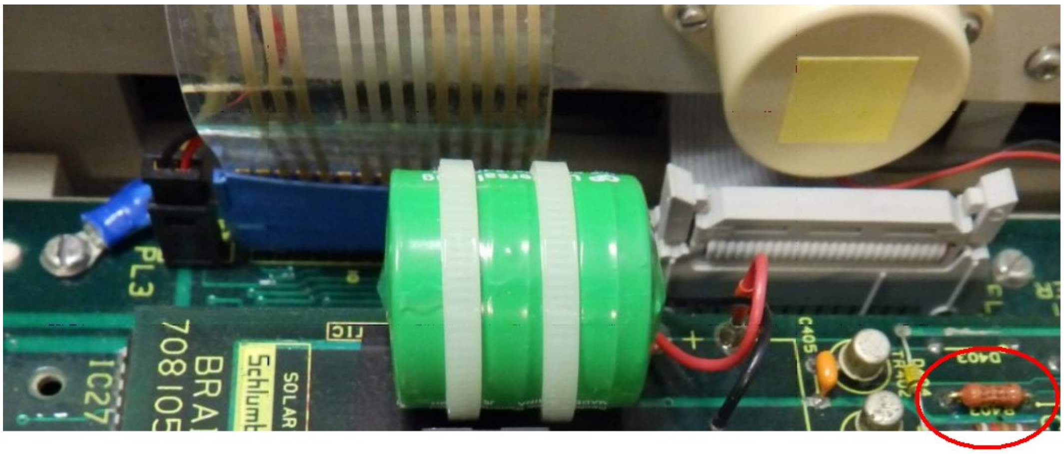
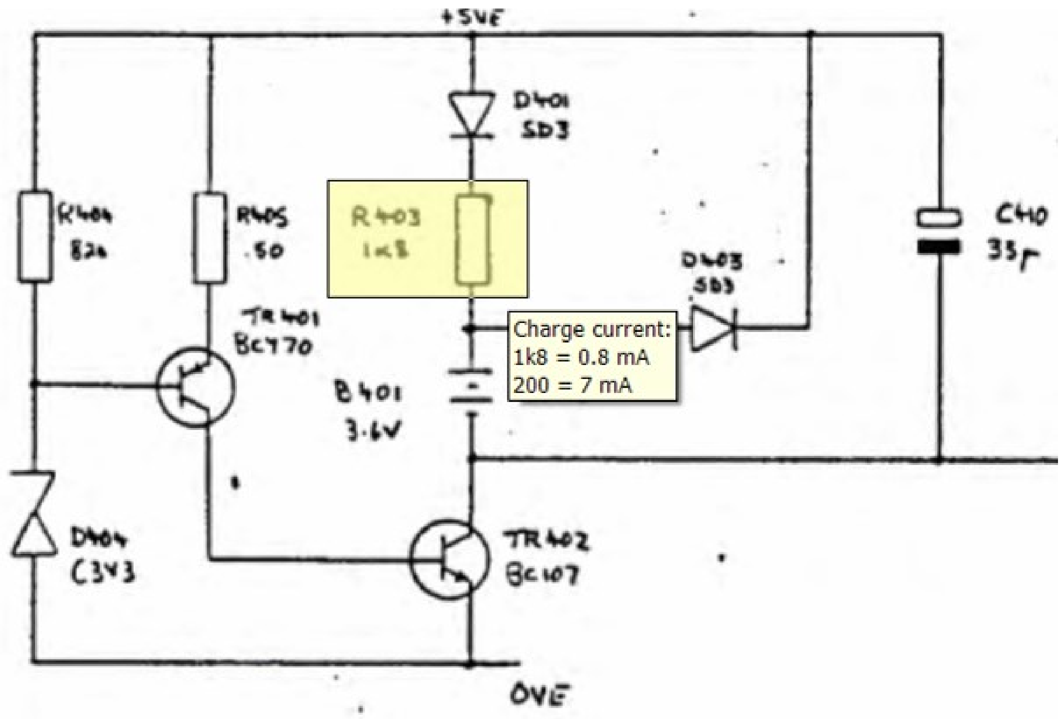
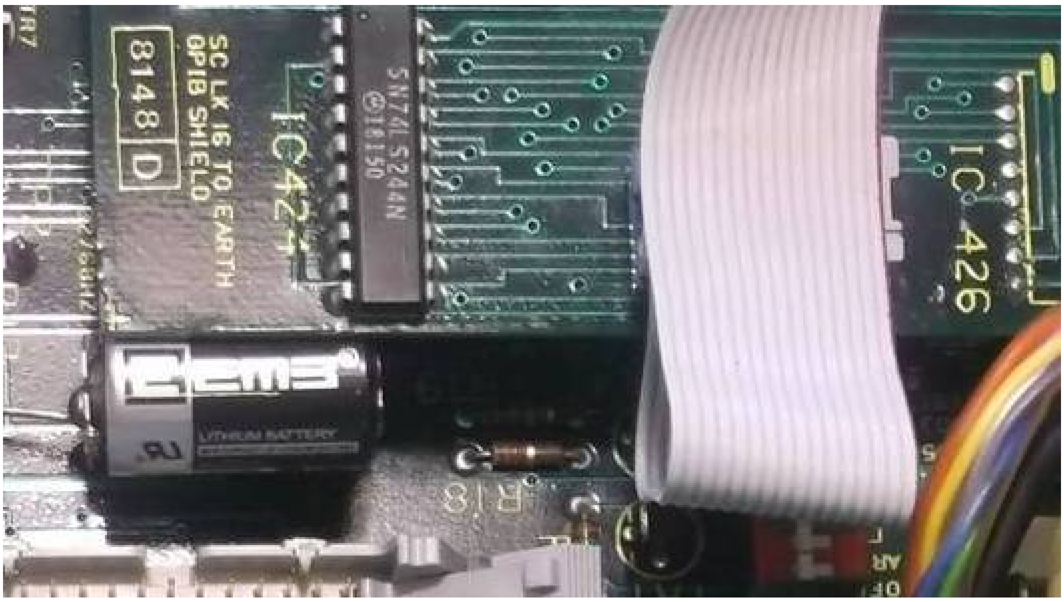
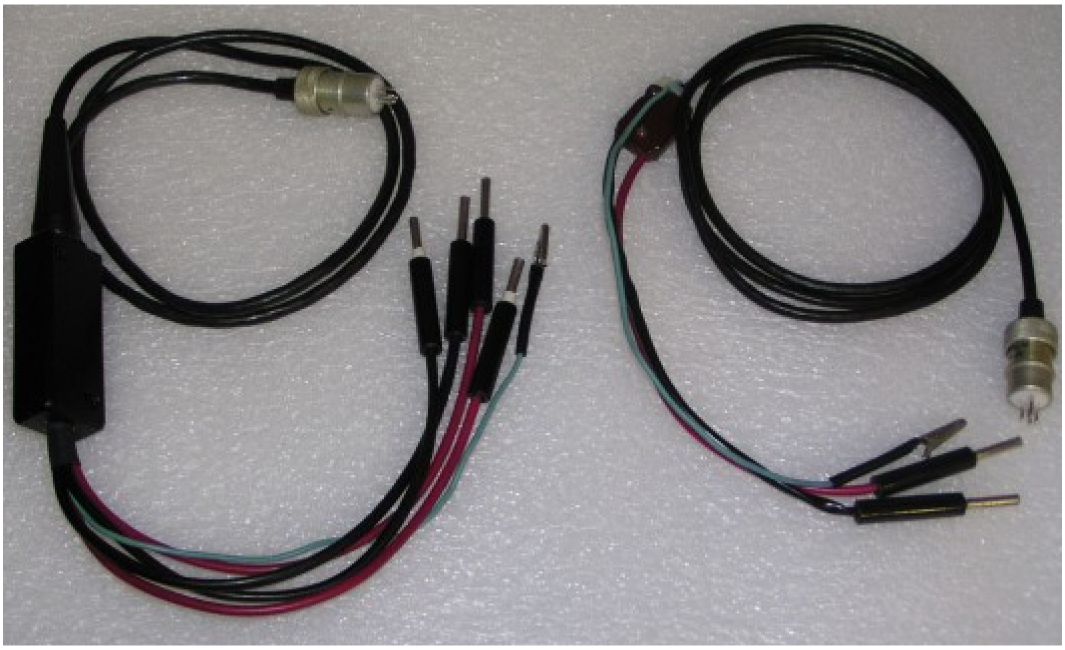
09/2011 The failed NiMH battery backup supply for the SRAM on the earthy logic board was replaced. The charge current for the new, higher capacity battery was increased to 7mA from 0.8mA by changing R403 from 1.8kΩ to 200Ω. The RTC battery was also replaced. The boards and connectors were cleaned of corrosion marks.

