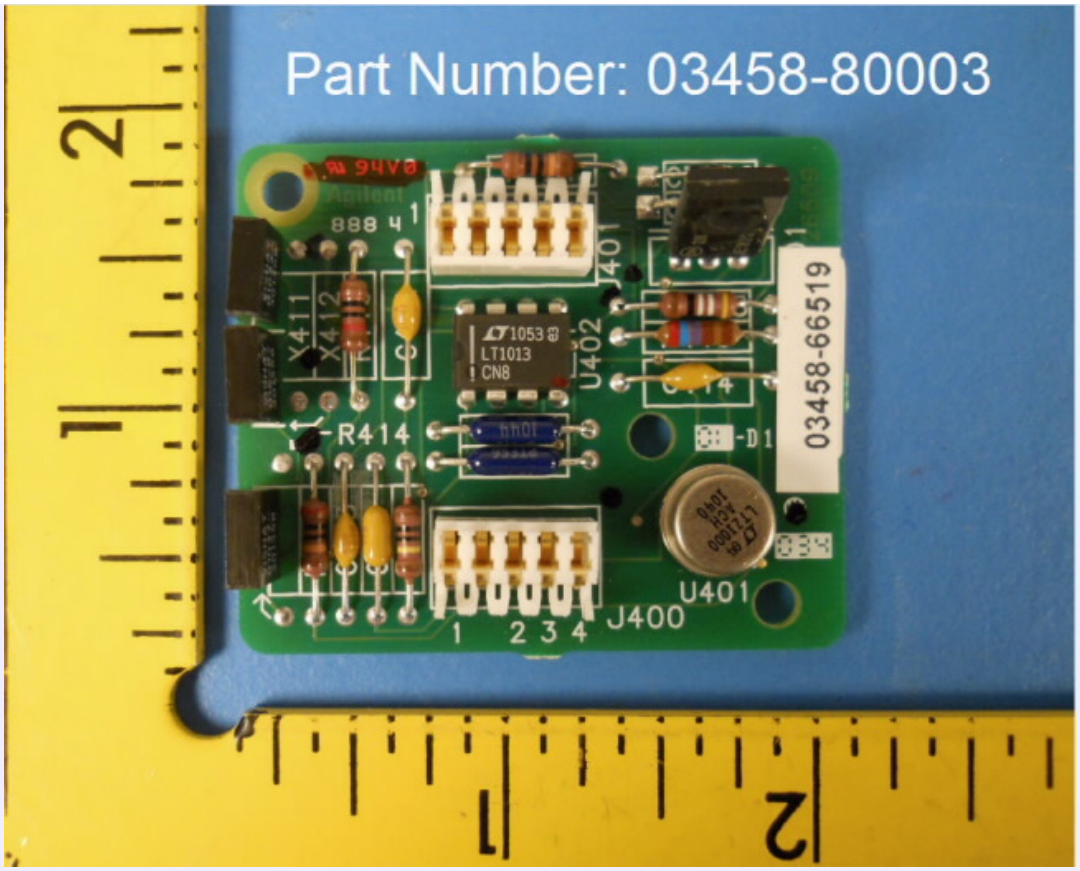
R412	1K Ω	±0.01%	±1.3 ppm/K	foil	**S102K**
R411	15 KΩ	±0.05%	±1.3 ppm/K	Vishay metal foil	Custom, type 301358
R413	74.25 KΩ	±0.1%	±10 ppm/K	Thin film	?
R415	74.25 KΩ	±0.1%	±10 ppm/K	Thin film	?

Rest of resistors are common 1% thin-film type.



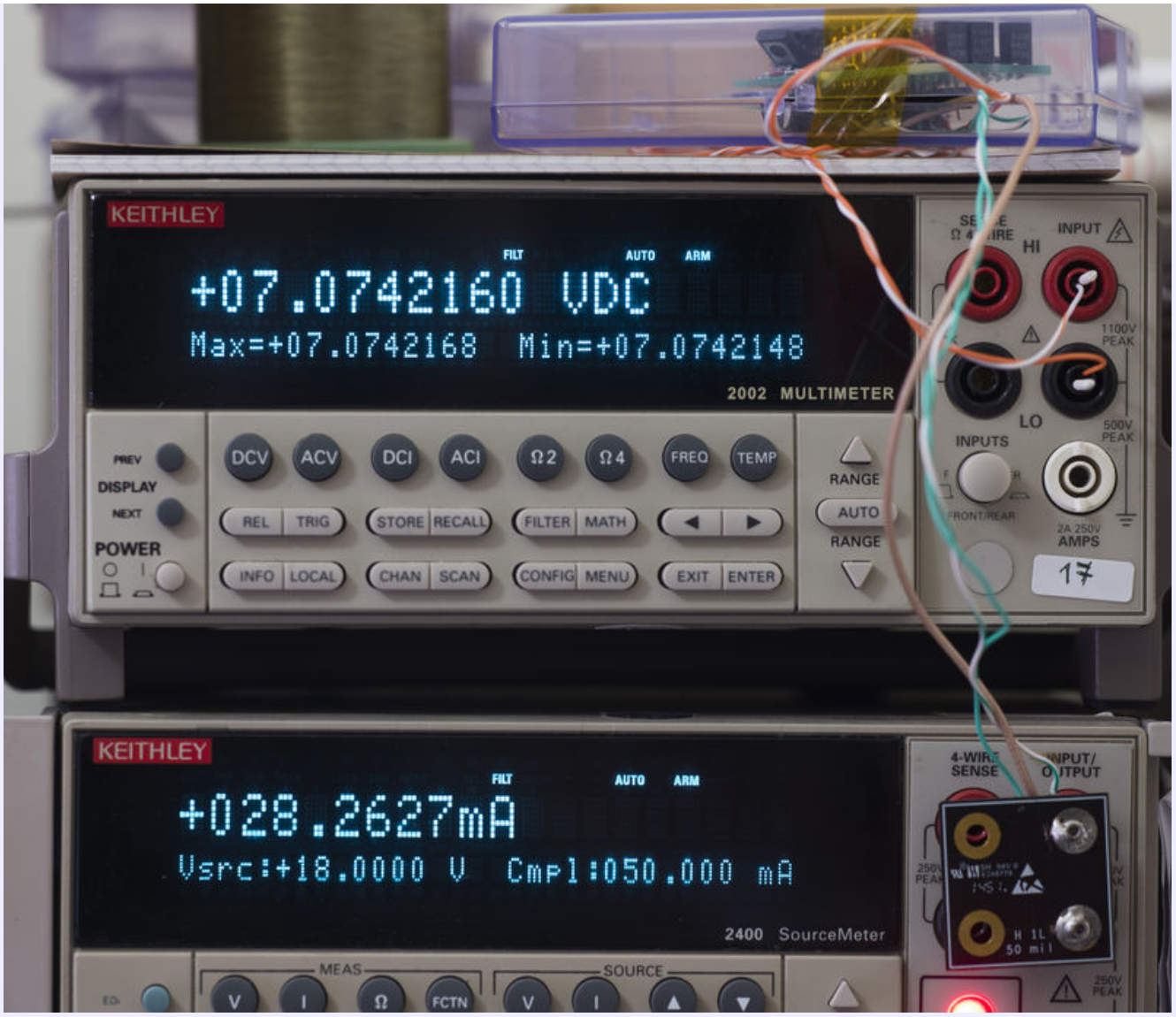
We will investigate reference performance and possible tweaks later after DMM repair.

Keysight also do provide higher-specced Opt.002 voltage reference modules (for $984 USD) and even HFL ±2 ppm/K version (only for $2195 USD :)) for ordering, in case someone need new PCBA directly from vendor.
Here's how 002 version look like:



Enough theory, let's check our A9 operation.

To do so, I used quick setup with **Keithley 2400 SMU** as power source to provide +18VDC to PCBA and **Keithley 2002 DMM** to measure output voltage.



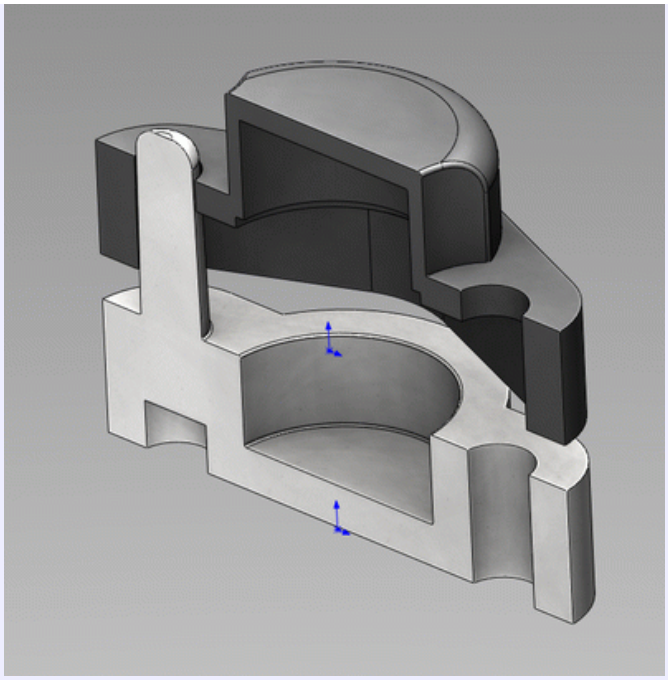
After prompt warm-up, reading stabilize around +7.07421x VDC, with +26.5 °C ambient temperature. My 2002 is few ~30ppm's low compared to calibrated 2001, so real voltage just a bit higher. Point here is, that our DCV reference board is operational and can be installed into 3458A without second doubt.

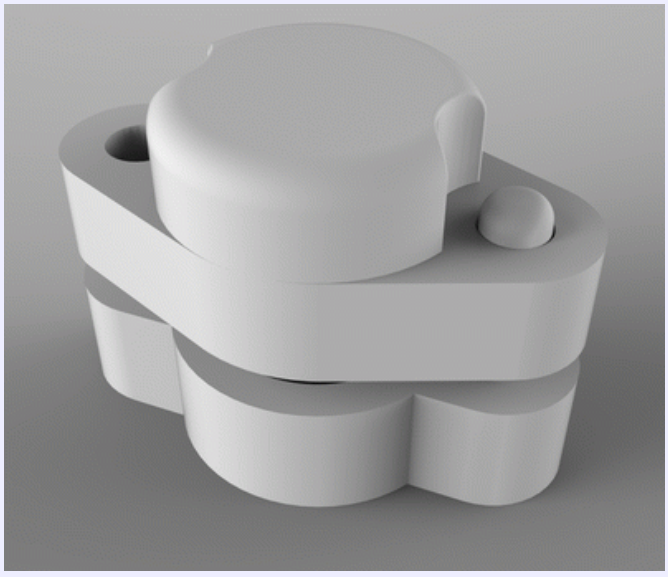
One good thing about used references, they likely to be nicely aged. LTZ1000A on this one is made in 1993, in case someone miss it.
Zeners like wine, only better with time. This is due aging process and residual stresses in silicon die. When chip just manufactured, there are lot of internal tensions and stress around elements, which is slowly stabilize over time. Its usual practice accelerated aging initial few thousand hours, by running references with high temperatures/currents, before further testing and use in normal conditions.

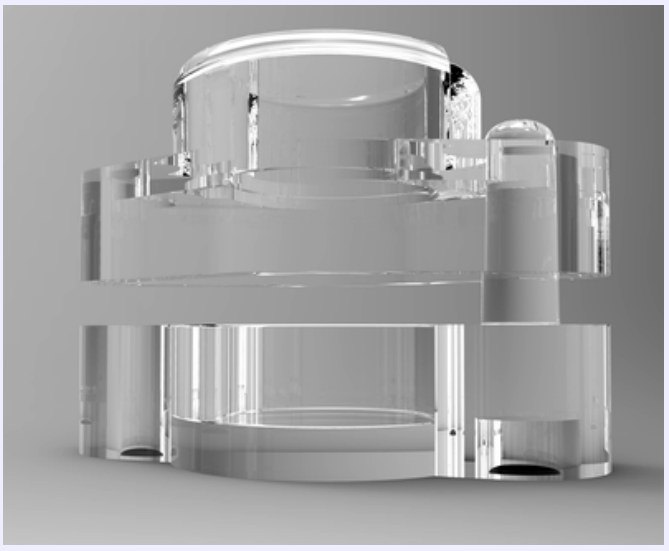
Also it's very important to keep LTZ1000A reference chip isolated from airflow, as that will easily create thermal gradients and thermocouple voltages on junctions, upsetting temperature and voltage stabilization of whole reference. Factory A9 PCBA come with PTFE caps (Keysight P/N 03458-44102), effectively making own enclosure around LTZ1000A, from both top and bottom sides. I also was lucky to get one set of original PTFE caps, and decided to make CAD 3D-model, so people who may go into buying used A9 REF boards can 3D-print or use CNC to produce their own caps.

Top and bottom caps drawing with PDF

STEP model, top cap
STEP model, bottom cap







Also sources for parts are available in Solidworks 2015 format, **Top cap Bot cap**

Cap assembly 3D CAD Solidworks 2015

A10 Front/rear switch board

This little board sits at Inguard section, just near A1 relay area and have mechanical Front/Rear switch for input terminals and some protection circuits, like gas arrestors.

Switch is orderable from Keysight, under P/N 3101-2969 for $55 USD. This type switches are often cause excessive leakage and noise on measurements, or even bigger issues, like I had with **Keithley 2000** repair

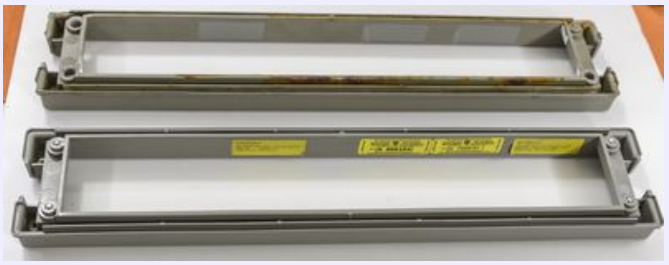
My board had missing switch spring mechanism, and it did not lock in positions. Since I already bought new switch, just replaced old one by desoldering and thorough cleaning board with isopropyl alcohol.

All wiring color is marked on PCB, so it's easy to connect all harness. For example for current input yellow wire marked as – **YC** (Yellow common, wire going to A1 PCB), **YF** (Yellow front, going to front panel terminal

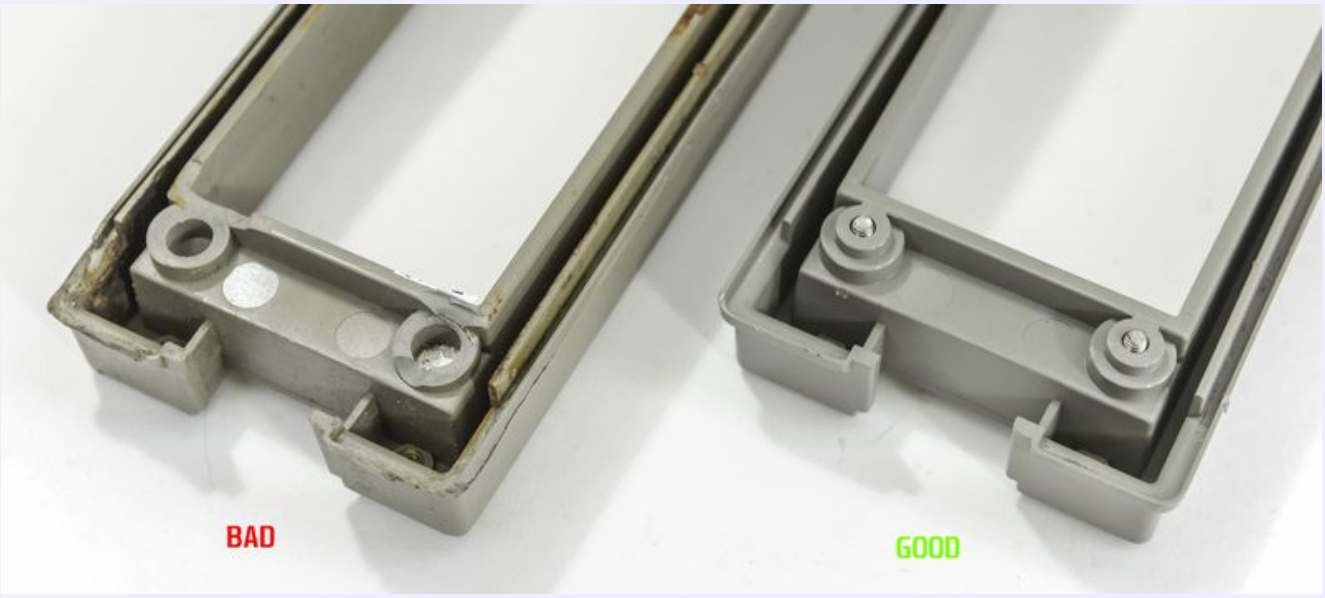
block), **YR** (Yellow rear, going to backside terminal block). Make sure you keep wiring, PCB surface and switch clean to avoid leakage, which would corrupt measurements.

Chassis repair

I got used bezel off eBay in good condition, to save some money on this project, as it's just mechanical part to keep meter in one piece. New one on bottom side, old busted rear bezel is on top:



Original unit's bezel had three out of four screw mounts destroyed, so it was not holding well.



How the hard part, removing rust and dirt off the steel frame.

STEP 0. Remove all boards and parts from chassis.

This is easy operation, system design made very serviceable and everything is modular.

Remove boards carefully, handle them only by touching corners, and do not touch any components on PCBA's inside guarded analog box. Oil and dust will contaminate surfaces and cause current leakage, thus ruining performance of analog circuitry. Boards interconnected between with ribbon cables and chassis-thru pin headers. Note screws from each board and chassis elements, it will help you later to assemble all back in right order.

STEP 1. Remove mains socket and BNC ports and prepare tools

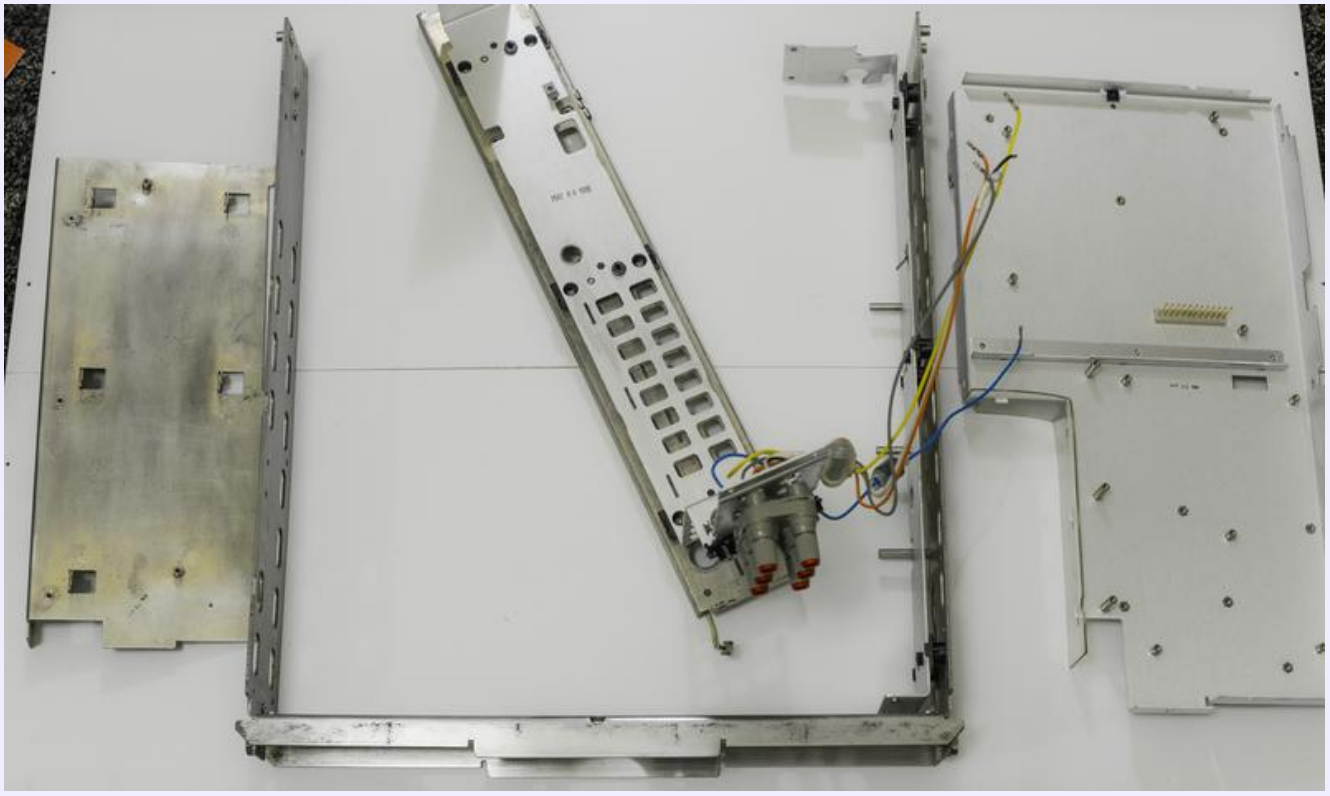
Now you have bare chassis frame separated, but some parts still on it.

To remove rear BNC ports release connector nuts and desolder signal wire.

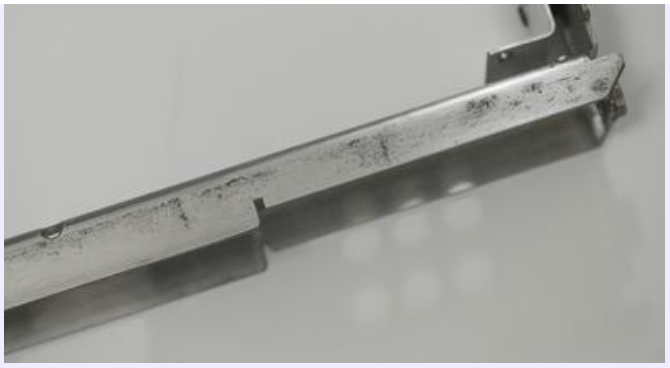
Removing fan is easy, just detach fan dust filter and release Torx screws holding fan in place.

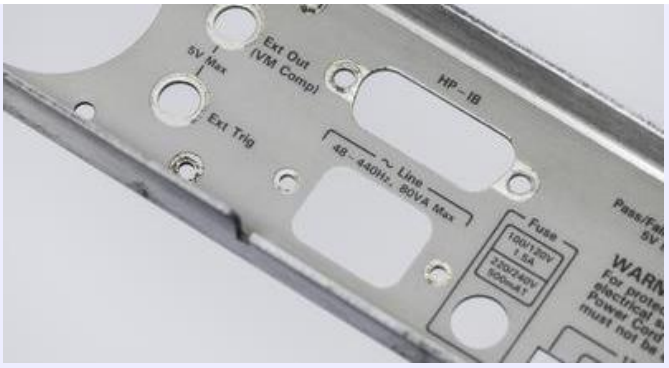
STEP 2. Clean steel frame from dirt and rust

I used **3M Scotch-Brite** with 95% alcohol to remove rusty particles first, then proceed with sandpaper, grit 200, 400 and finishing 600 to get nice shiny metal.

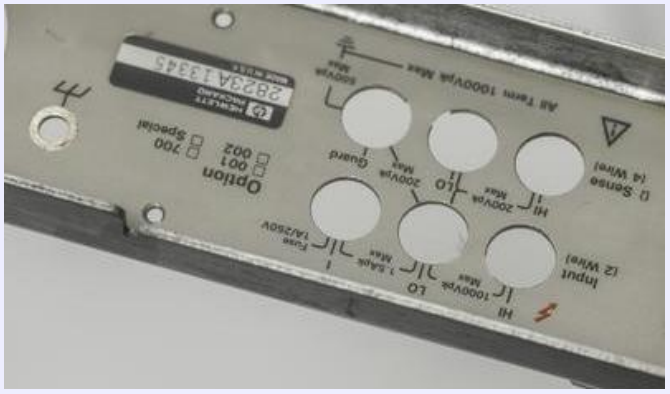


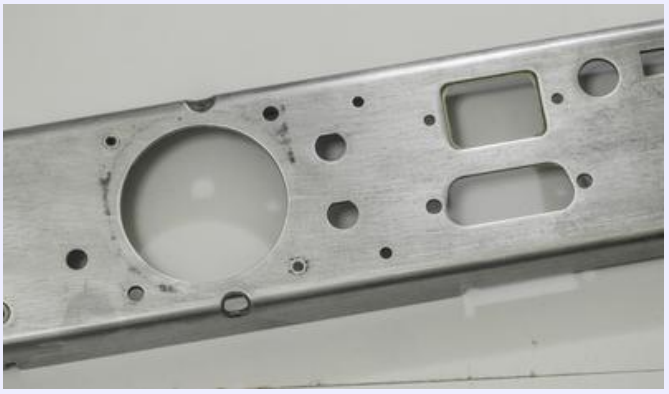
Aluminum inner frame have date code marks, MAY 04 1995 and May 23 1995, confirming conspiracy theory that all meter boards, except A5 Outguard controller are ~1995 year, while A5 is was swapped out to older 1990 board.





Suspicions to explosions Schaffner FN 323-3/05 IEC mains filter socket was fixed to chassis with rivets. Just push it out with rod and little hammer action, and remove the filter. I'll use suitable screws instead with new socket.





Few spots around nuts and corners still need some attention, will do it later with finer tools, just before assembly.

Use paper towels with alcohol to remove any metal particles and dust off the frame. You don't want little bits of metal dropping off to your electronic PCBs, causing possible disasters.
Pay extra attention to terminals area, as any conductive contamination will be a path for leakage and errors in measurements.

I swiped all surfaces many times till paper come out white and clean as a result. Avoid water to touch frame, to prevent rust and corrosion on fresh metal.

STEP 3. Exterior cleaning, covers

This is what we had originally:

Dirty and nasty, but nothing is hopeless, with help of **3M Scotch-brite** and half a bottle of alcohol (not drinking, like some might thought!), everything is possible.

Looking better now. Few final touches will be done prior to final assembly.

STEP 4. Front panel cleaning

Also clean front panel from alien stickers. It's almost mint condition now, satisfied with front face condition so far.

Cleaned keypad as well, who knows whose dirty fingers pressed teh buttons :)

Diagnostics

Now after all initial repairs are complete, it's time to power it up and test main functions and operation.

For minimal test meter would need to have boards A4,A5,A6,A3 assembled and connected. After voltage checks I went ahead and install all boards in chassis already.

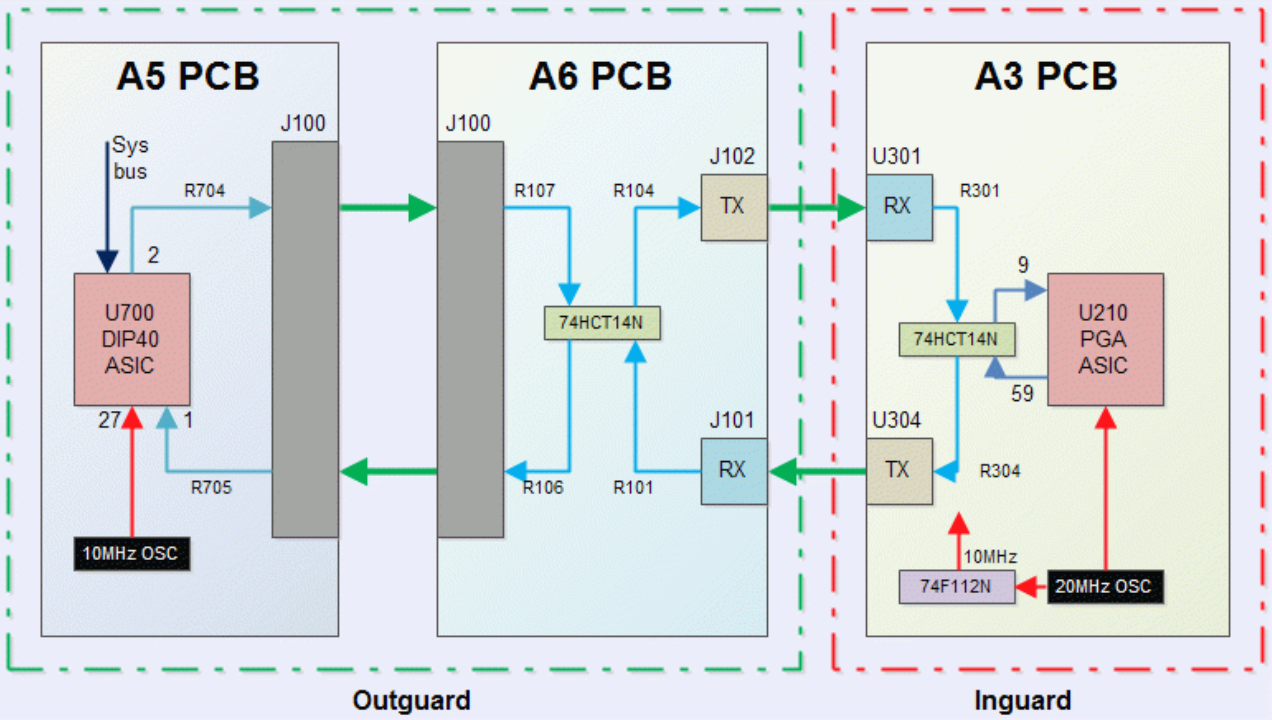
6 hours worth timelapse, 0.142 FPS , 4K resolution, using my **repaired Nikon D3**. 1880 photos.

First power on – test power supply voltages:

Rail	Measured value	Result
+5V		PASS

Front panel reports **REQUIRED ACAL ALL**, then quickly passing **TEST RAM, TEST CHECKSUM** and advances to **TEST HARDWARE**.
After about 5 seconds unit have one short beep and error message **ISOLATOR FAILURE**. This meaning digital side cannot talk to digital side of Inguard section via isolation interface.

Here's simplified block diagram of what interfacing look like:

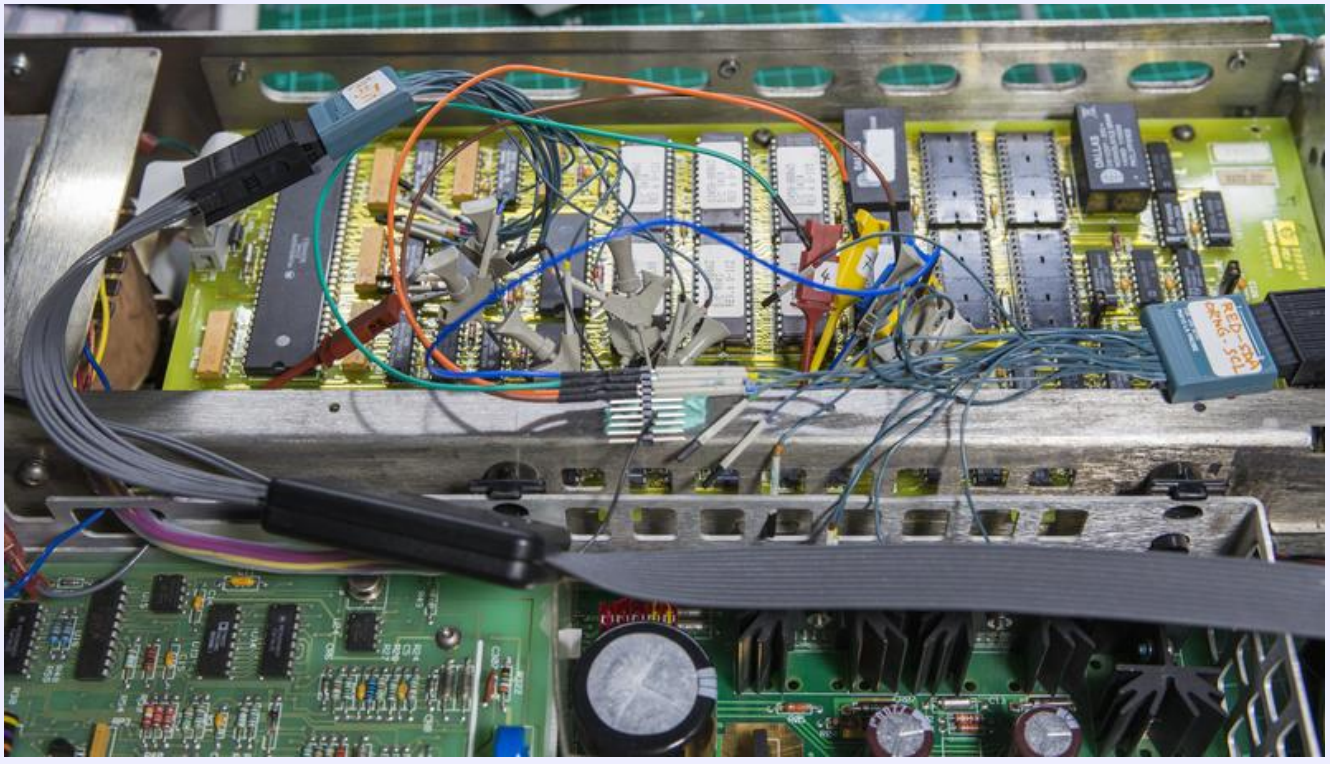


Basically it's one unobtanium ASIC on A5 board trying to communicate with another unobtanium ASIC on A3 board, and something somewhere going wrong.
If there is problem with either ASIC, it would be very hard to find replacement without buying new expensive boards. Let's try troubleshoot issue on circuit level first, and hope for the best.