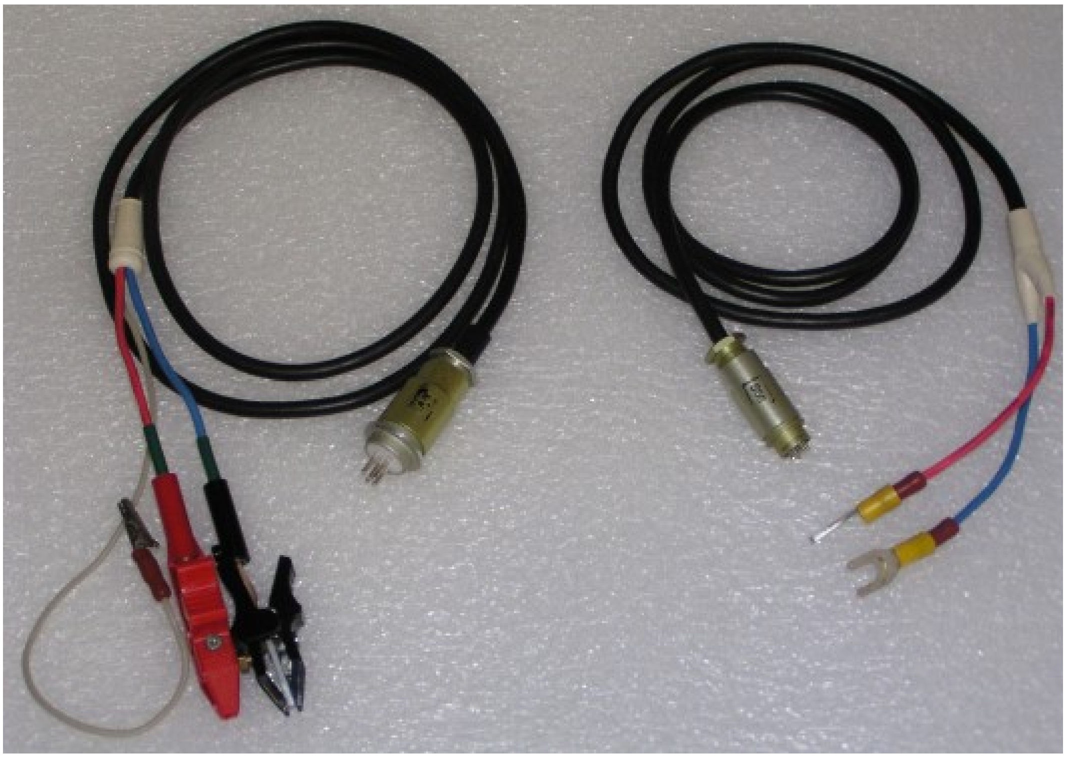




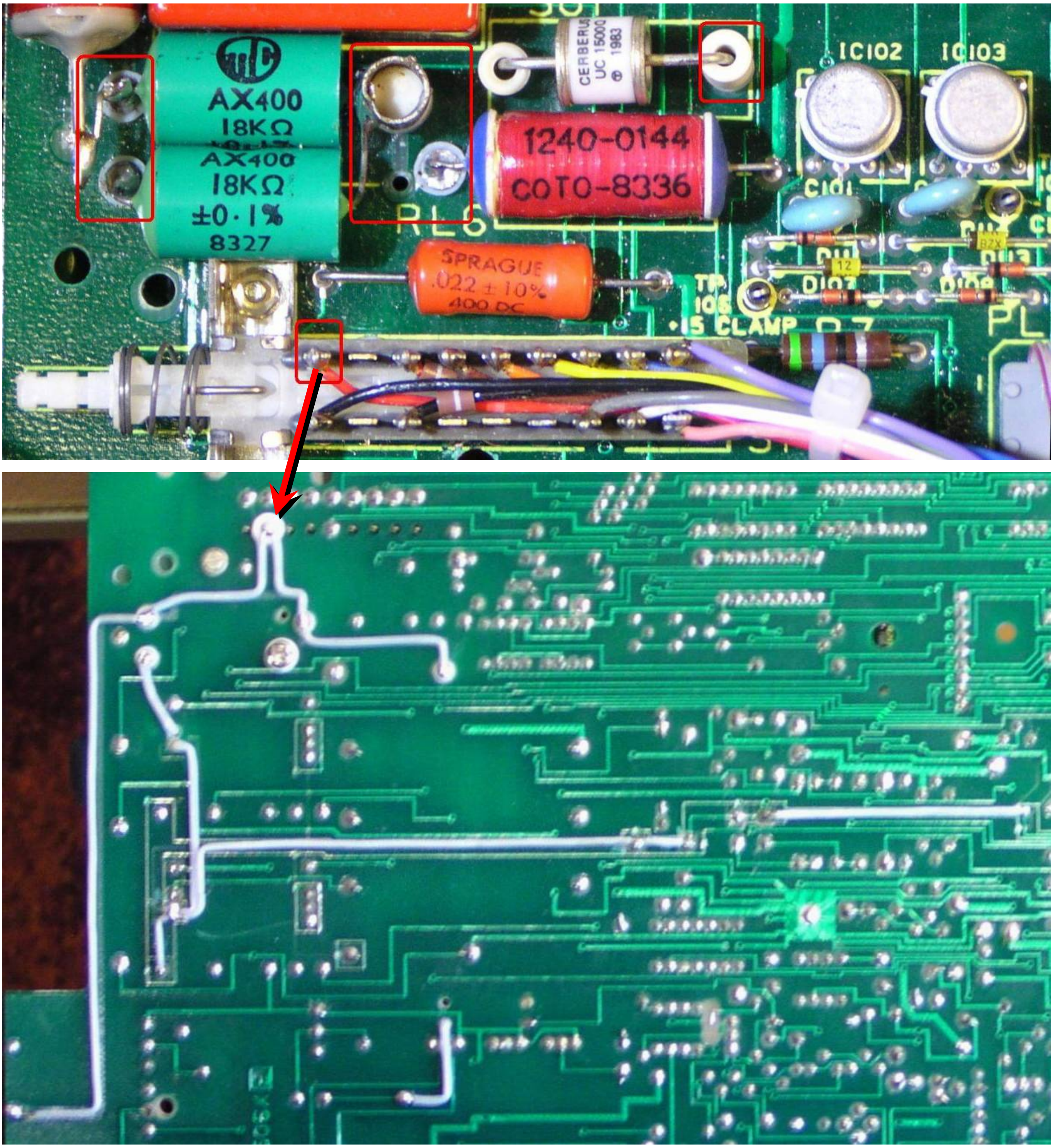


09.2011 A set of shielded cables was made.

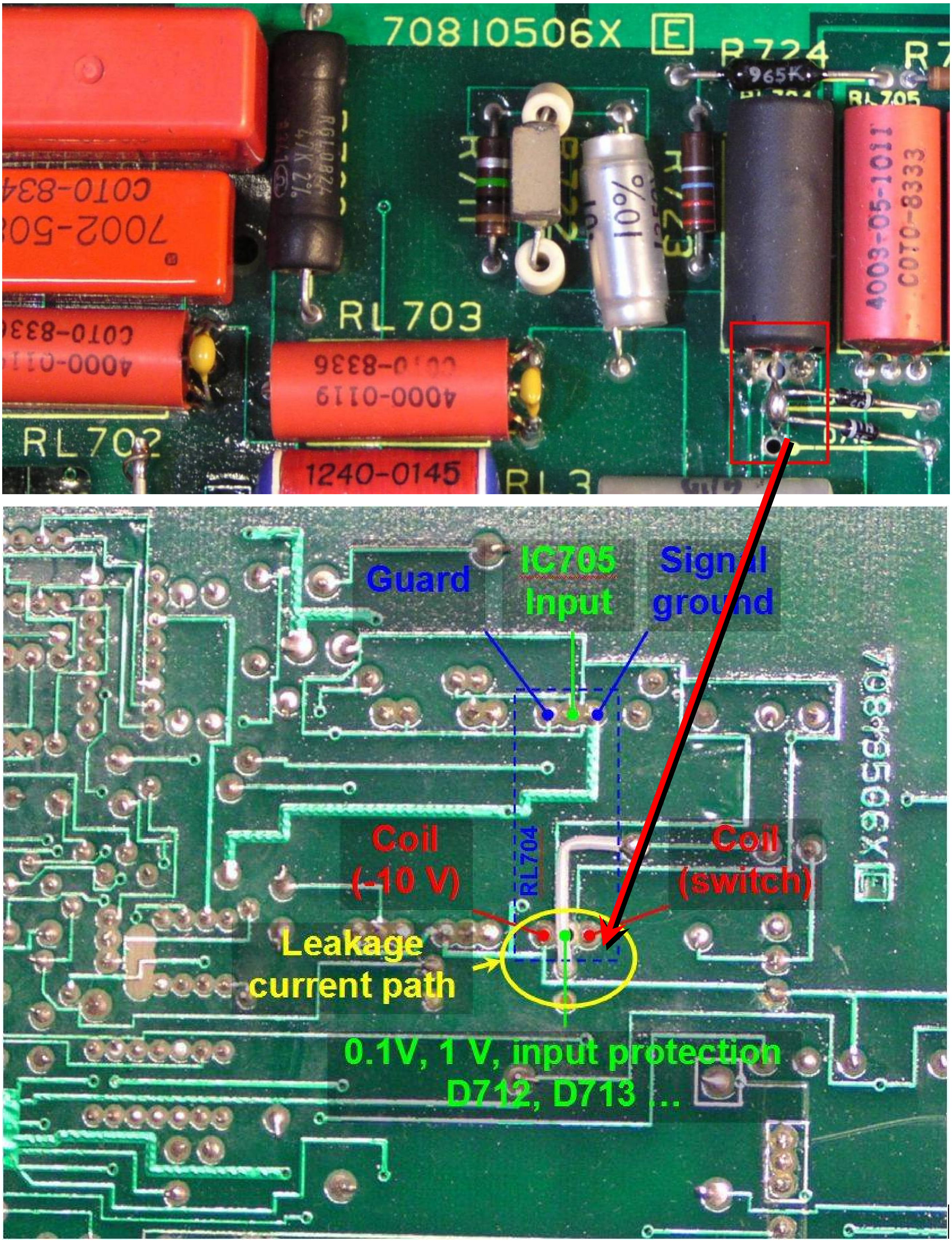




09/2011 Elements of the input circuit for the DCV channel were changed to use point to point PTFE wiring connected to PTFE pass-thru insulators to reduce the leakage current.



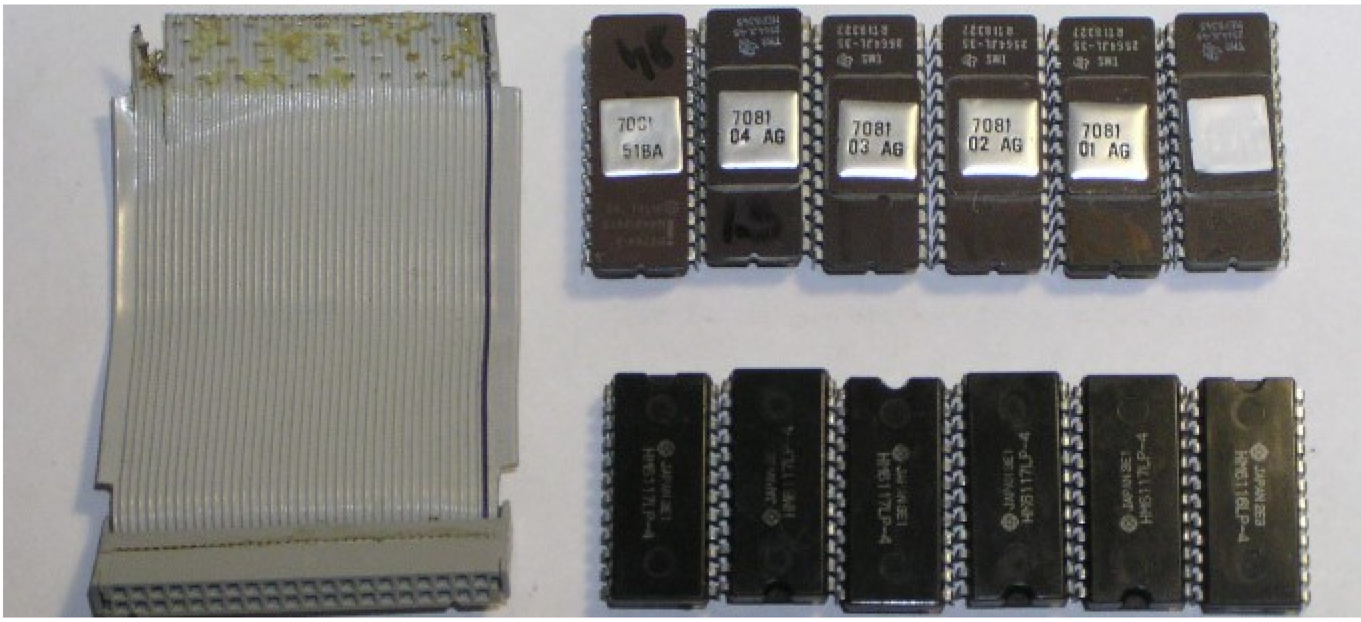
09/2011 The input high-impedance part of ACV channel circuits was partly changed to use point to point PTFE wiring connected to PTFE pass-thru insulators to reduce the zero-drift as the meter warmed up. Relay contact RL704 channel ACV was isolated from the PCB to reduce leakage and reduce zero drift. Blocking capacitors not present in this revision are added to the windings of relays RL702 and RL703.