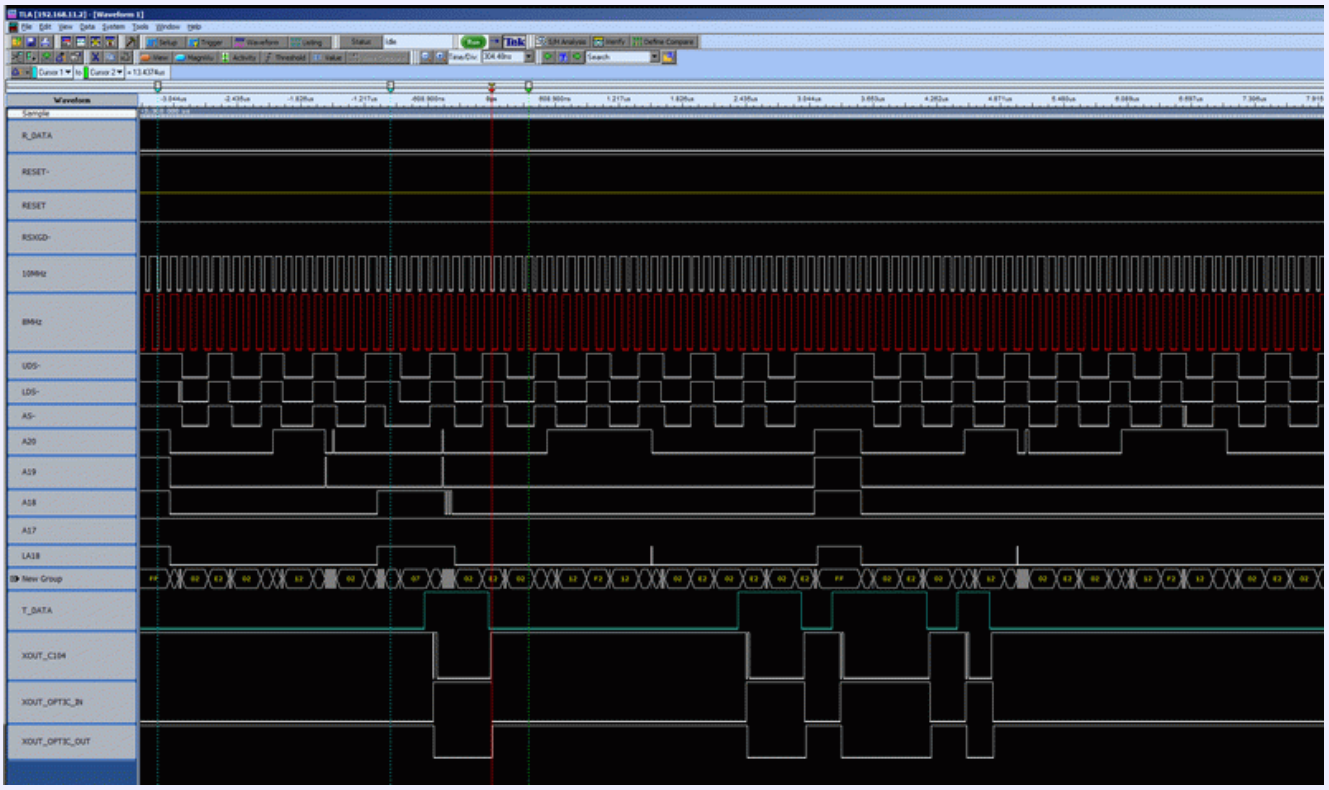
Optical cables are simple plastic fiber, and pretty easy to check, since used receivers and transmitter are using 660nm light, which is visible red.
I can see red light on transmitter, and swapped cables without effect, having same error.

When meter stuck on **ISOLATOR FAILURE** message it tries to send data, activating J102 Transmitter. If constant 660nm light directed on J101 receiver during meter power on, it resets itself in loop right after testing RAM, so likely that receiver path on A6 board is working.

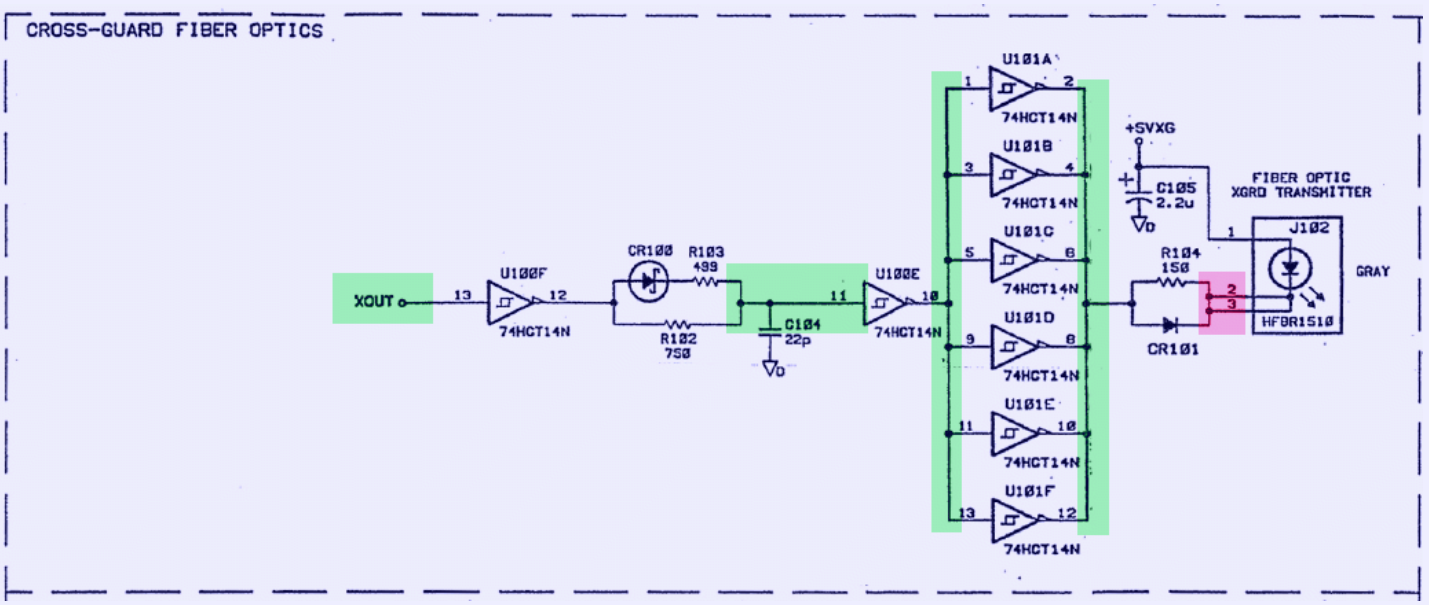
...



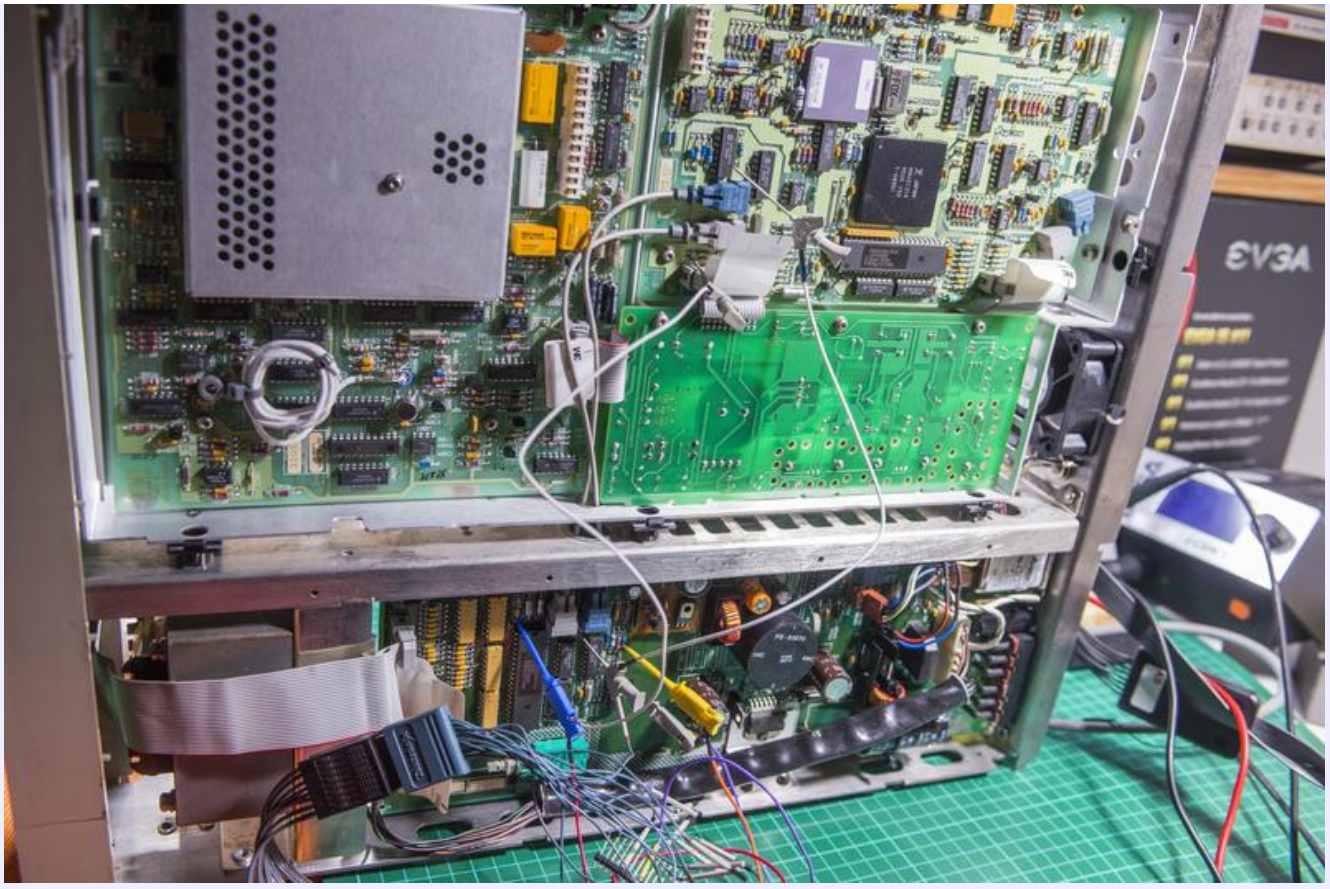
After initial testing, suspect were U700 ASIC and U106 **MMI 8L14** PAL with HP 03458-88804 mask, but measurement with TLA714 logic analyzer on A5 and A6 PCBA quickly revealed that transmit signal from A5 to A3 PCBA stops just before J102 optical transmitter.



Signal path section on schematic of A6 PCBA:



One thing I notice before, LED light on J102 is really dim, could be also show actual problem with transmitter diode. Since it was easy, I actually swapped J102 with J303 before (which used for external triggering BNC ports), but result was same, so could be both transmitters are faulty.



Transmitters and receivers are orderable from DigiKey, they are **Avago HFBR-1521Z** and **HFBR-2521Z**. Cable assembly is available as well, **DigiKey 516-2090-ND for 1m**

…

To test this I had bypass transmit isolation path by adding a shorted between anode of A6 CR101 diode to U302 pin 9 input on A3 A/D board. Guess what, it booted and let me to UI.

It does lit up ERR with next errors:

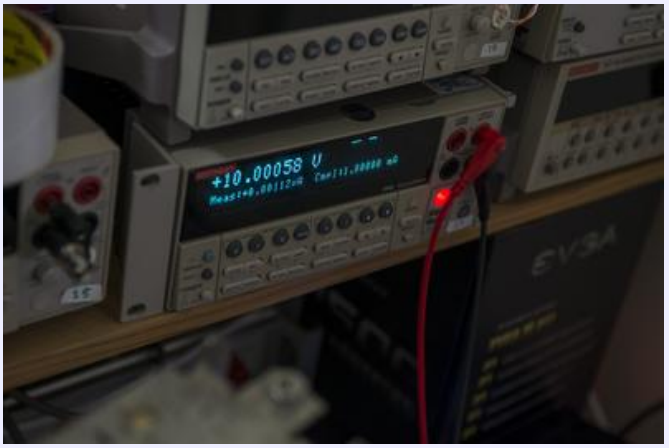
202,“HARDWARE FAILURE — SLAVE TEST: CONVERGENCE”
110,“CALIBRATION REQUIRED — ACAL”

If I try run ACAL ALL, it says **205,“HARDWARE FAILURE — CAL VALUE OUT OF RANGE: 72”** which is DCV A1 value, as per ALRM document.

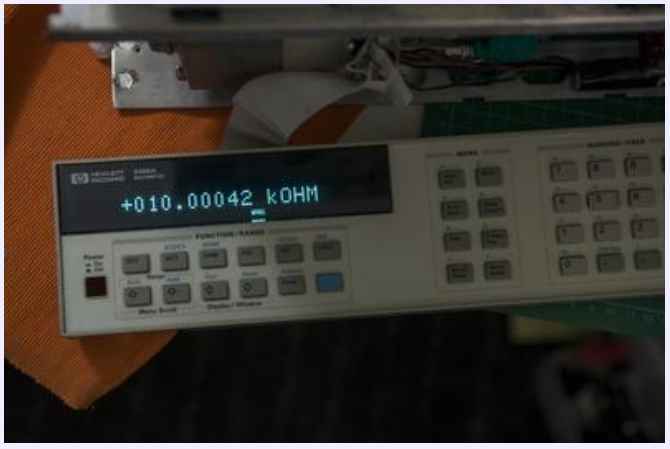
—-

Update 10/7/2015: Mistery resolved, it was receiver **U301** on A3 A/D convertor board which gone bad. After swap receivers with external trigger link, main isolation link working now without any problem.
I will buy new receivers and replace afterwards, but for now external triggering is not critical function and not affect self-test and meter diagnostics.

10.0006 VDC supplied from Keithley 2400, directly to DCV input on A1 PCB.

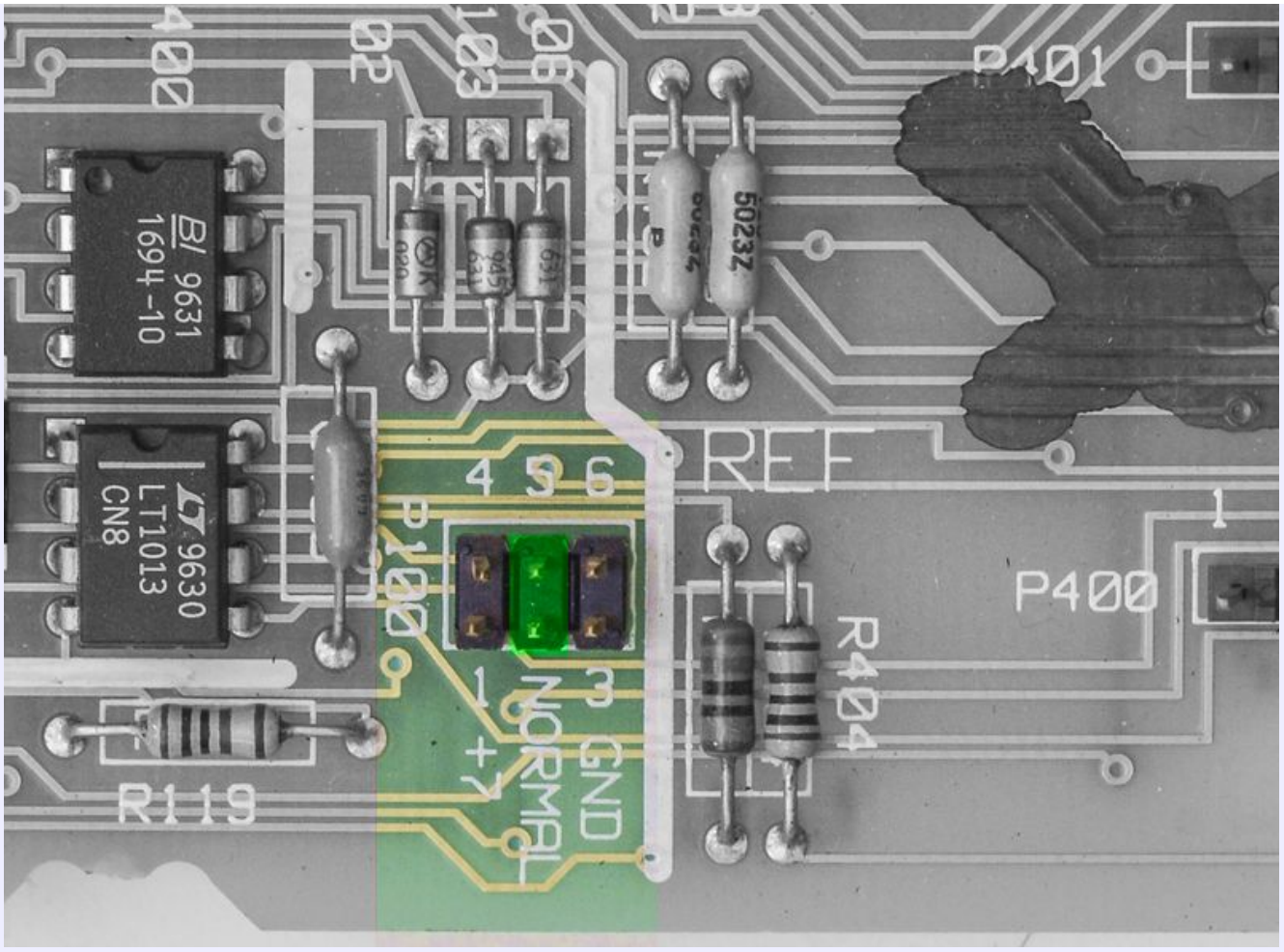


Around 0.5V supplied to input to fit 10K reading, meter in Ohm mode.



Repair for HARDWARE FAILURE — SLAVE TEST: CONVERGENCE

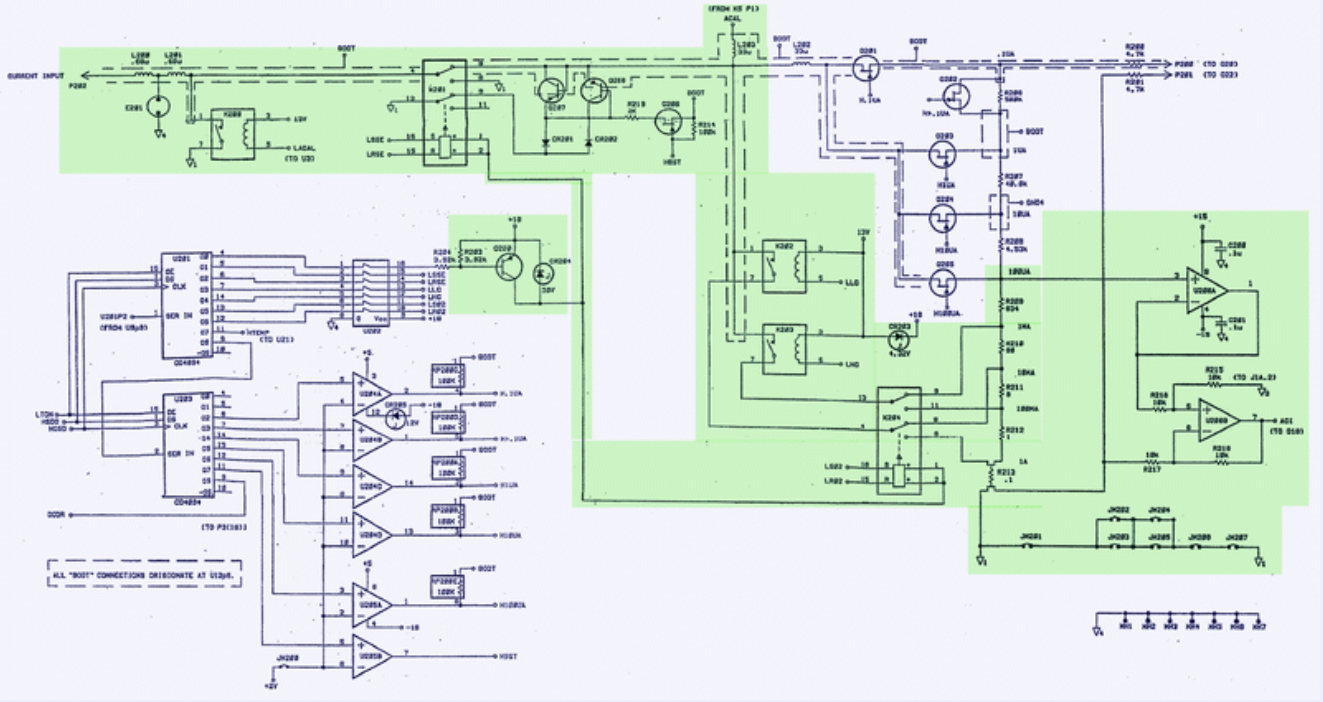
Issue was simply in missing jumper on A1 DC Board, which selects voltage reference input for rest of circuitry.



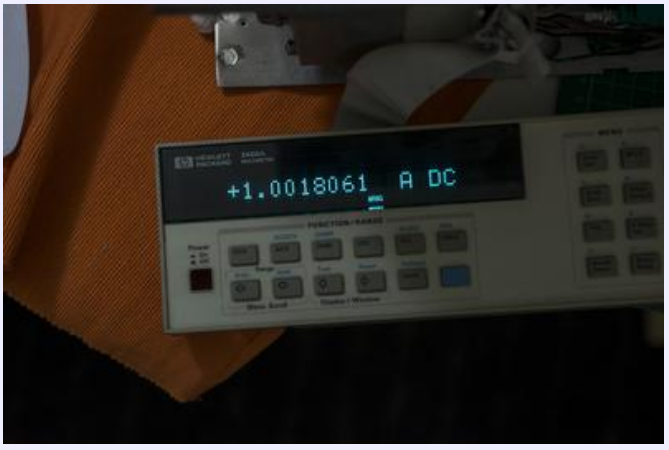
After installation jumper on position NORMAL, as marked in green on photo above – this error is gone, as well as meter's function on DCV,Ohms,ACV,frequency,period were recovered!

Repair for DCI ranges 100nA, 1µA, 10µA, 100µA

Further diagnostics revealed that low current ranges on DCI are not working, reading around zero current, disregarding actual current on input.
This is also confirmed by failure in self-test and ACAL: **205,"HARDWARE FAILURE — CAL VALUE OUT OF RANGE: 95"** which is DCV gain for 10µA value, as per ALRM document.



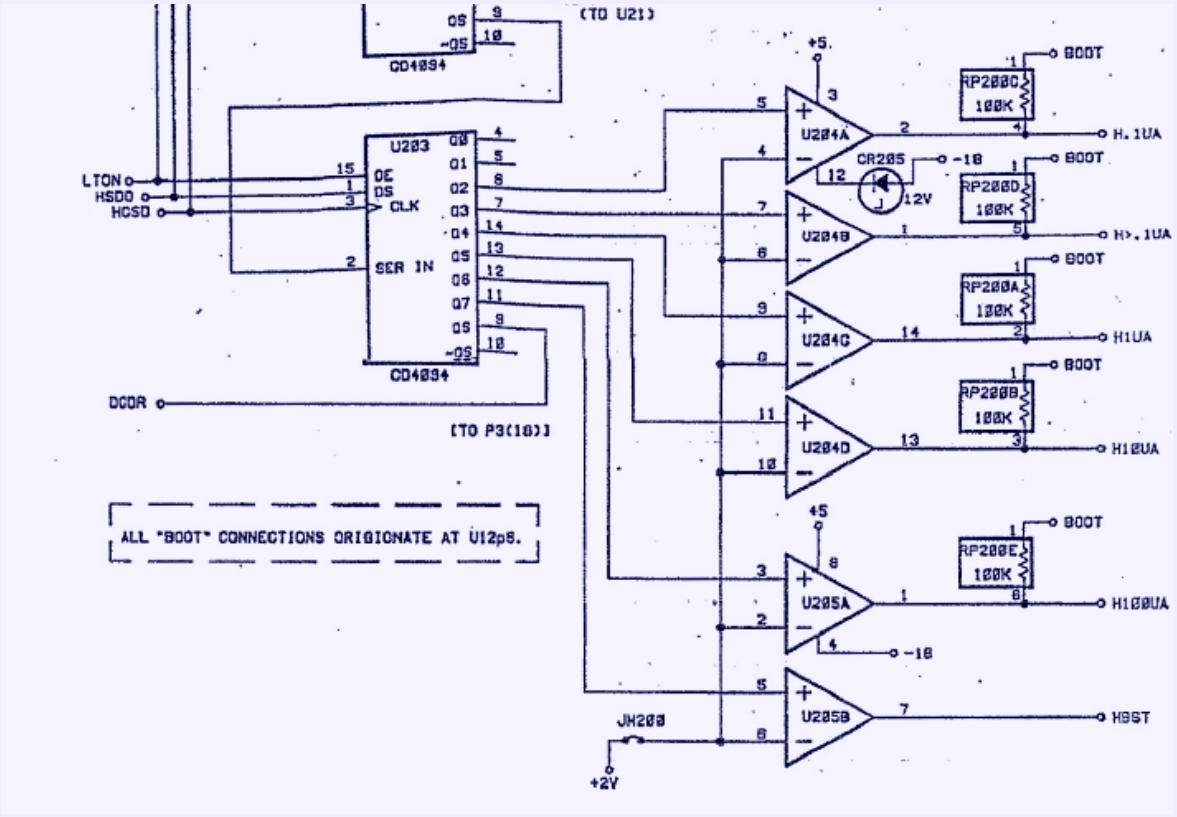
Since ranges 1mA and more working ok, we can rule out R210,R211,R212,R213 current shunt path, as well as input relays K201,K202,K203.



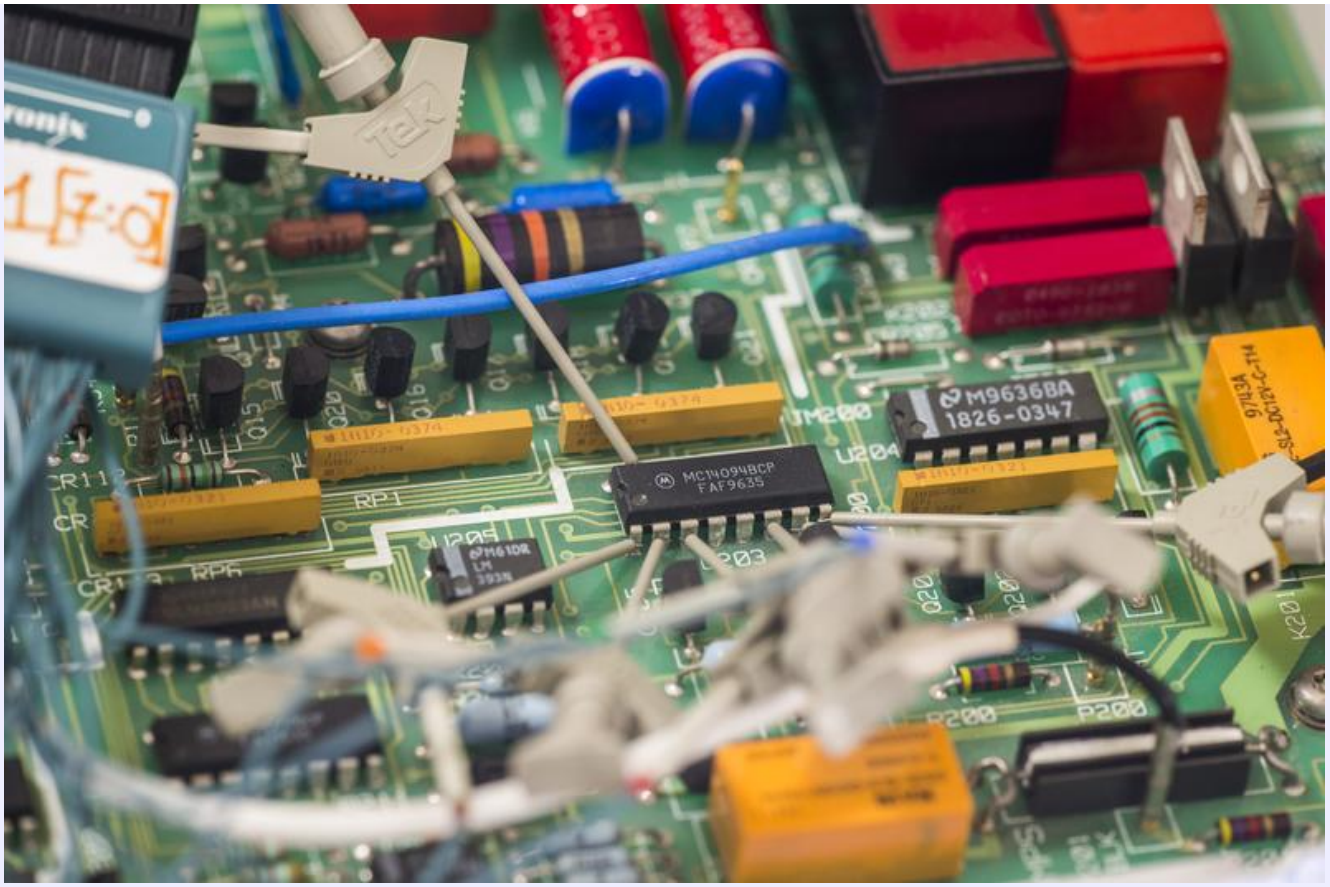
It is not likely that issue to be damaged JFET switches Q201-Q205 for low-current shunts R209-R206, as it's less probable that all of them died.
So I will test control circuitry first, which consists of U204 and U205 LM339 comparator for level shifting, U203 4094 shift register and RP200 generic resistor network and CR205 zener.
One thing we know from initial inspection – resistor network RP200 was resoldered by previous owner. I have bought RP200 replacement before, just in case, so it could come handy.

Parts summary:

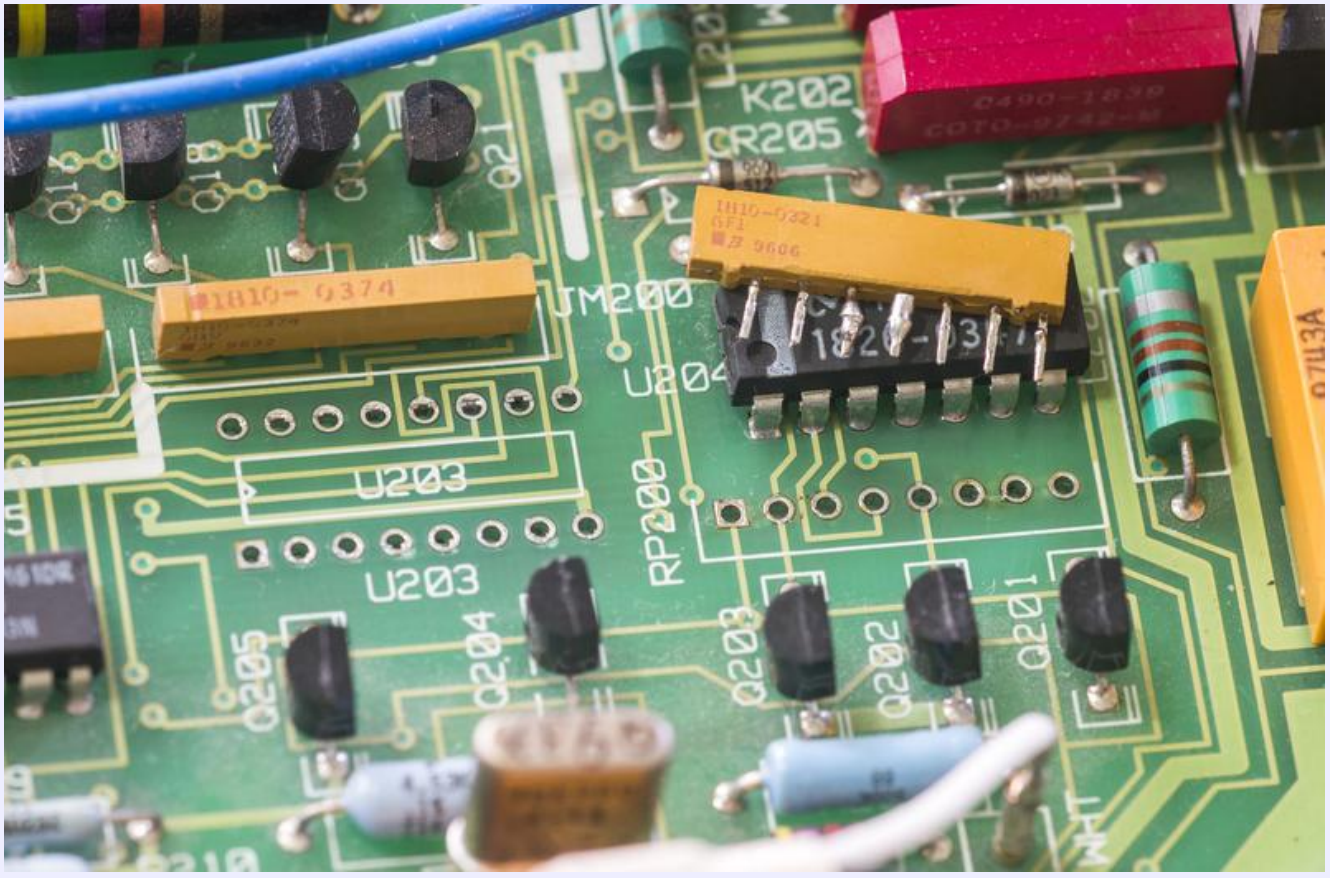
RefDes	Part type	Digikey ID	Test result
RP200	Resistor network, 8-SIP 220K&Omega x 7pcs		Replaced
U203	Shift register, serial in, parallel out, 8bit, MC14094BCP		Replaced
U204	Comparator, LM339N, Selected		OK
U205	Comparator, LM393N		OK
CR205	Zener 12V 5% 0.4W, TC ±0.077%, 1N963B		OK



Something tells us, most difficult in this repair would be finding jellybean LM339 and LM393 in DIP package :). Today modern electronics is using SMT widely to save costs and size.