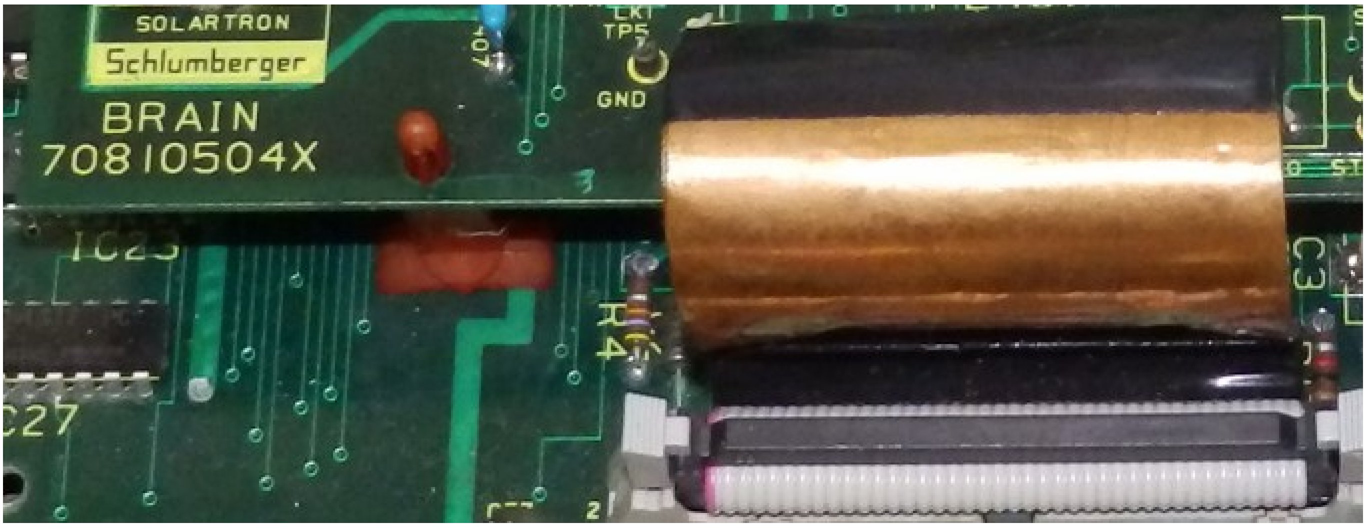


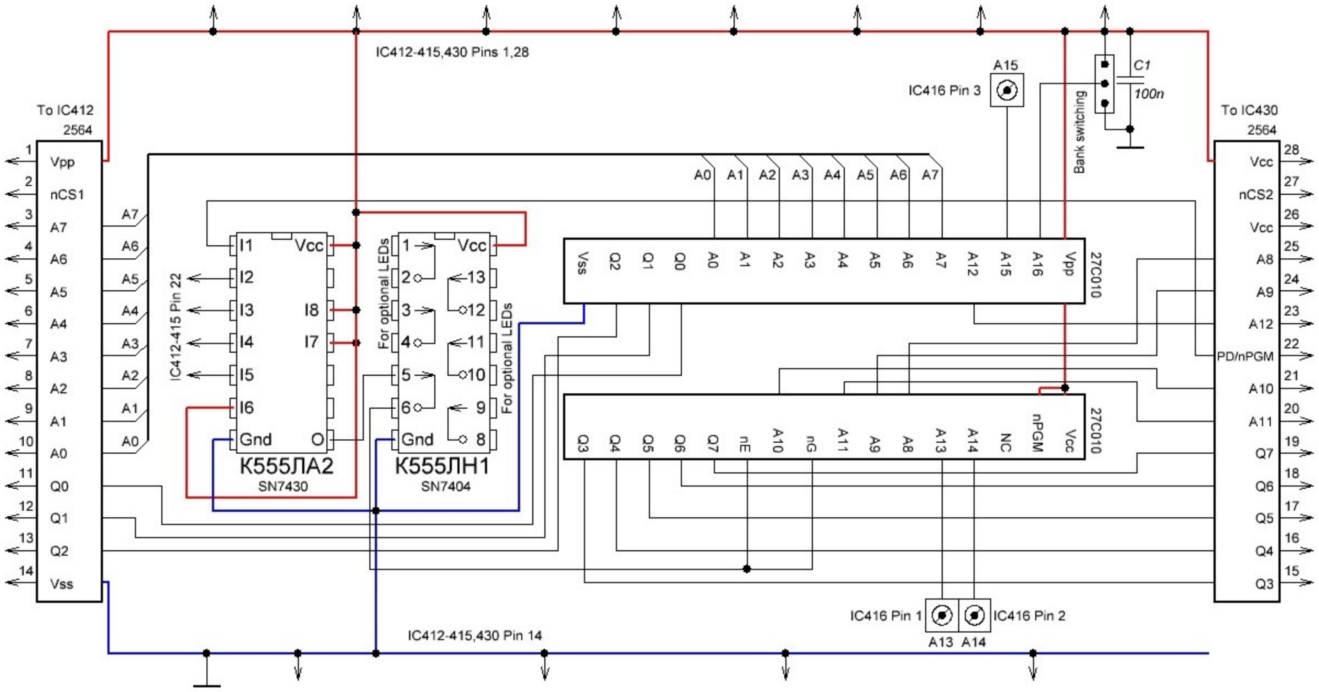
09/2011 A zero-balancing resistor was added to the IC403 Tracking Amplifier op-amp to decrease the bias voltage[1]. The four op-amps on the PCB 6 board were fitted with heat-sinks.

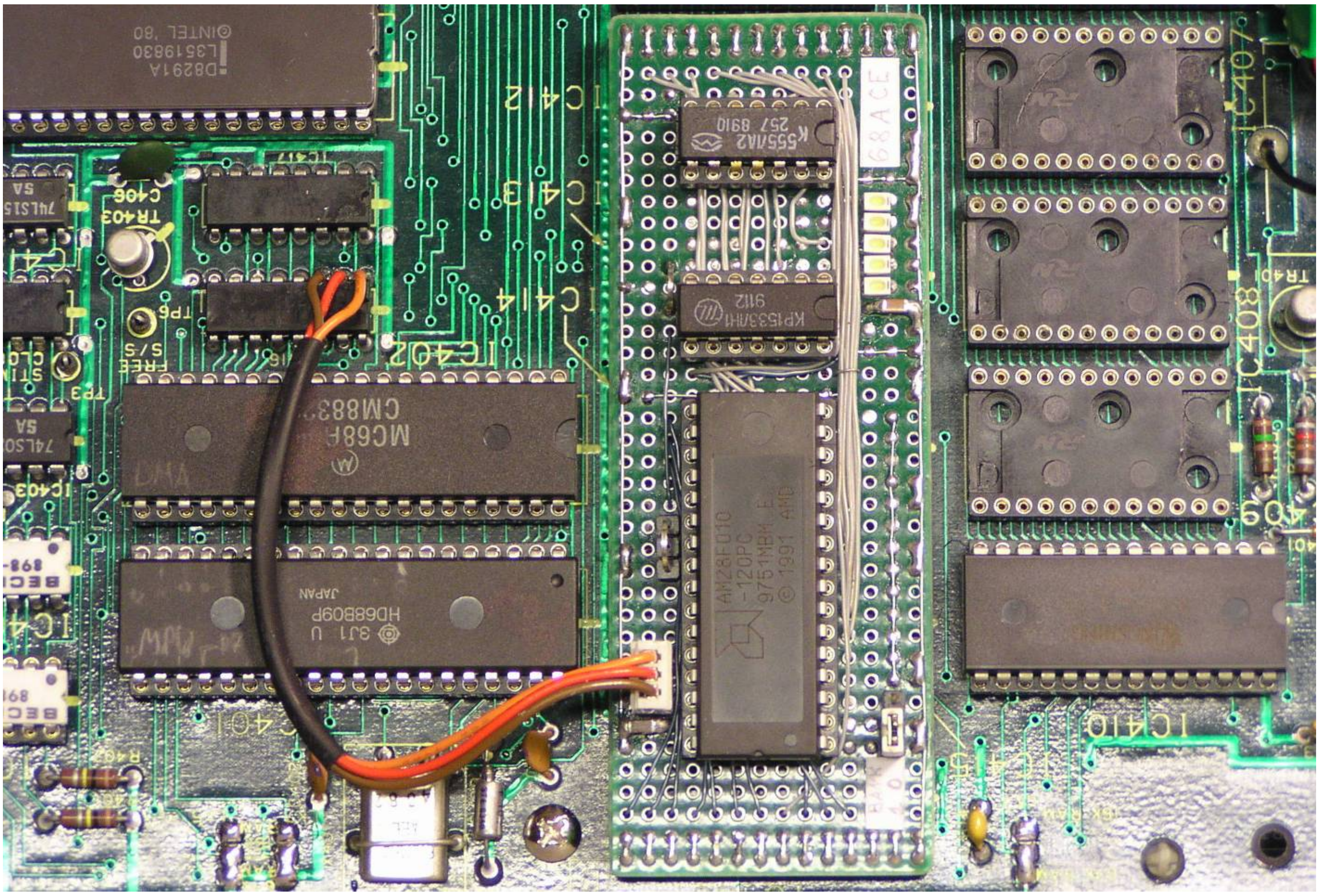
[1] Probably better to connect a 100kΩ trimmer between pins 1 and 5 with the wiper to pin 4, allowing adjustable zero offset compensation.

11/2011 The faulty ribbon cable to the Earthy Processor board was replaced with a home-made shielded cable. Replaced 6 6416 SRAMs with two 6464. Instead of the 5 2764 ROM ICs I installed a 28F010 flash ROM on a mezzanine board with jumpers to allow a choice between software levels. The 2764 EPROM on the Floating Logic board was replaced with a 28C64. All firmware was updated to the latest level.

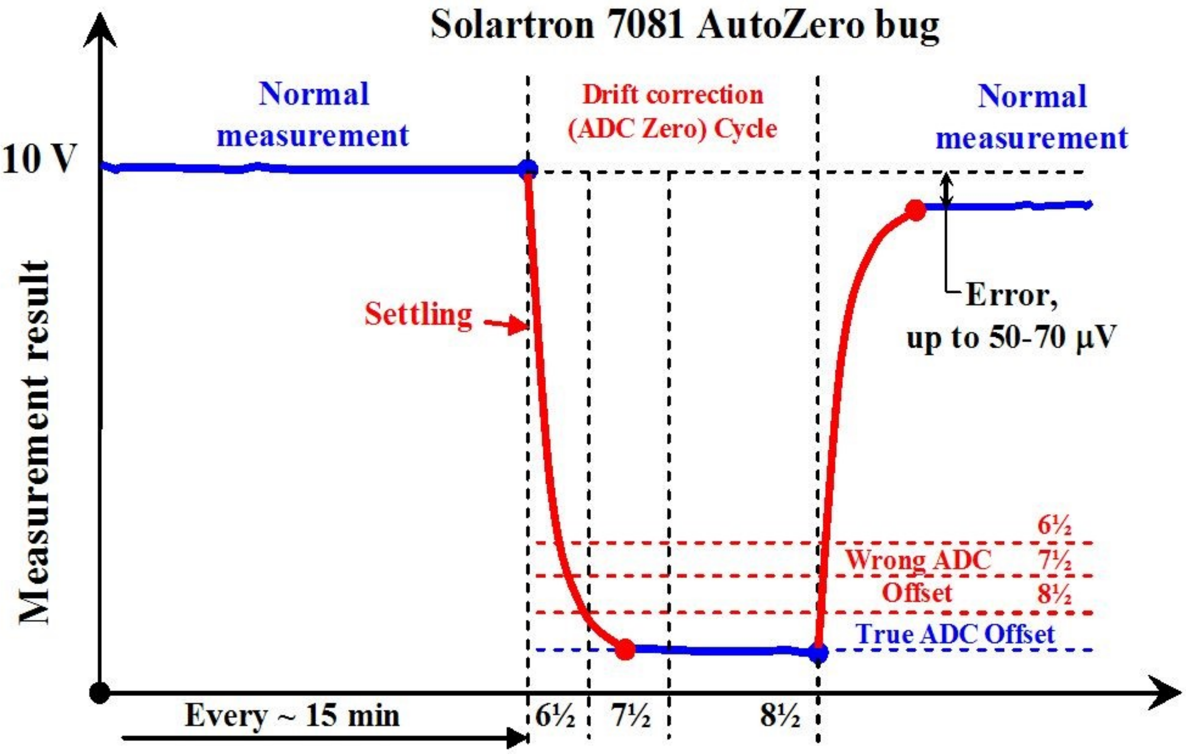




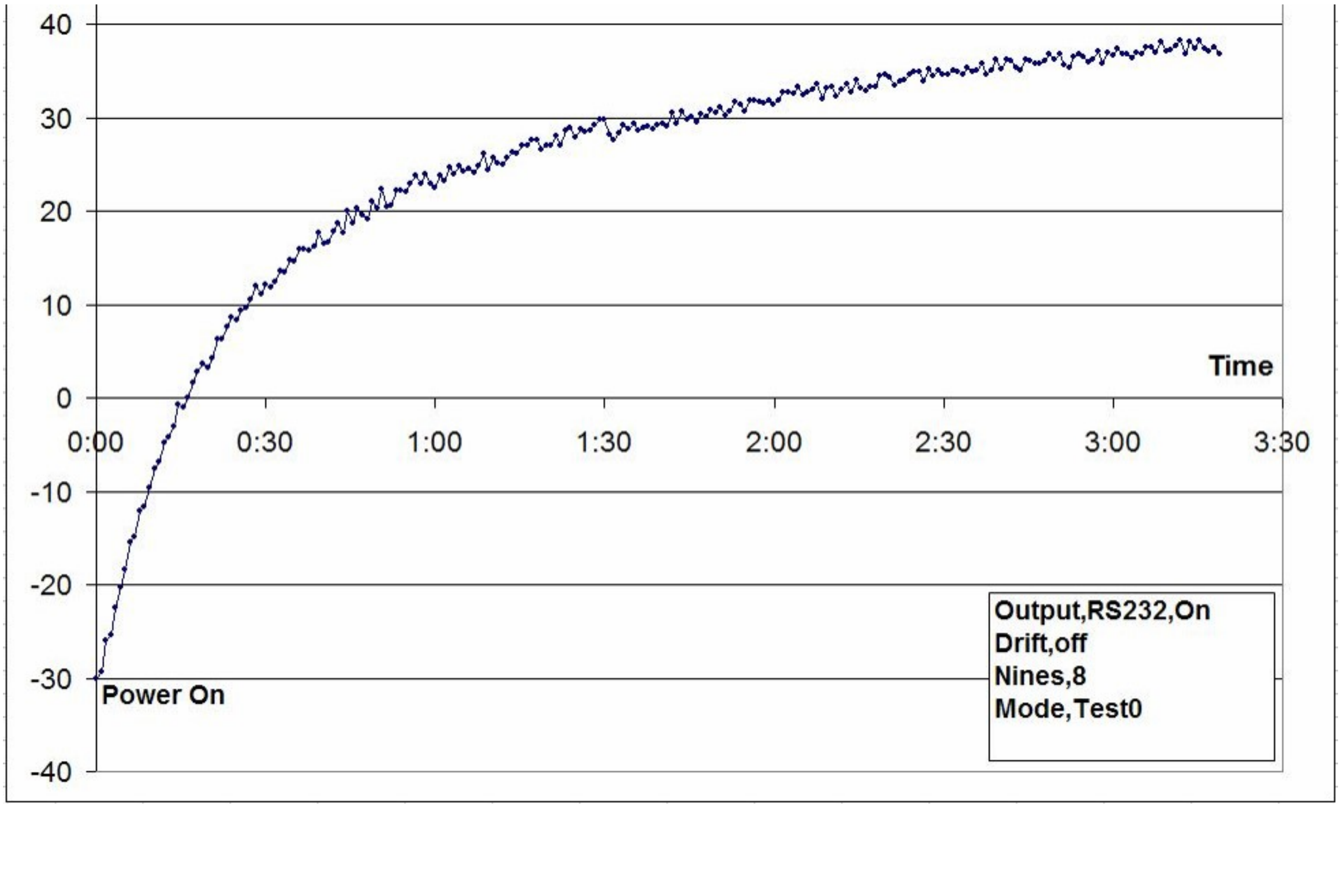




11/2011 I A problem with the automatic zero offset correction was discovered which was dependent on the input voltage. This problem arises because of the finite settling time when the Auto-Zero correction logic switches the ADC multiplexer between the inputl signal and zero volts. To solve the problem, the software in the Floating CPU was disassembled, maps of memory allocation and I/O ports were compiled, and the algorithms of two finite automata were established. Using a logic analyser, the structure and timings of the inter-processor messaging system were determined, and the way the messages were encoded were determined. In the Floating CPU firmware Test_Zero_Patch procedure was added, which provides an additional delay for the transients during the automatic zero correction of the ADC. Although the problem did not completely disappear, the zero-offset error became several times smaller

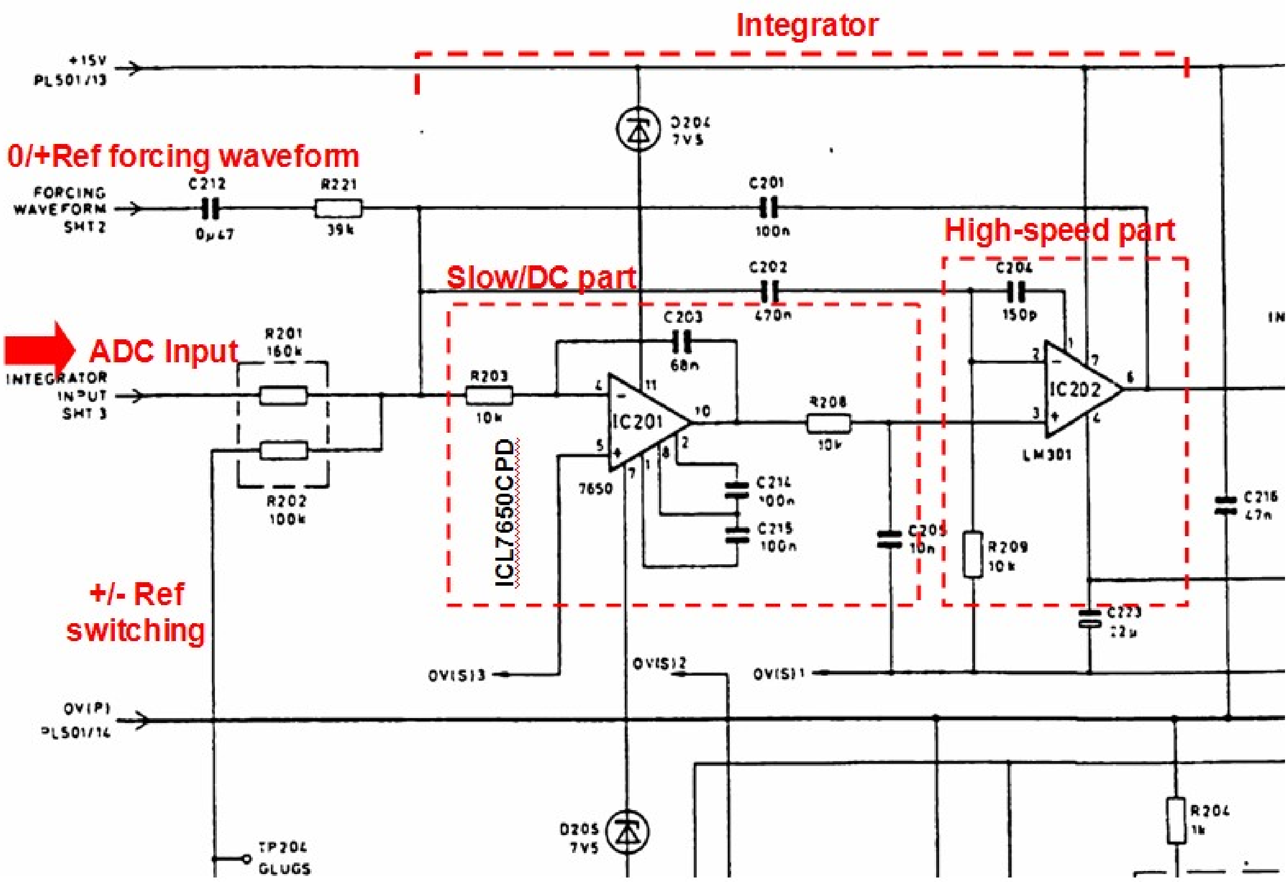


01/2012 A problem of a large zero offset drift was found in the instrument readings as the instrument warmed up from a cold start with a shorted input to the ADC.