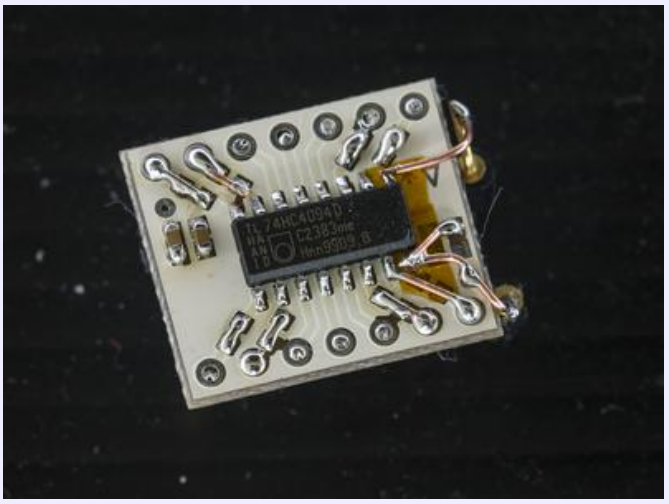
Since I did not have DIP 4094 S/R on hand, I decided to use little bodged SMD adapter just to try if it's fixes the problem. I'll order proper DIP-version for final repair later, after confirming solution



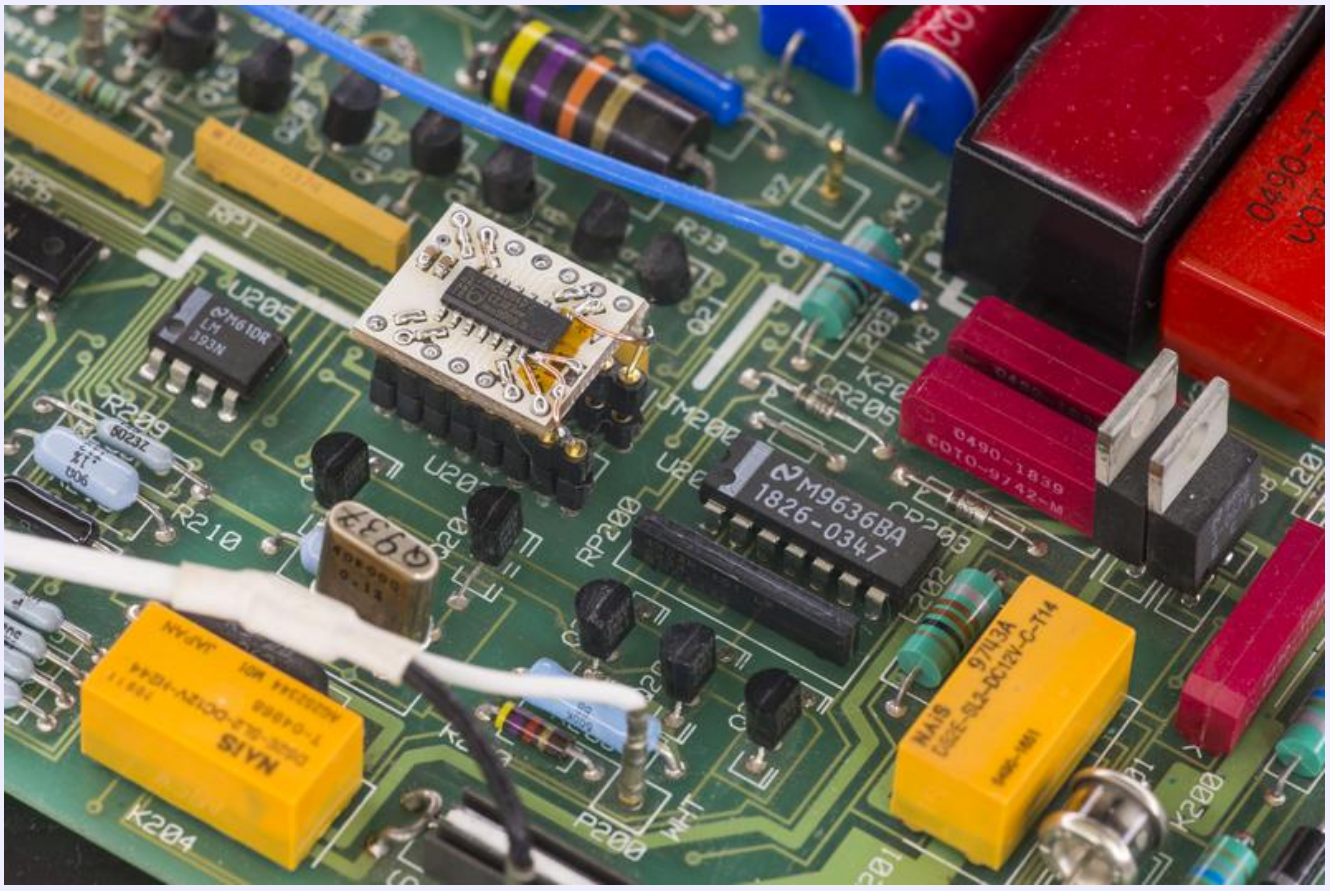
After removal both U203 and RP200, I quickly discovered issue. RP200 missing common pin 1 for resistor array! I don't know how that happen or what previous owner do to poor resistor. I replaced it with new 220Kohm 7-resistor SIP array. Worth to note, that schematics does show RP200 as pack of 100KΩ resistors, while BOM and actual A1 PCBA have 220K array installed. I used 220K, following original part resistance

value.

I quickly made bodge for 4094 U203 :



Someone would say it’s wrong way to do things, but I was desperate to see unit working..



And it did, no problems on low current ranges anymore.

Unit also does complete whole selftest diagnostings. Very happy to see this **SELF TEST PASSED** message after all the work we had done above. Now left to do is overall assembly and make sure everything is secured and nice.
I did also ACAL and it passed without problems.

Repair for SYSTEM ERROR — multislope rundown convergence

Well, I left unit working overnight, just sampling 10VDC from Keithley 2400. No problems, did couple self-test runs, all pass with flying colors.
Then connected 1Meg resistance from ESI DB52 decade box and left it sampling for about 6 hours. After I come back to check on it, there was **ERR** lit and measurements halted. Pressing Enter key allow to do some measurements but it halted with ERR after few seconds.

Checking revealed **ERRSTR 114 SYSTEM ERROR — multislope rundown convergence**.

It does happen sometimes after a second, sometimes after three seconds on any DCV,DCI,OHM,OHMF functions, and does not occur on ACV,ACI,FREQ,PERIOD or digitize functions.
This error is not listed in repair manual, but there is **Service note for Modification to Fix Intermittent Error "Multislope Rundown Conversion"** which probably related and suggesting nothing else than replacing whole 03458-69503 A3 A/D Converter and Inguard Logic Assembly. This is not an option for us, due to involved costs of new A/D board.

There are few other owners of 3458A who had similar issues with A/D like **here**, **here** and **here** and some of solutions suggest replacement of EL2018 comparators.

Now important note, as there are multiple A3 board revisions, and schematics in CLIP is for one of first revisions. There are some differences, not reflected in schematics.

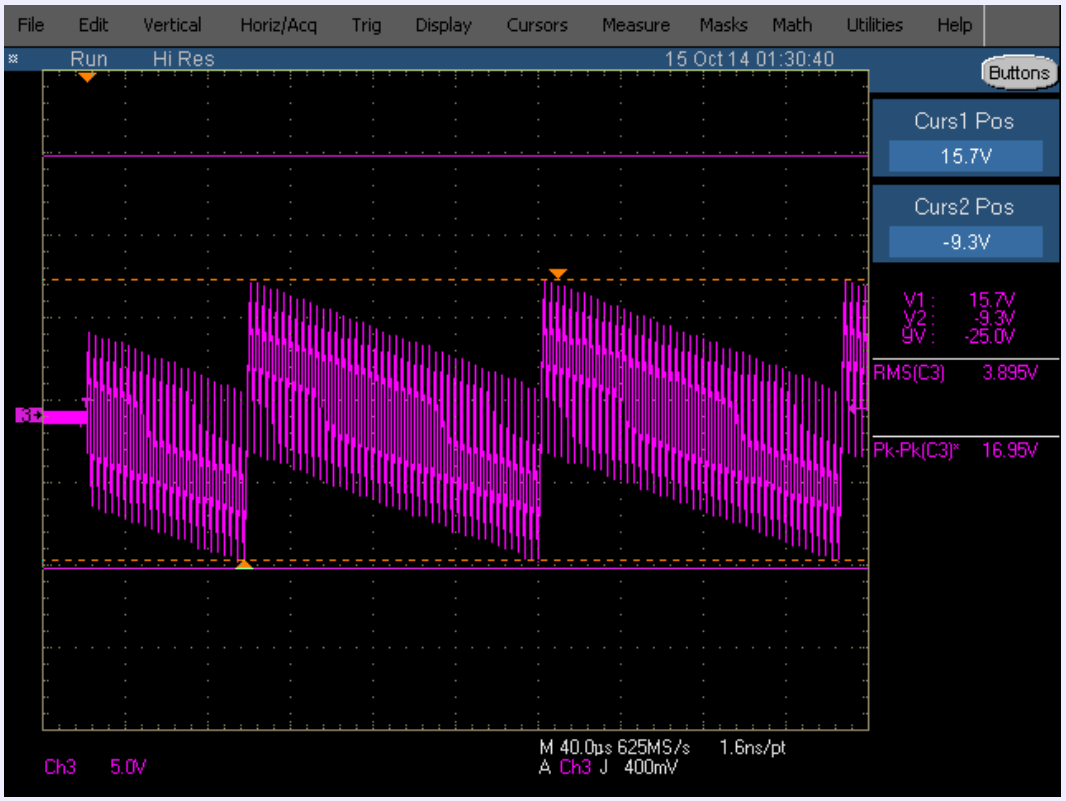
	3458A A3 PCB 03458-66503 Rev.A	3458A A3 PCB 03458-66503 Rev.B	3458A A3 PCB 03458-66503 Rev.C	3458A A3 PCB 03458-66503 Rev.D

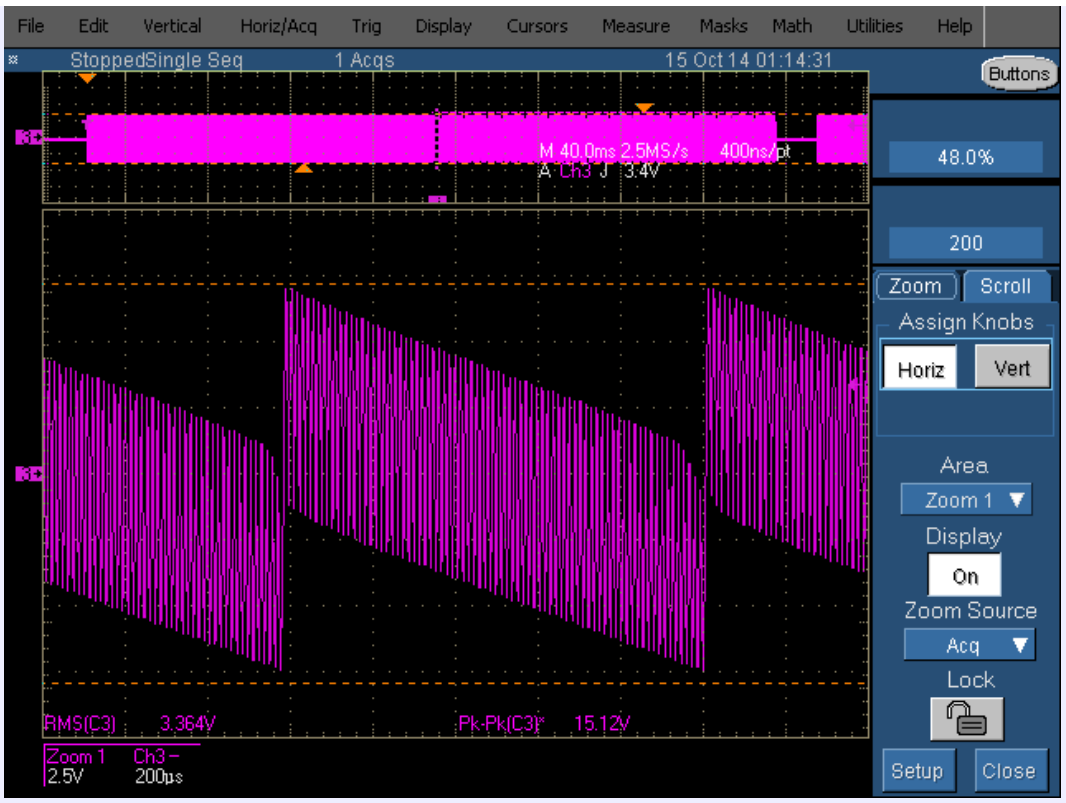
Photo				
Year				
Difference				
ERC range				

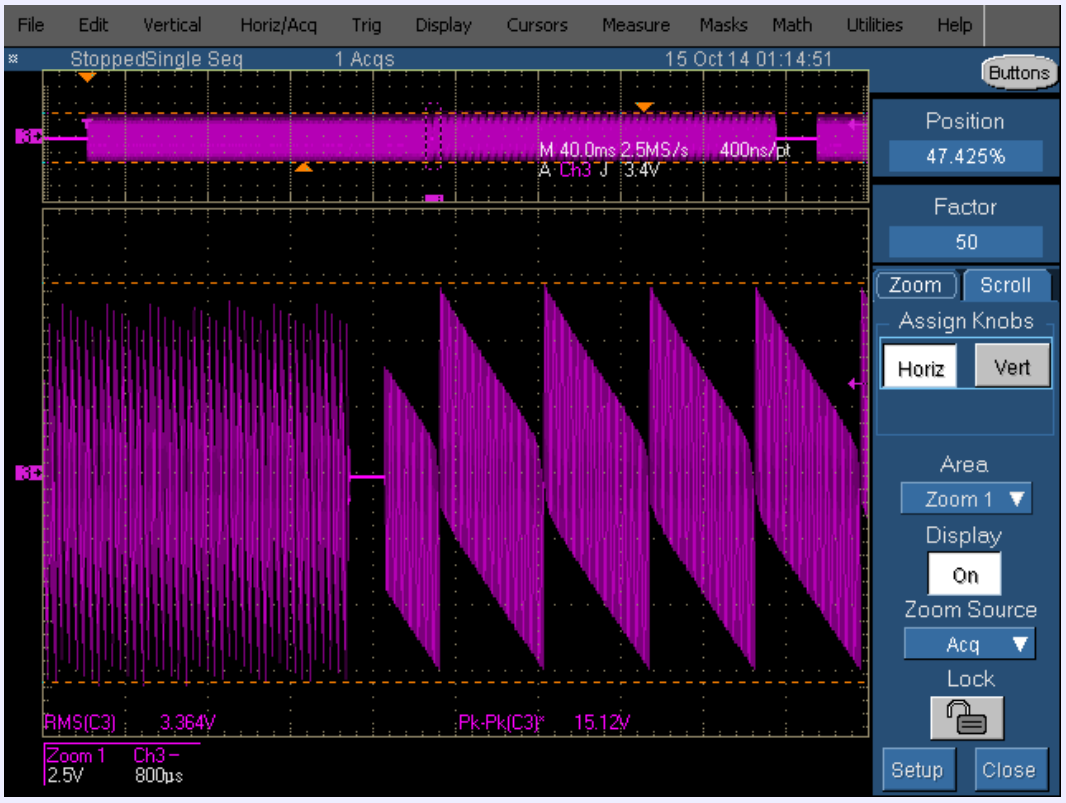
Some signals waveform captures were made during debug:

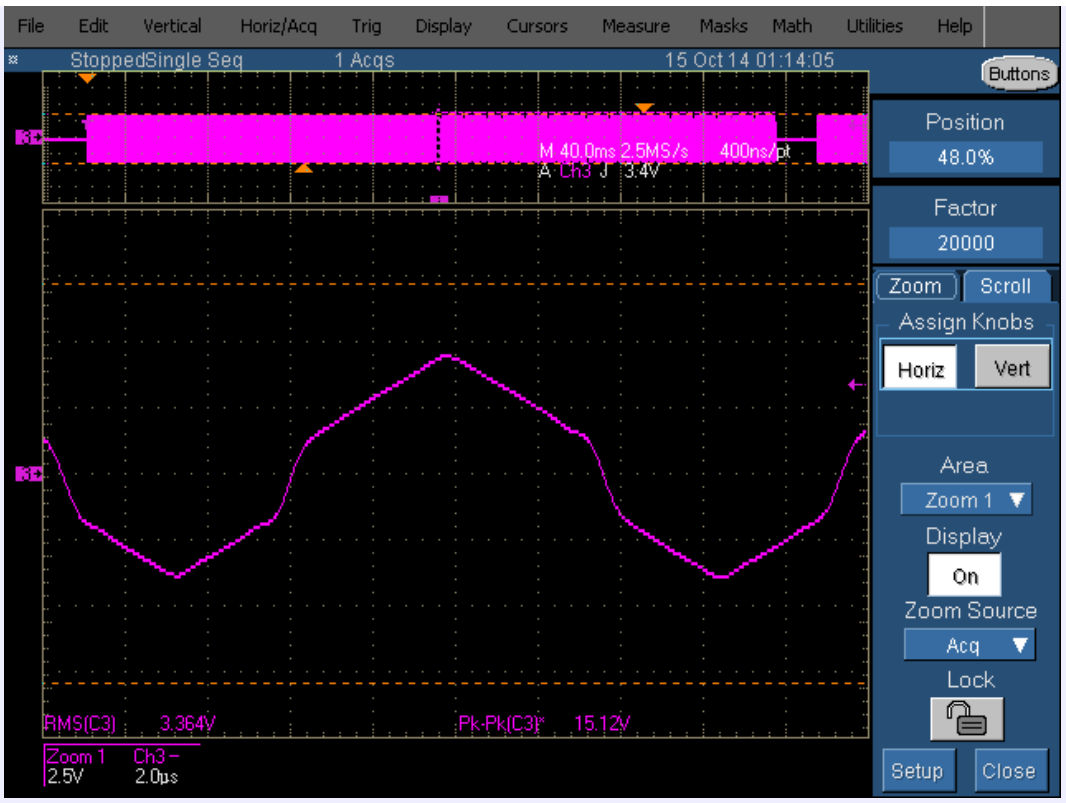
U142 EL2018 comparator output to digital domain of ADC:

NPLC 1:

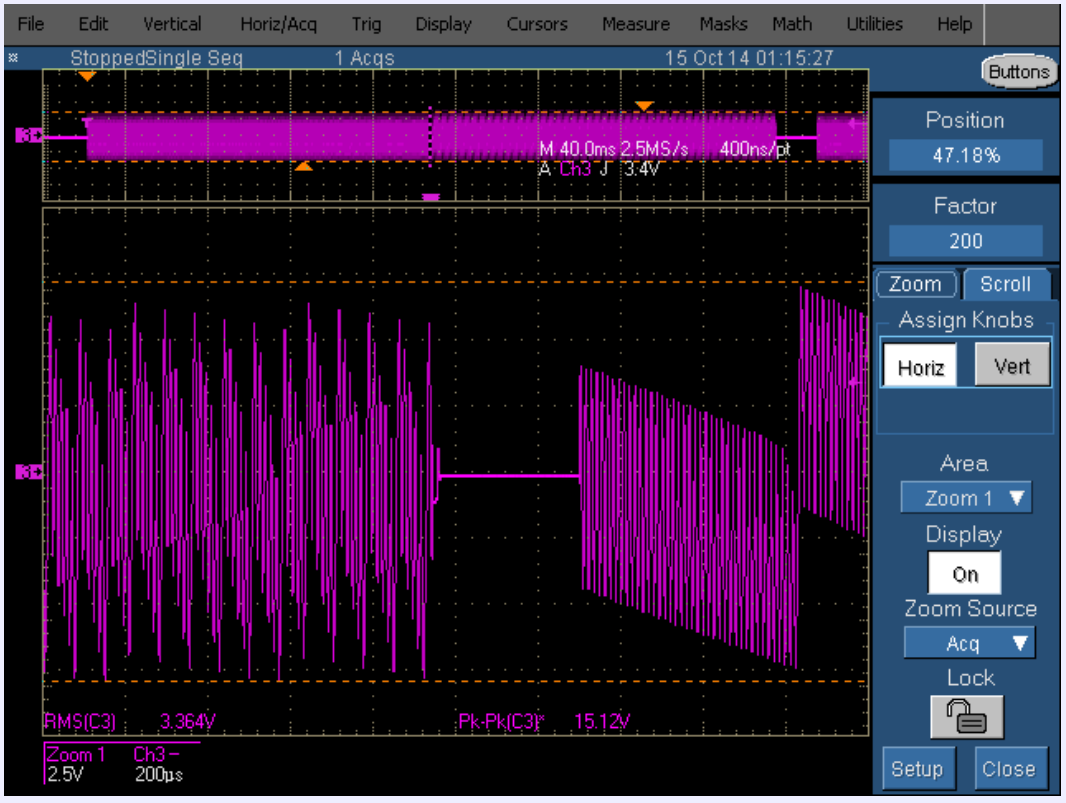



File Edit Vertical Horiz/Acq Trig Display Cursors Measure Masks Math Utilities Help
Stopped Single Seq 1 Acqs 15 Oct 14 01:14:31
Buttons
M 40.0ms 2.5MS/s 400ns/pt
A Ch3 3.4V
48.0%
200
Zoom Scroll
Assign Knobs
Horiz Vert
Area
Zoom 1
Display
On
Zoom Source
Acq
Lock
Setup Close
RMS(C3) 3.364V
Pk-Pk(C3) 15.12V
Zoom 1 Ch3
2.5V 200µs


File Edit Vertical Horiz/Acq Trig Display Cursors Measure Masks Math Utilities Help
Stopped Single Seq 1 Acqs 15 Oct 14 01:14:51
Buttons
M 40.0ms 2.5MS/s 400ns/pt
A Ch3 3.4V
Position
47.425%
Factor
50
Zoom Scroll
Assign Knobs
Horiz Vert
Area
Zoom 1
Display
On
Zoom Source
Acq
Lock
Setup Close
RMS(C3) 3.364V
Pk-Pk(C3) 15.12V
Zoom 1 Ch3
2.5V 800µs

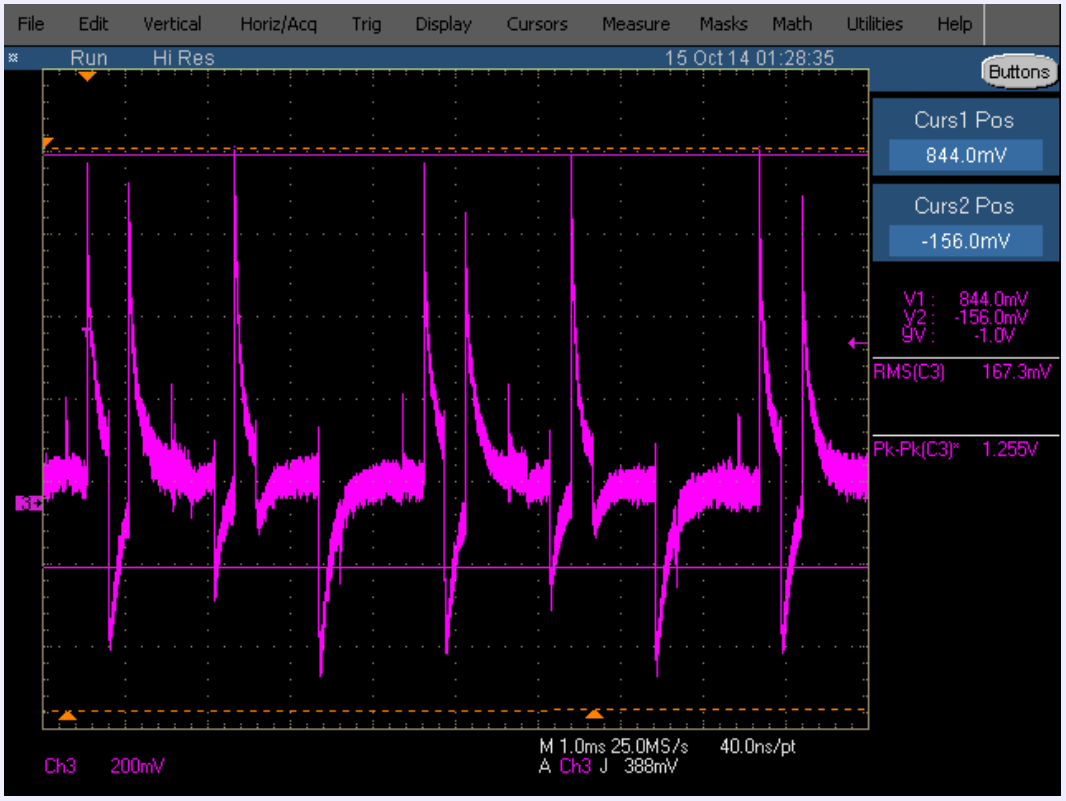


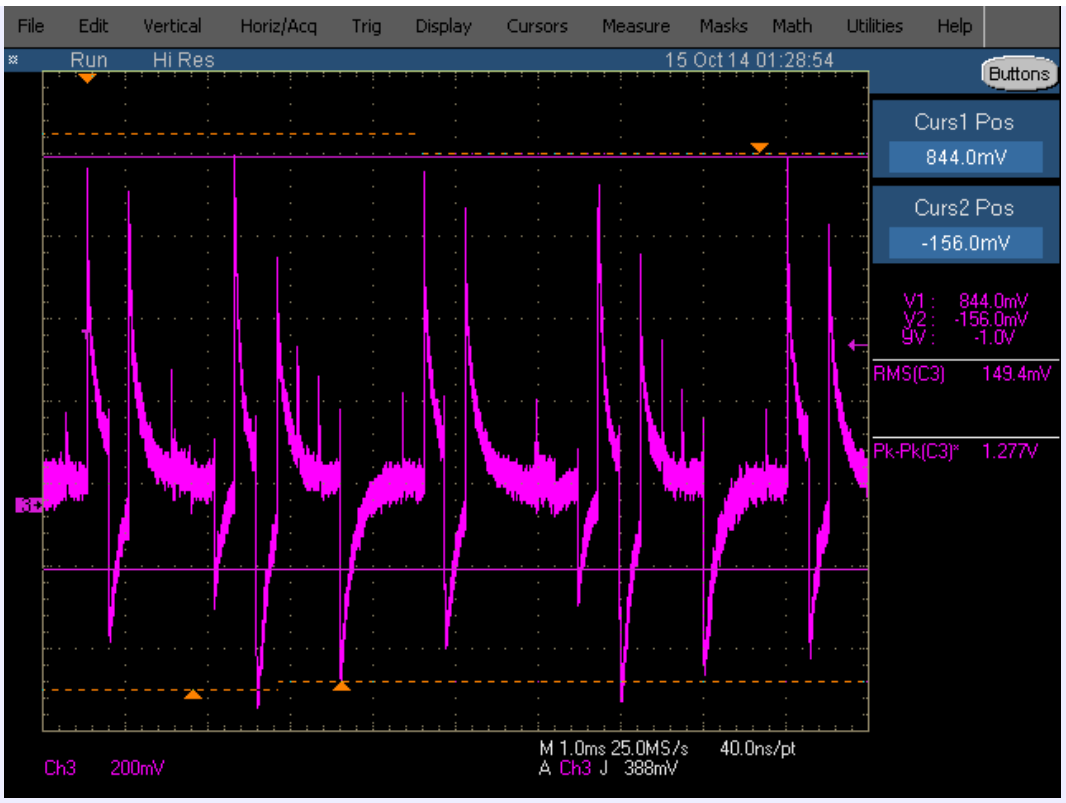
It does seem to be working, at least signal is there. This could also indicate that problem lies in timing/sync, which is more difficult to troubleshoot, as we don't know correct waveform timings.



Above two blocks of pulses, first fast ramps and then slower ramps. Longer pulse train usually have valid measurement displayed on screen.
Sometimes there are only first half of pulses, and also aborted conversion without value shown on screen. Square pulse train waveform is comparator's output.

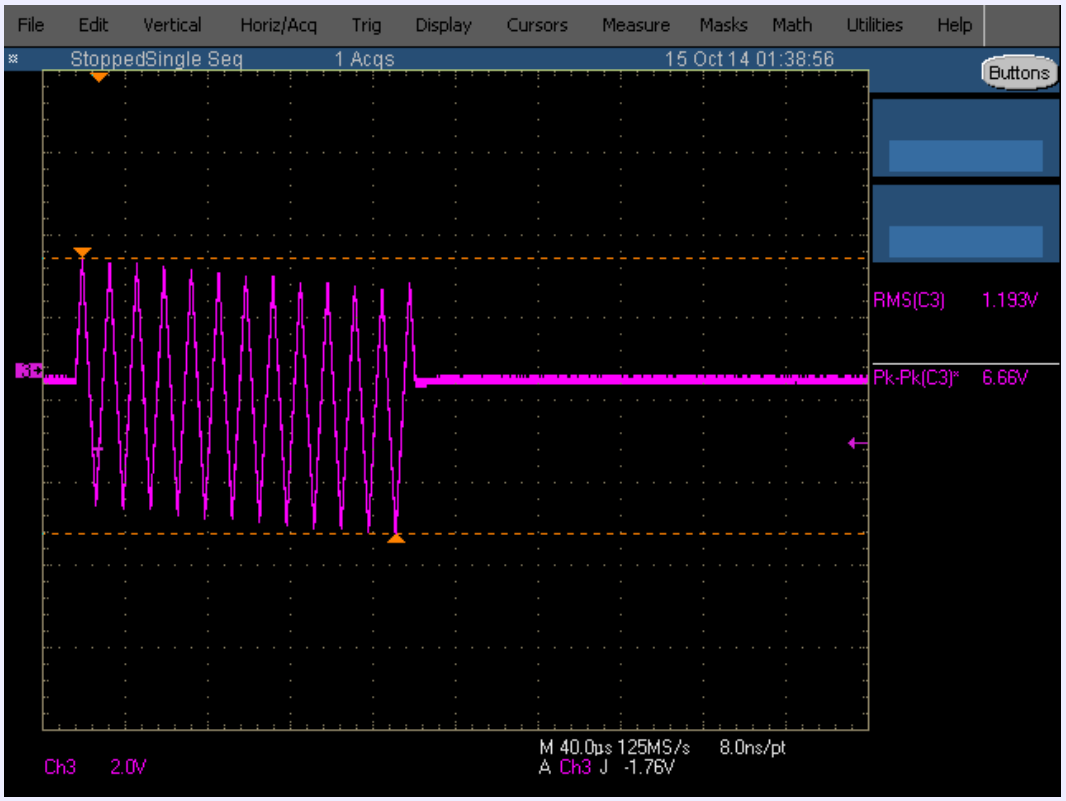
A2 Board, U504 buffer (left input pin 2, right output pin 3), meter in mV range on ACV.