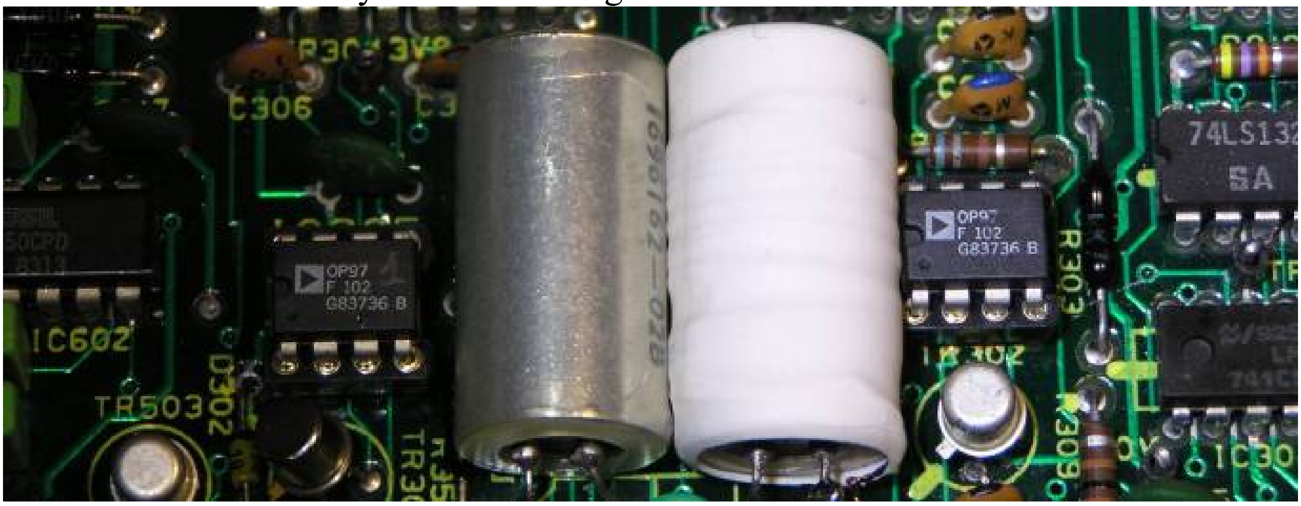
The search for a source of bias led to the following possible reasons:

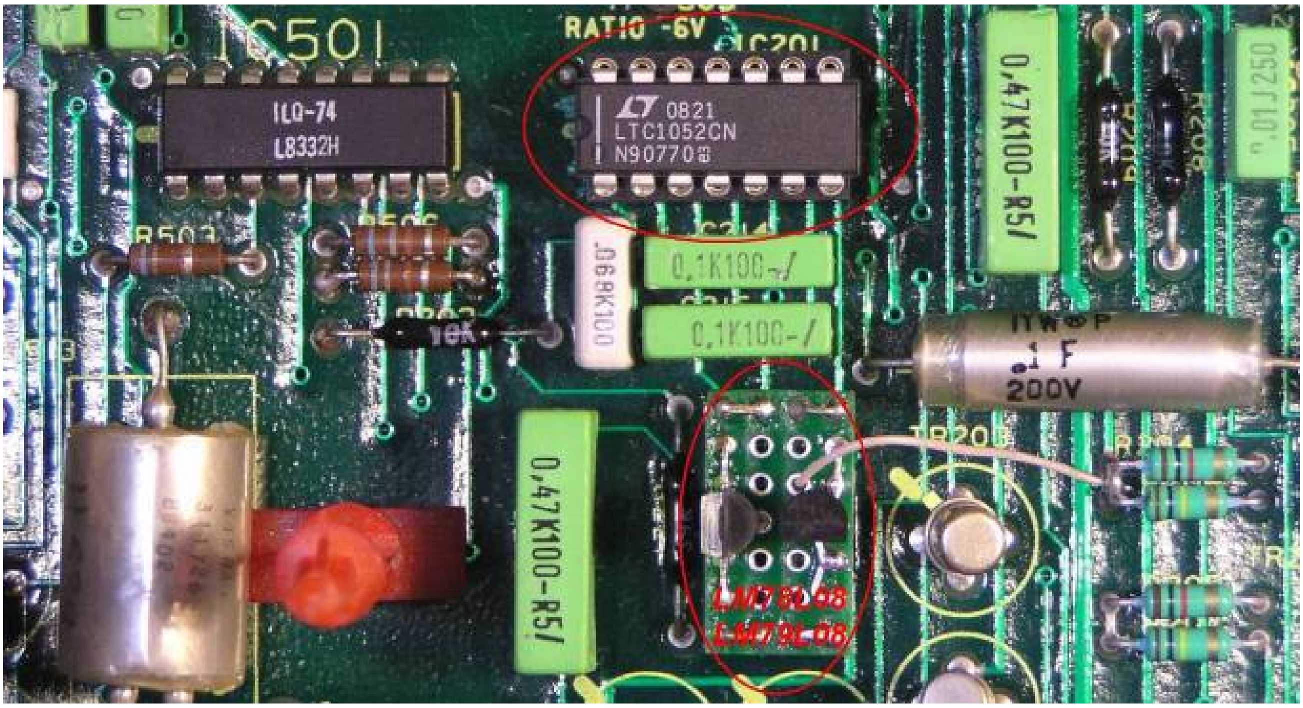
a) IC201 (ICL7650CPD) in the low-pass channel of the ADC integrator,
b) Dual resistor R305 10 + 10 kOhm in the reference circuit,
c) Op-amps IC305 and IC306 (OP07EZ) in the reference circuit, and
d) Transistor TR302 in the negative voltage reference.



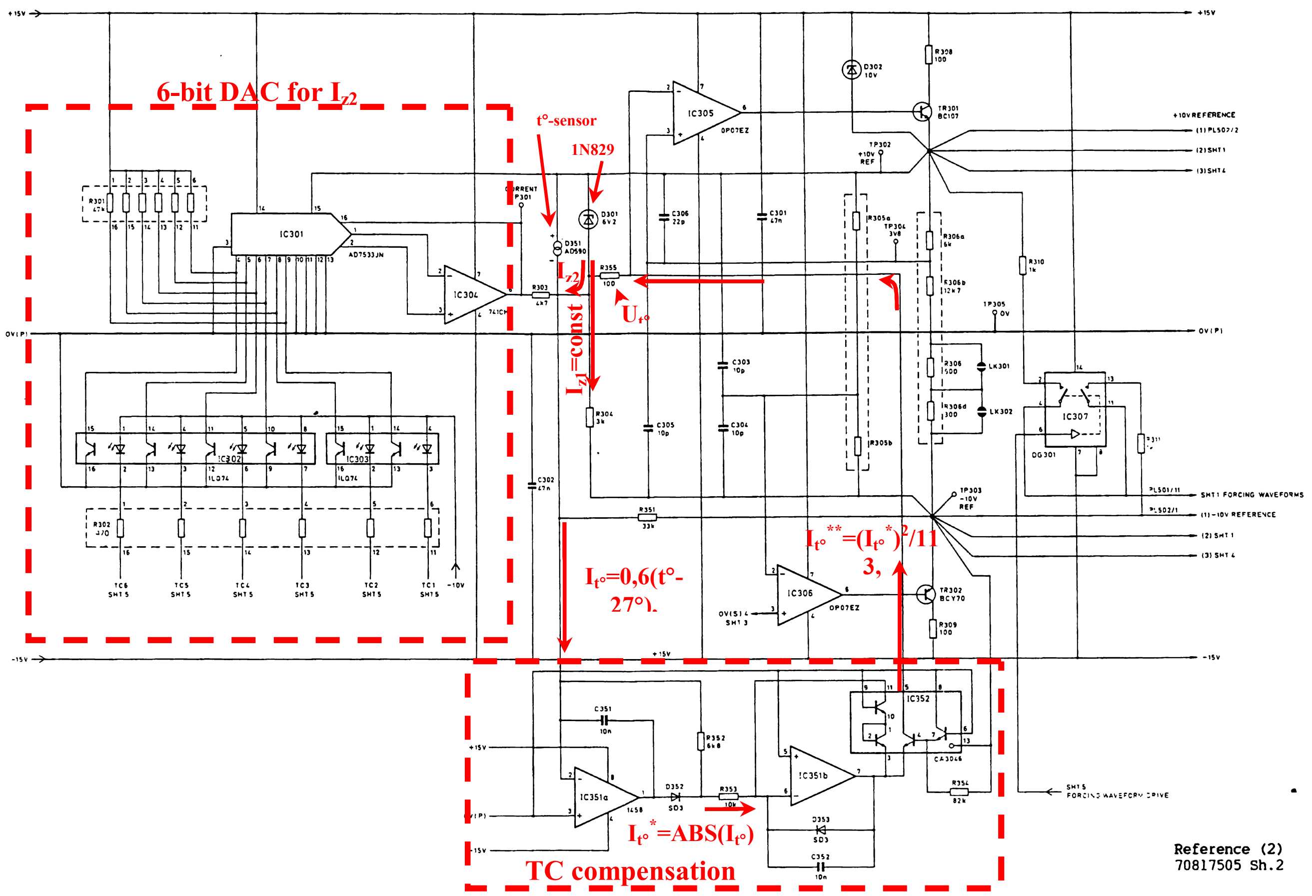
Op-amps IC305 and IC306 (OP07EZ) were replaced with OP97F in sockets. Op-amp IC201 (ICL7650CPD) was removed, and temporarily replaced with an LTC1052CN. The Zener diodes in the power circuits of Op-Amp IC201 were replaced by linear regulators LM78L08 and LM79L08 with smoothing capacitors. R305 was removed and the TCR for each half was measured. They were found to be different. This was adjusted by bifilar winding 0.99 m of 0.25 mm diameter copper (measured resistance 0.43 Ohms) over the case of R305 and connecting it in series with the lower end of R305b.

The drift was reduced by an order of magnitude.



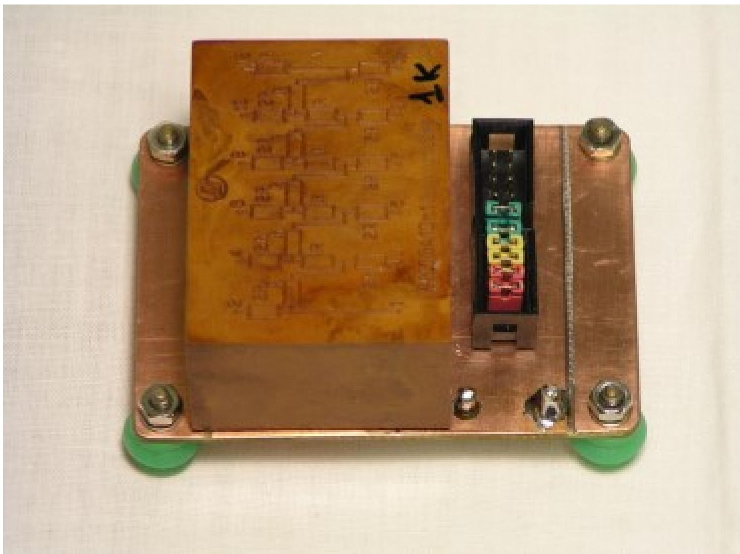


02/2012 A problem with the parabolic temperature compensation of the reference Zener diode was identified

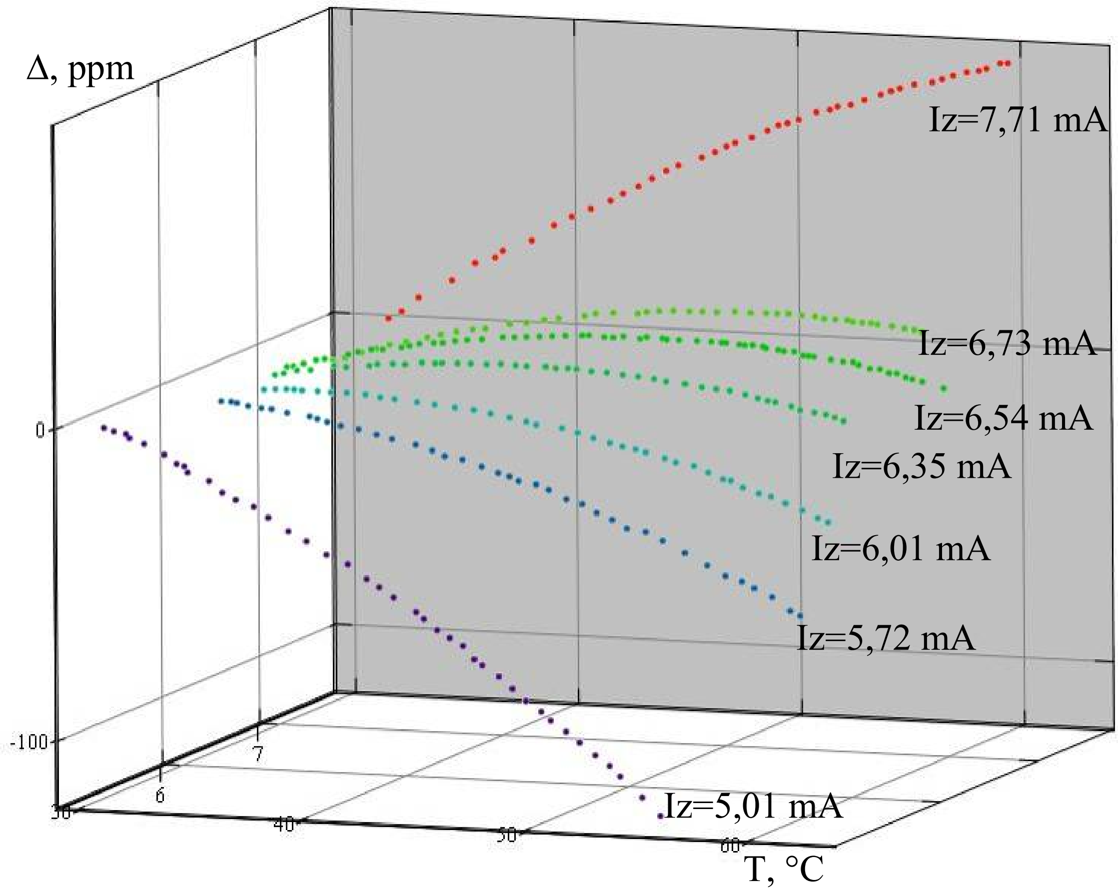


The reference Zener D301 (1N829A), temperature sensor D351 (AD590), compensation resistors R351 and R354 (which set the intercept and slope of the compensation curve) were removed. The actual resistance of the resistors R351 and R354 were measured.

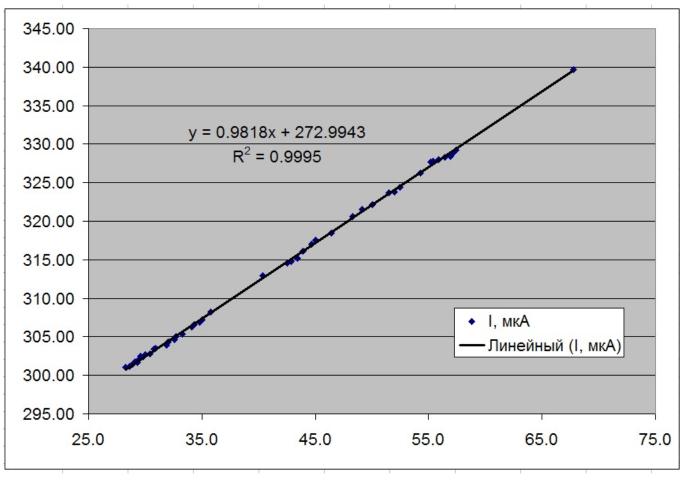
An experimental setup was assembled from a thermostatically controlled oven, a 10 V reference based on an LTZ1000 and precision resistance box based on the precision wire-wound voltage divider DND5A10-1. The temperature drift of the Zener voltage of D301 was measured at various operating currents.

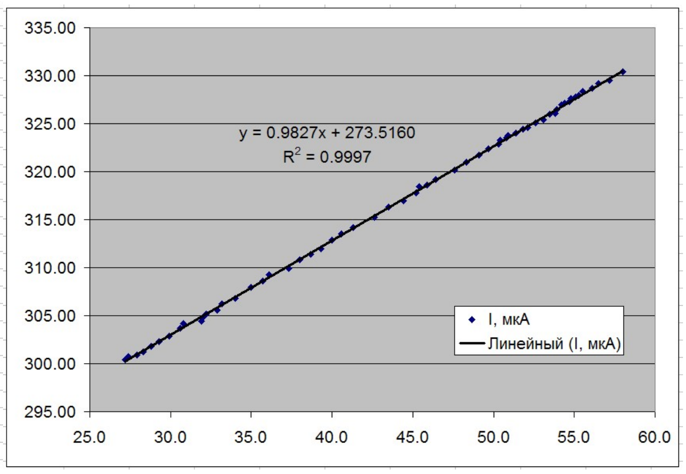


Zener diode D301 characteristics



03/2012 A new AD590 temperature sensor was purchased. Measured parameters transfer function of the new sensor as compared to the regular temperature sensor D351.





Using the contour current method, a mathematical model was derived of the parabolic temperature compensation as a function of the correction current (voltage) from the set point of the DAC, the Zener diode, the AD590 sensor, the values of resistors R303, R304, and R351-R355, and the multiplier.

$Uz := 6.14$ $U10 := 10$ $R304 := 3000$ $R303 := 4700$

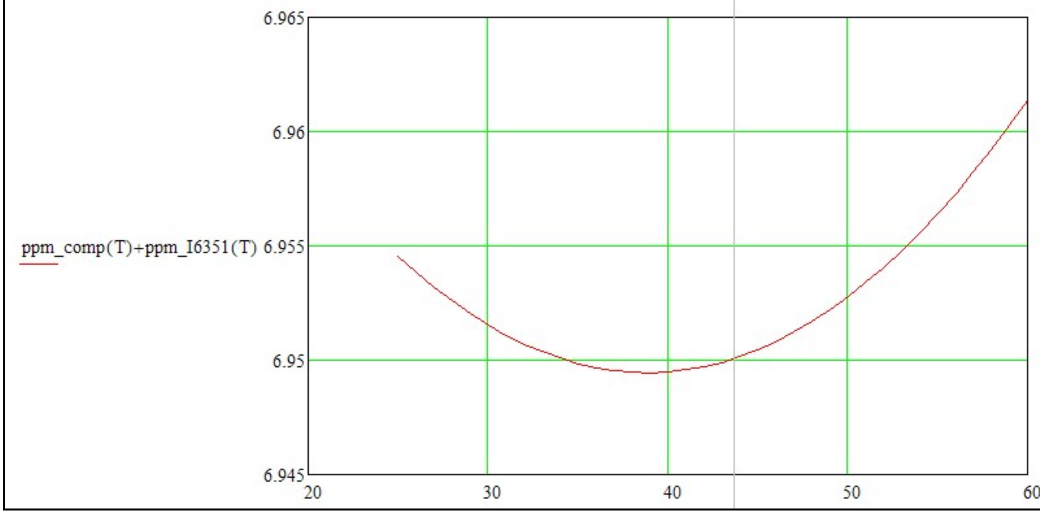
$R355 := 100$ $R351 := 31588$ $R352 := 6800$ $R353 := 10000$ $R354 := 77200$ $R355 := 100$