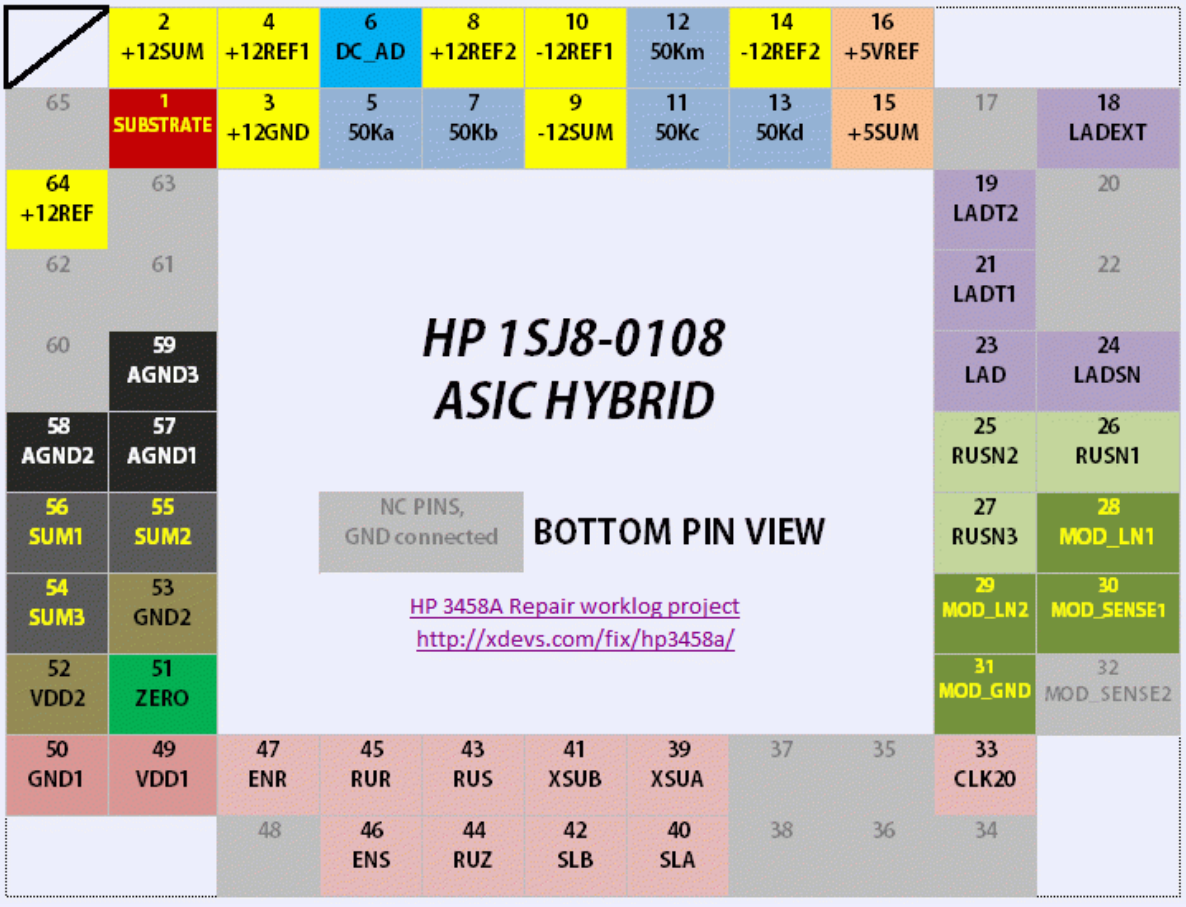
Looking OK, desprite U504 running rather warm.

Integrator capacitor waveform (test point TP112, left is NPLC 0.001 failing, right is NPLC 0.0001). Can easy see on faster setting it just takes 2 big ramps to converge voltage, while on slower setting it takes 12 much smaller ramps.

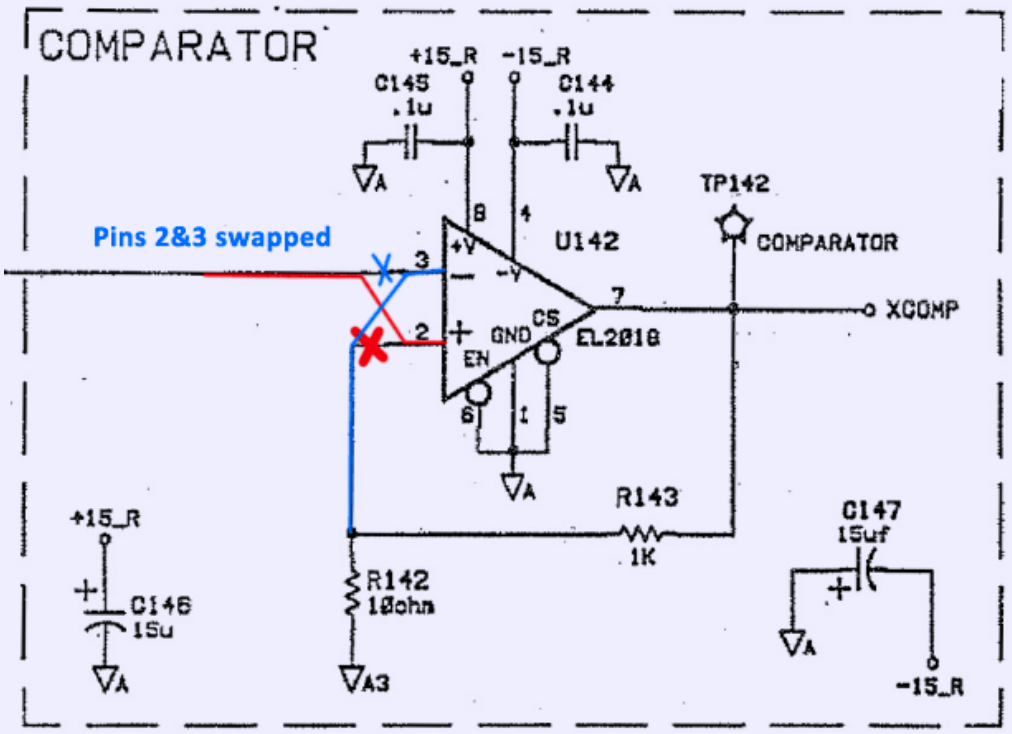


Not sure if those little dips should be there…

To aid probing and resistance measurement here's pinout of U180 Hybrid chip (smaller PGA package on A3 PCB).



Also there is an error in HP 3458A CLIP, regarding U142 comparator inputs. They are swapped on schematics, so slope amplifier actually connected to non-inverting input of comparator, pin 3.



Up by now I had replaced next parts on A3 PCBA:

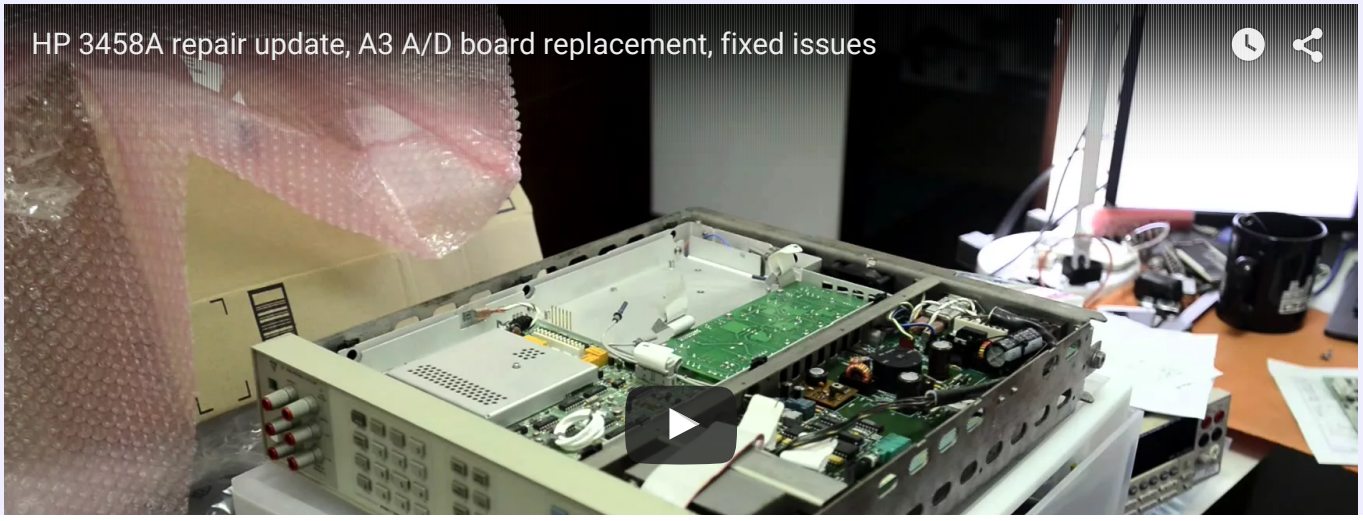
RefDes	Old part	New part	Effect
U142	EL2018CN	EL2018	None
U181	EL2018CN	EL2018	None
U405	EL2018CN	EL2018	None
U170	LM358	LT1013CN8	None
U230	FOX 20.0000MHz 50ppm	XO 20MHz 50ppm	None
U301	Receiver	Receiver	Fixed isolator failure issue
U304	Transmitter	Avago HFBR-1521Z	Fixed isolator failure issue

This did not help.

So I had no chance but to use **plan B**, which involved replacement of whole A3 A/D PCBA resolved issue.

Repair for Error 204: Hardware Failure: Level DAC Convergence

This issue is due faulty **U501** EL2018 comparator on A2 AC PCBA. After replacement with good EL2018 this issue was resolved.



Now meter running non-stop, to see if we can get any issues.

Firmware

You can determine firmware revision via the front panel command “Rev?”.

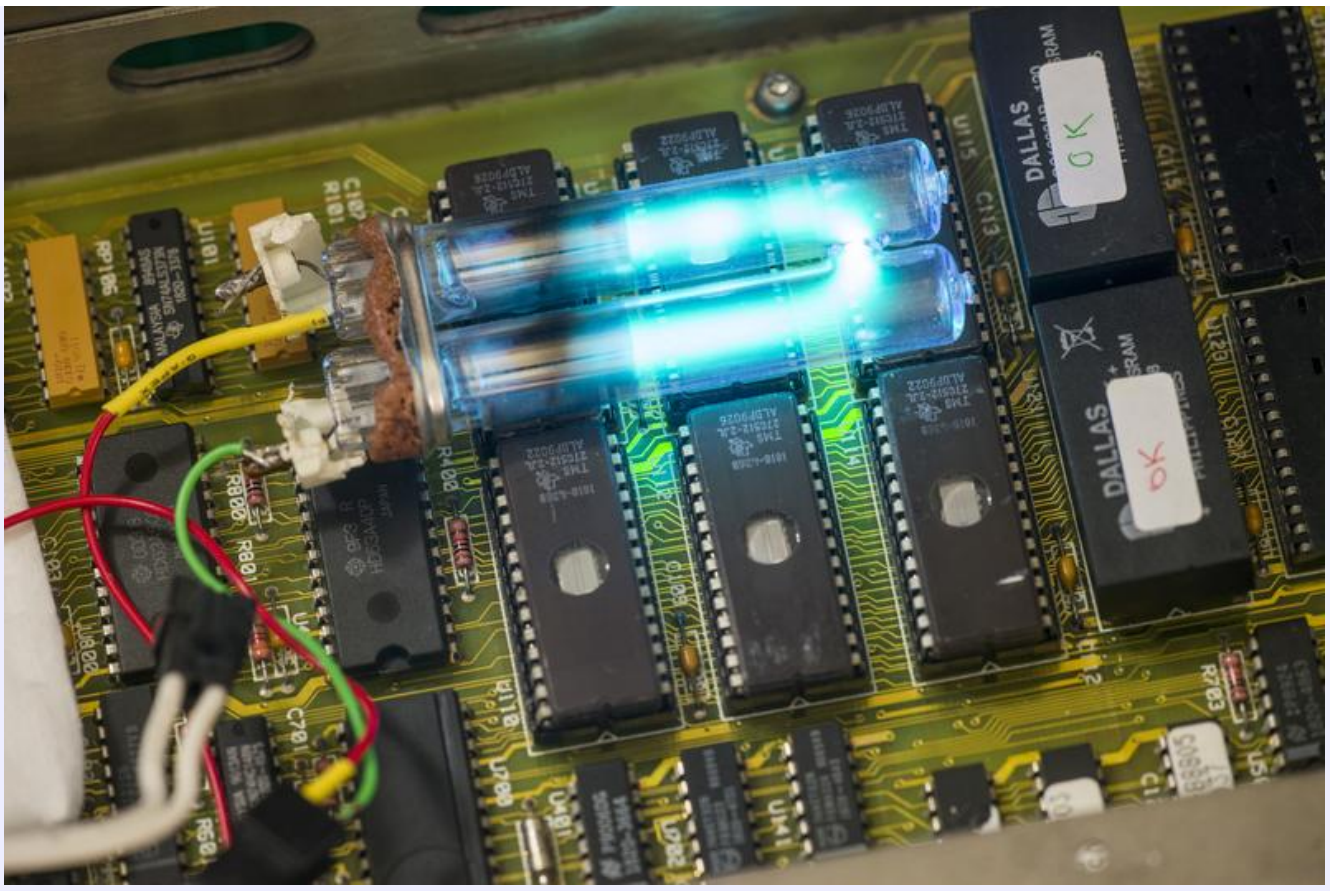
> In many cases an old unit might have been retrofitted with newer firmware, so later firmware revision cannot be used as proof of the date of manufacture.

Firmware ROM dumps for HP/Agilent/Keysight 3458A, read by general purpose ROM programmer.
From information we have, firmware dumps are compatible with all hardware versions.

Revision 6	Revision 7 (1992)	Revision 8 (1998)	Revision 9 (latest)
03458-88860	**03458-88870**	**03458-88880**	**03458-88890**
03458-88861	**03458-88871**	**03458-88881**	**03458-88891**
03458-88862	**03458-88872**	**03458-88882**	**03458-88892**
03458-88863	**03458-88873**	**03458-88883**	**03458-88893**
03458-88864	**03458-88874**	**03458-88884**	**03458-88894**
03458-88865	**03458-88875**	**03458-88885**	**03458-88895**
			03458-88887 Single ROM

Based on **this discussion** Firmware 9.2 is no different in function than 8.2.

I had used UV lamp with little CCFL boost DC-DC (12V powered) supply to erase TMS27C512 UVEPROMs on by A5 board.



After 10 minute exposure chips were successfully erased and flashed to REV 9.2 firmware.
Firmware update was successful.

Other possible 3458A issues, reported by community

Here are some common failures reported by other 3458A owners, with provided solutions.

Error 209: Hardware Failure: Timeout – Unable to read A/D

One of users had this issue, discussed in **EEVBlog thread**
Reason was in faulty U405 EL2018.

Time drift issue for very old 3458A's

Additionally, if possible run a "Time Drift" test per Service Note 3458A-18 to make sure your A3 A/D board is OK. If the meter fails this test, you're probably looking at an expensive A3 board repair.

Tweaks and tricks

Adding extra memory option

Outguard controller A5 PCB support extra memory option, which is **001** per HP's classification. Upgrade consisting by installation of extra four 32K * 8 SRAMs into sockets. Access time of 150ns or faster is recommended. Suitable chip example could be **HM62256-15** in DIP28 package.

Installation note for 03458-66505 covers this operation in detail. Most important is STEP 6 – apply proper label sticker on upgraded board :)

Newer SMT-version of A5 PCBA have specific **installation note** covering upgrade to Opt.001. This involve purshuase new PAL chip from Keysight, so it's not free field-upgrade, like with older 03458-66505 A5 board

Improving long-term stability of LTZ1000A voltage reference module

Standard 3458A have spec for DCV at 8ppm/year, but there is high-stability option 002 to half this value. If meter used for extended period of times, this could be achieved by simple DIY modification.

It's useful to tack your voltage reference voltage by reading CAL Variable 2 value from periodically or from calibration to calibration and see how much it is changing (CAL? 2 ENTER). This will only take a few years to get a pretty good idea of how much it drifts, if readings taken with same temperature and environment conditions.

Dr.Frank had performed this and covered in great detail before.

> ⚠ If you change the oven temperature, you will lose the 10V calibration, as the LTZ1000A will change its reference voltage.