$$Iz(token) := \frac{2 \cdot U10 - Uz}{R304} + \frac{1}{R303} \cdot \left[U10 - Uz + \frac{U10}{64} \cdot (token - 64) \right] \qquad Iz(76) = 5.84 \times 10^{-3}$$

$$AD590(T) := 1 \cdot 10^{-6} \cdot (273.2 + T)$$

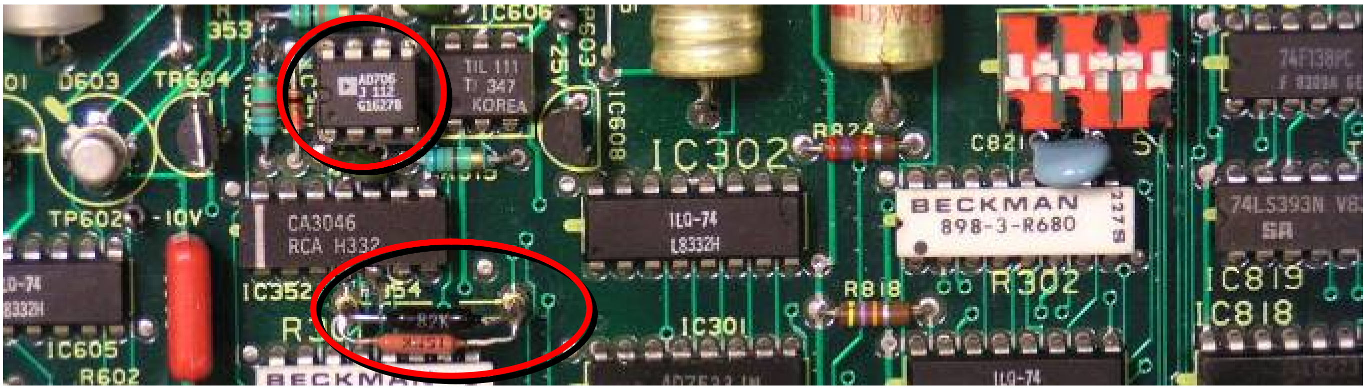
$$Icomp(T) := \left[AD590(T) - \frac{U10 + AD590(T) \cdot (R352 + R353)}{R351 + R352 + R353} \right]^2 \cdot \frac{R354}{U10 - 0.718}$$

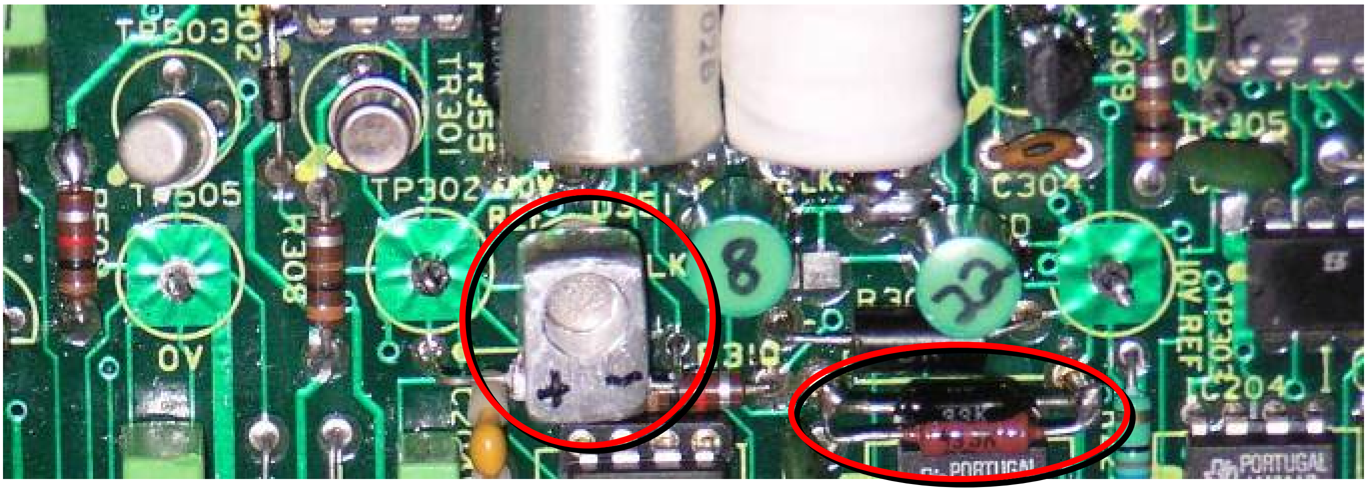
$$Ucomp(T) := Icomp(T) \cdot R355 \qquad ppm\_comp(T) := \frac{Ucomp(T)}{Uz} \cdot 10^6$$



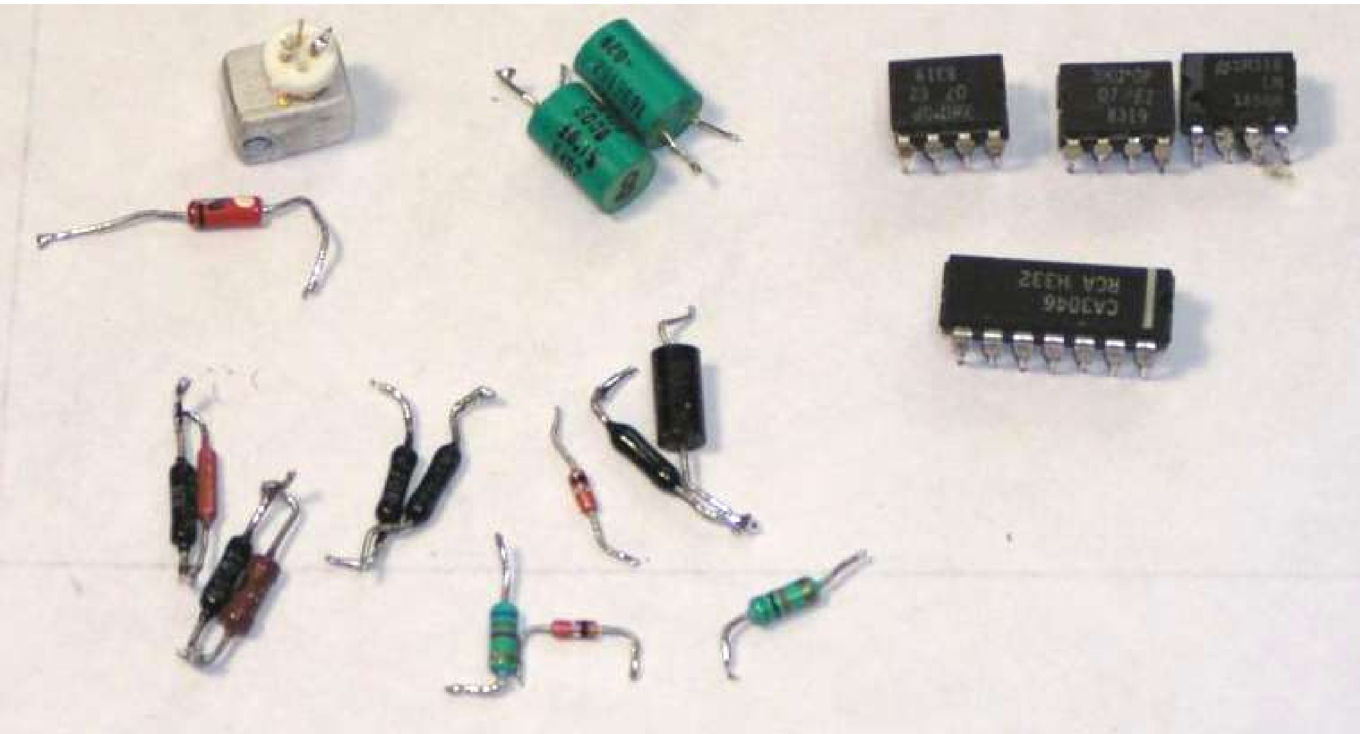
05/2012 Zener diode working point and parabolic temperature compensation circuit parameters were reconfigured. A new DAC #102 token is assigned instead of #76, that is, the working current is established via a Zener diode Iz = 6.540 mA, the Zener point of the Zener diode is shifted from 27 to 48.2 degrees Celsius. The resistances of resistors R351 and R354 were reduced to 31.11 kOhm and 81.6 kOhm, respectively, by parallel connection with additional resistors 15 MΩ and 499 kΩ.

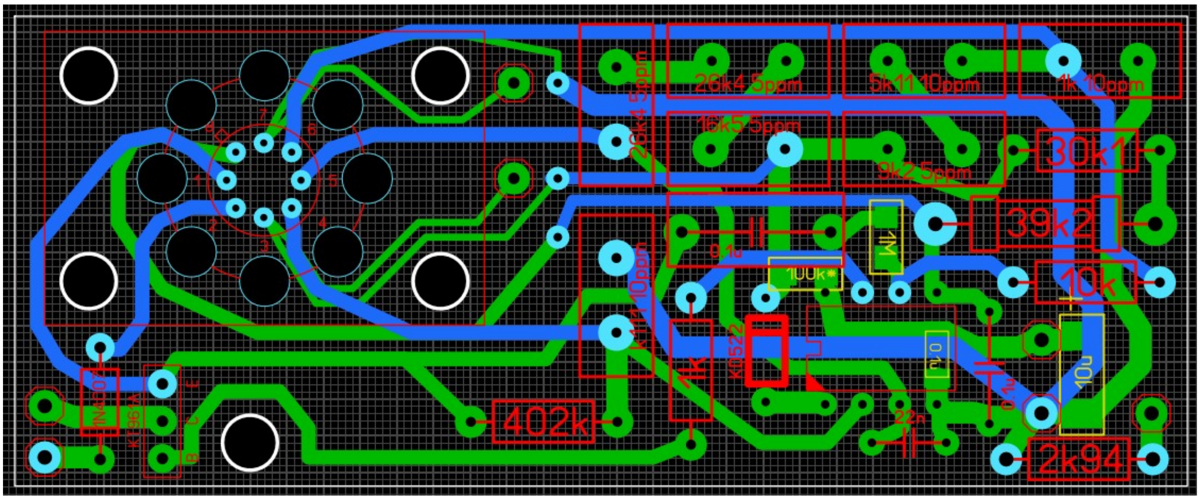
The dual op-amp IC351 (LM1458) was replaced by a precision AD706 in the socket. An aluminium holder for both the Zener diode and temperature sensor was designed, constructed and then fitted to the diode and sensor with thermal grease.