STEP 1 – Access reference board A9

- Remove top cover and shield cover on top side of instrument.
- Locate A9 VREF assembly at top right corner (looking at instrument's face side at bottom)
- Remove A9 VREF carefully. Avoid touching any components with bare fingers, handle on board edges only.

STEP 2 – Change temperature setpoint

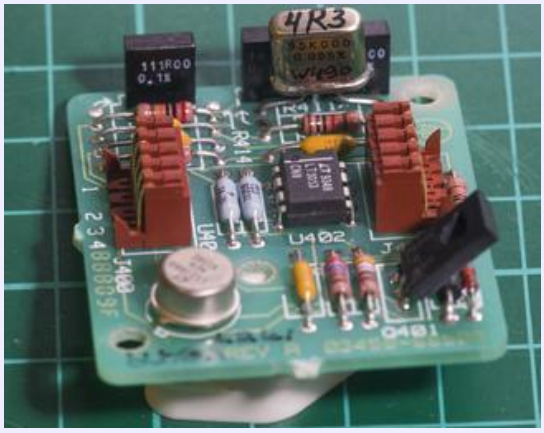
- Solder 100K stable resistor in parallel to 15k BMF resistor. Resistor temperature coefficient must be no more than 3ppm/K, better less.
- That gives 13k in total resistance, setting temperature setpoint about 65°C
- An alternative placement is already foreseen on the PCB; in the CLIP, its component designator is X411.

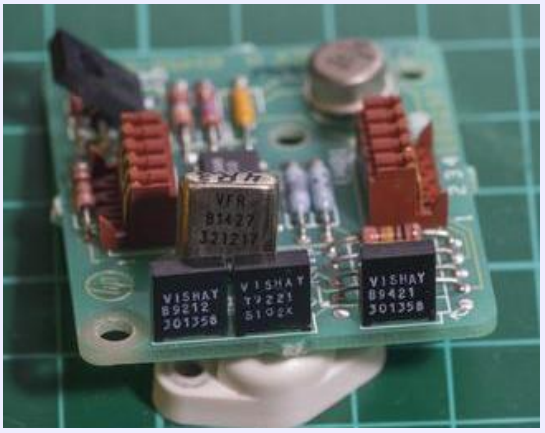
With 100K/65°C, the oven runs about 30°C lower. Therefore, the ambient temperature has to be limited to max. 35°C, the fan has ALWAYS to be kept clean, giving a maximum temperature rise of 15°C, and the instrument may not be put in a rack (which would give additional 10..20°C temperature rise). Under these conditions, (35°C ambient + 15°C 3458A inner heating + 10°C self heating of LTZ1000A + 5°C regulation margin), the oven will always be stable. You can monitor 3458A inner temperature (GPIB command : TEMP?).

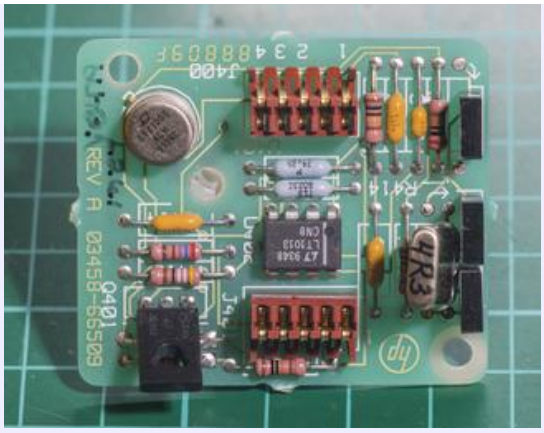
STEP 3 – Recalibrate instrument with either ACAL ALL or external calibration

Use known stable and characterized 10V and 10Kohm references to perform calibration. Or perform full calibration with external calibrator.
If instrument planned for service calibration by calibration center, it's wise to perform this modification prior to sending meter to cal facility.

Here's how I did it on my A9 PCBA:







Used Vishay Precision Group 95.000 KΩ resistor, which is custom-made VHP101 specced 0.3 ppm/°C in +20...+40°C range.

Improving long-term stability for resistance measurement

Most stable resistor in circuit, 40KΩ is currently specified in CLIP's BOM as ±1.3 ppm/°C. But actual resistor on our board (and any newer 3458A's as well), is Vishay Precision Group Foil **VHP101**, in hermetic oil-filled can. This series were released by VPG in 1996, so it's later change, not reflected in old CLIP. Actual specification for VHP101 shelf-life stability is ± 0.00002% (or 2 ppm) stability in 6 years, and typical TCR ±0.3 ppm/K in +15°C to +45°C window.

So finding a replacement for this already ultra-stable resistor would be extremely expensive *(hundreds of dollars range, such as VH102Z or VHZ555 with PMO)*, and is questionable task, as new resistor would need to be aged for few years till it can reach old VHP101 stability.

But other resistors in meter are not so advanced, so replacing one's used in the Ohm measuring function signal path, with more stable type, like Vishay foils could improve overall stability.

Current resistors used in 3458A's OHM current source are

RefDes	Type	Resistance value	TC, ppm/°C
R307	BMF	300 Ω	
R308	BMF	3.00 KΩ	
R310	BMF	10.00 KΩ	
RP300	Vishay custom array	30k, 60k, 600k, 6M, 10k, 0.3k, 3k	

We will study viability of this later, after repair of instrument is complete.

Improving long-term stability for current measurement

VHP101 40K resistor is also part of the DCI/current measurement circuit, which are also could be improved.

Resistors used as current sense elements are

RefDes	Type	Resistance value	TC, ppm/°C
R206	BMF	500 KΩ	10
R207	Foil **VPG VHP101**	40.00 KΩ	±0.3, typical
R208	BMF	4.53 KΩ	5
R209	BMF	634 Ω	10
R210	BMF	90 Ω	10
R211	BMF	9 Ω	10

R212	Custom?	1 Ω , 2W	50
R	Custom?	0.1 Ω	5

Other accessory for meter

Rackmount kit is available from vendor under **P/N 3458A-909** for $110 USD.

Calibration

Repair of instrument is one thing, but how do we know if it's meets specifications? Well, we don't, unless we test known standards/voltages and compare readings from meter to actual values. If reading not match actual value more than specification limits, meter need adjustment. Process of comparison measurements to known value (either it need adjustment or not) is called calibration.

Now, that's where really difficult part comes. Calibration of let's say, 4½-digit meter to 10.000 VDC reading is relatively easy, as getting this voltage down to 4th digit is possible without much trouble using shelf parts. Signal must stay constant during whole calibration timeframe (it's not long, but not seconds either). Also you want to have signal be at least few times more stable, so you will not run on edge during adjustment/calibration. Now, since we want 8 digits, this means we must have stable signal 10.0000000 VDC, down to <100 nanovolts! Also it's also must be known value. Today's voltage standard is delivered from quantum standard, JJA, operated at liquid helium temperatures. Very few lab's have such stable known-value sources, suitable for calibration 8.5-digit instrument like 3458A. Some useful information about calibration procedure can be found **here**.

Since at this moment I don't have ability and need to get best calibration for our unit, I'll just use artifact calibration to 10V/10KΩ sources, measured by Keithley 2002, calibrated back in 2007. In future, after confirming proper operation and no long-term issues with my 3458A, I'll likely to send it for calibration.

Details on calibration **to be done**.

There is a way to read internal voltage and resistance references by issuing next commands:

Command	Result before cal	Result after cal and A9 tweak	Meaning
CAL? 1,0	40.0000000E03		default value
CAL? 1,1	39.9995999E03	39.99987145 E03	actual value = cal value
CAL? 1,0	40.0800000E03		max. actual value
CAL? 1,0	39.9200000E03		min. actual value
CAL? 2,0	7.20000000E00		default value
CAL? 2,1	7.07422543E00	7.06747856 E0	actual value = cal value
CAL? 2,0	7.50000000E00		max. actual value
CAL? 2,0	7.00000000E00		min. actual value

Performance verification

To be done. Measurements with voltage references, foil resistors, ESI decade, frequency, period, currents, temperature, RTD

Restoration summary

Item	Cost	Shipping	Supplier
Dead rusty HP 3458A	750$	190$	eBay
Transformer HP 9100-4715	337$	N/A	Keysight

Key cap HP 03458-40214	12.12$	N/a	Keysight
Key cap HP 03458-40215	12.12$	n/a	Keysight
Pushrod on/off front/rear 03458-43701	16.42$	n/a	Keysight
Fuse holder 03458-67912	51.63$	n/a	Keysight
Foot 5041-8167	46.36$	n/a	Keysight
Shadow switch 3101-2969	55.12$	n/a	Keysight
Tax and shipping	34.21$	73.30$	Keysight
Reference A9 board 03458-66509	132.4$	9.3$	eBay
50pcs IN5365B zener	6.06$	Free	eBay
HP Rear Bezel 03458-47901	21.45$	26.5$	eBay
DS1220Y-200+ NVRAM	11.51$	7.4$	eBay
5pcs DS1230Y-200 NVRAM	22.32$	7.06$	eBay
A3 A/D board, 3458-66503	Priceless	N/A	;)

Also some generic parts were ordered from DigiKey store, such as DC fan, capacitors for A6 board, suspect resistor arrays for logic on DC board and new IEC connector mains filter. Here's order list (there were some other parts for other projects, not shown here, to make up for >100$ bill, as then it's eligible for free shipping to Taiwan :).

Index	Quantity	Part Number	Description	Available Quantity	Unit Price USD	Extended Price USD
1	1	P14736-ND	FAN AXIAL 60X25MM 12VDC WIRE	1	9.59000	9.59
2	1	565-1846-ND	CAP ALUM 680UF 20% 50V RADIAL	2	1.23000	2.46
3	10	565-1546-ND	CAP ALUM 220UF 20% 25V RADIAL	10	0.28500	2.85
4	10	495-6008-ND	CAP ALUM 330UF 20% 35V RADIAL	10	0.76100	7.61
5	10	1189-2353-ND	CAP ALUM 47UF 20% 63V RADIAL	10	0.33500	3.35
6	2	493-8635-ND	CAP ALUM 8200UF 20% 35V SNAP	2	4.06000	8.12
7	10	4308R-1-104-ND	RES ARRAY 7 RES 100K OHM 8SIP	10	0.76000	7.60
8	10	4308R-1-224LF-ND	RES ARRAY 7 RES 220K OHM 8SIP	10	0.76000	7.60
9	1	603-1155-ND	FILTER IEC CONNECTOR 115/250VAC	1	6.61000	6.61

Second order for DigiKey:

5	ISL55141IVZ-ND	IC COMP CMOS HS 18V 14-TSSOP	2.92000	14.60
10	296-2069-5-ND	IC BUS REGISTER 8STAGE 16-DIP	0.42600	4.26
10	296-26002-5-ND	IC 8STG SHFT/STOR BUS REG 16DIP	0.47700	4.77
10	LM339ANFS-ND	IC COMPARATOR QUAD 14-DIP	0.40200	4.02

10	LM393AN-ND	IC COMPRTR DUAL 0-70DEG C 8-DIP	0.34100	3.41
10	296-36143-5-ND	IC HEX INVERTER HEX SCHM 14-DIP	0.59000	5.90
3	516-2043-ND	XMITTER FIBER OPTIC 600NM 5MBD	12.48000	37.44
2	516-2062-ND	RECEIVER FIBER OPTIC 600NM 5MBD	12.48000	24.96
10	568-7933-1-ND	DIODE ZENER 3V 400MW ALF2	0.19200	1.92
20	568-5885-1-ND	DIODE ZENER 12V 500MW ALF2	0.18300	3.66
3	399-4433-ND	CAP CER 2.2UF 50V X7R RADIAL	3.24000	9.72

Total repair cost in parts as for today: **$1212.64 USD**

9/15/2015	Received unit, initial teardown	1 hour
9/17/2015	Repair evaluation, testing Outguard boards and PSU, won A9 reference on eBay	3 hours
9/24/2015	Replaced C11,CR12 zeners on A4 board, tested board, Keysight parts order shipped	4 hours
9/26/2015	Removed DS1220 from A5 board, installed collet socket, installed new DS1220	1 hour
9/26/2015	Ordered caps and new DC fan from DigiKey	1 hour
9/28/2015	Cleaning steel chassis from rust, clean front panel	2 hours
9/29/2015	Cleaning outside instrument covers, inner frame steel bar	2 hours
10/1/2015	Received A9 VREF PCBA, tested standalone with Keithley SMU+DMM	2 hours
10/4/2015	Replaced GPIB connector on A5, removed caps on A6, finished chassis cleaning	3 hours
10/5/2015	Received parts, bought few more capacitors	2 hours
10/6/2015	Test assemble unit, debug **ISOLATOR FAILURE** error	8 hours
10/7/2015	Capture logic diagrams around A5.U700, narrow down isolator failure on A3 PCBA	4 hours
10/8/2015	Fixed optical link, got first measurements out of unit	6 hours
10/10/2015	Debug attempts on A3 board for 114 convergence error	3 hours
10/11/2015	Debug attempts on A3 board for 114 convergence error	12 hours
10/14/2015	Debug attempts on A3 board for 114 convergence error	6 hours
10/18/2015	Debug attempts on for 114 convergence error	6 hours
10/20/2015	Debug attempts for multislope convergence error, measurements on A1	5 hours
10/24/2015	Debug attempts for multislope convergence error, measurements on A3	6 hours
11/4/2015	Replaced A3 A/D board, Error 114 fixed	0.5 hours
11/4/2015	Error LEVEL DAC CONVERGENCE fixed by U504 replacement	0.5 hours
	Taking photos, writing up article sections and posts	33 hours

Total time spent on this project around **111 hours**, give or take few. Was it worth doing? That's up to you, so please leave your comments, so I can do more stuff like this.

Equipment used during restoration project:

- Soldering gear, **ERSA I-CON station**
- **MiniPro TL866CS** programmer to read/write ROMs/RAMs
- Tektronix TLA714 with **TLA7AA4** and P6810 to capture signals and debug
- Tektronix **CSA7404**
- **Keithley 2001 DMM** (calibration 02/2014)
- **Keithley 2002 DMM** (calibration 2007)
- **Keithley 2400 SMU** (calibration 05/2015)
- **HP 3245A**
- ±30 ppm/K **EDC MV106 DC voltage standard** (calibrated 02/2014 from K2001)
- **ESI DB52 resistance decade** to test OHM operation
- Set of Vishay foil resistors for resistance artifact calibration
- **Nikon D3** for timelapse shooting
- Nikon D800 with 28-70/2.8D, Sigma 150/2.8 Macro, 35/1.8G DX lenses, tripod
- 1L of IPA and alcohol to clean chassis and parts
- **Google** – used lots of it!

Also my appreciation goes to **Todd**, **Dr.Frank**, **plesa** and **all EEVBlog members**, who provided great support and suggestion. None of this would happen without great volt-nut community all over the globe. May the Volt be with you. One more dream (of having 3458A) come to life.

Other related documents

Security, Reliability and Backdoors – Interesting security analysis, covering HP 3458A.
OldSchoolTechCorner's 3458A photos from EEVBlog forum

Remote control examples and software

Raspberry Pi + Python GPIB

HP3458 uses "ID?" instead of "*IDN?" to return ID string.

http://www.keysight.com/owc_discussions/thread.jspa?threadID=35498&tstart=60
http://www.keysight.com/owc_discussions/thread.jspa?threadID=32613&tstart=120
http://www.keysight.com/owc_discussions/thread.jspa?threadID=32612&tstart=120
http://www.keysight.com/owc_discussions/thread.jspa?threadID=32597&tstart=135
http://www.keysight.com/owc_discussions/thread.jspa?threadID=32589&tstart=135
http://www.keysight.com/owc_discussions/thread.jspa?threadID=32588&tstart=135

LabView

Author: Illya Tsemenko

Published: Sept. 15, 2015, 7:37 p.m.

Modified: Nov. 4, 2015, 12:41 p.m.

References

1. Geller Labs: The HP 3458A DMM
2. Keysight product page : 3458A Digital Multimeter, 8½ Digit
3. Linear : LTZ1000 Ultra-stable reference
4. HP/Agilent message group
5. EEVBlog forum : Repair log, Old rusty HP 3458A
6. Brooke Clarke's repair 3458A article
7. Ultra Precise Voltage Reference based on A9 PCBA project

8. DC Voltage references solutions
9. Radiokot forum : Ремонт ржавого HP 3458A
10. EEVBlog : HP3458A Schaffner mains line filter failure
11. Wiki : Josephson effect use as SI voltage standard
12. HP 3245A Universal source article
13. Share 0

Comments