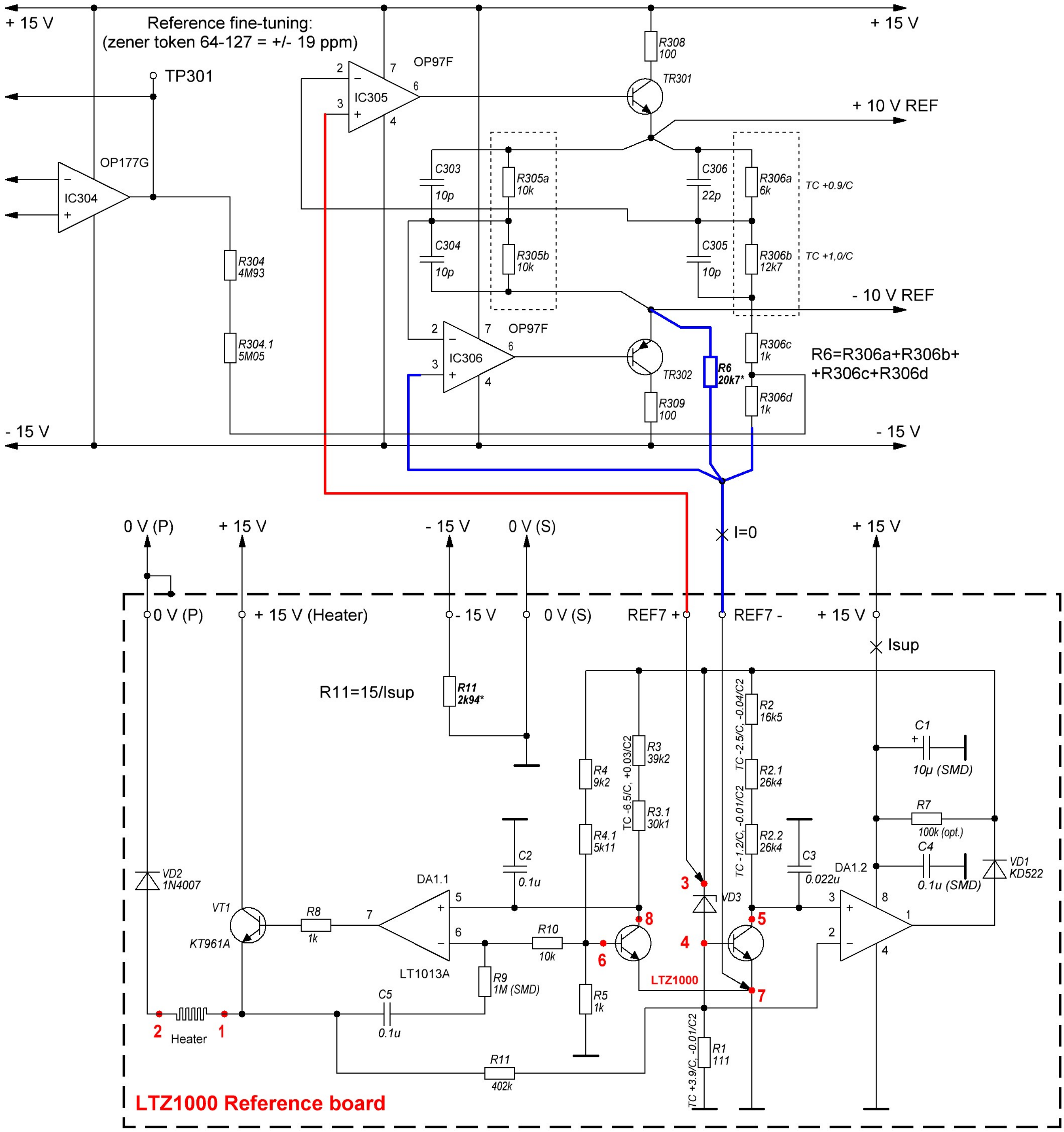


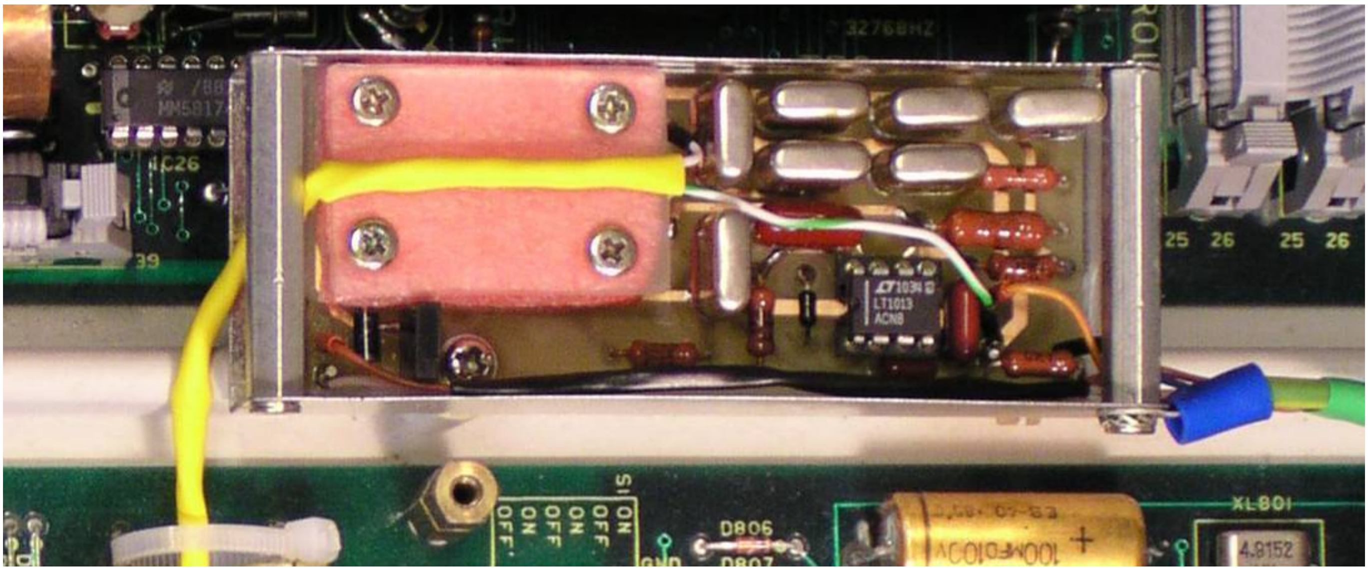


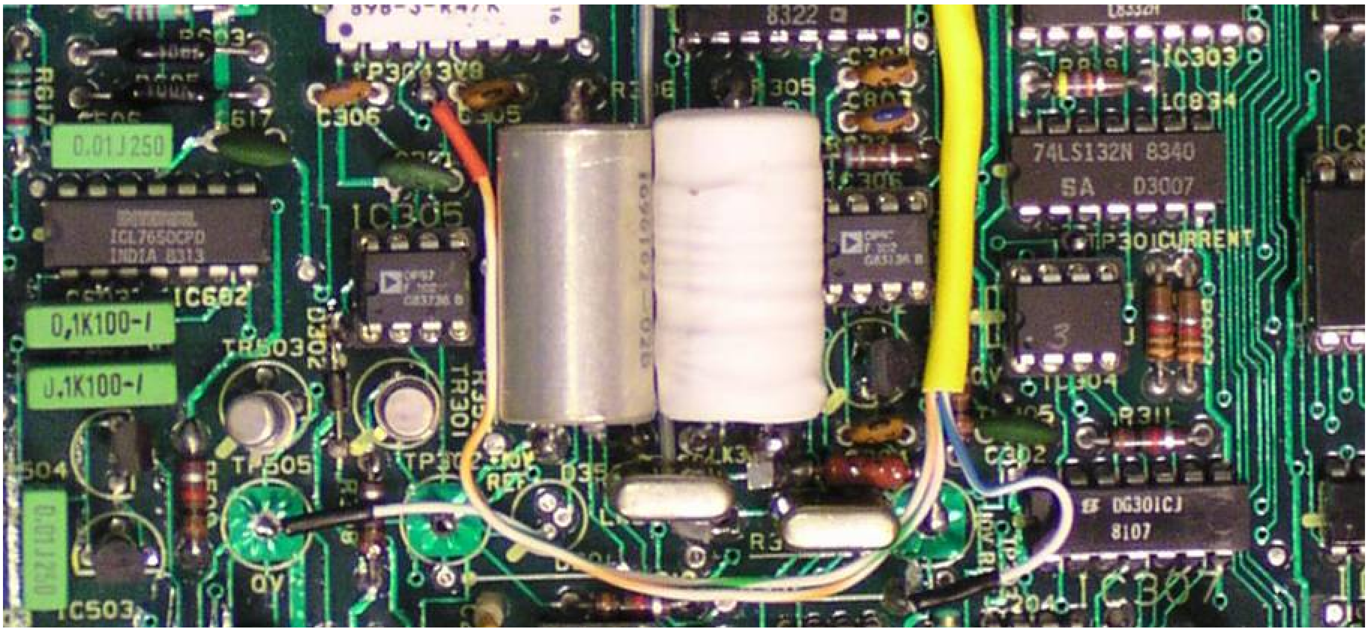
08/2012 I decided to replace the Zener diode and parabolic node compensation with a voltage reference module based on the LTZ1000, positioned just above the mainboard.




26k4 5ppm
5k11 10ppm
1k 10ppm
16k5 5ppm
9k2 5ppm
30k1
39k2
10k
100k*
1M
0.1u
1k 10ppm
1k
KD522
402k
22p
10u
2k94
1N4007
KT961A
E
C
B


+ 15 V
Reference fine-tuning:
(zener token 64-127 = +/- 19 ppm)
TP301
OP177G
IC304
R304
4M93
R304.1
5M05
OP97F
IC305
R308
100
TR301
+ 10 V REF
C303
10p
R305a
10k
C304
10p
R305b
10k
C306
22p
R306a
6k
TC +0.9/C
C305
10p
R306b
12k7
TC +1,0/C
- 10 V REF
IC306
OP97F
TR302
R6
20k7*
R306c
1k
R6=R306a+R306b+
+R306c+R306d
R306d
1k
R309
100
- 15 V
0 V (P)
+ 15 V (Heater)
- 15 V
0 V (S)
REF7 +
REF7 -
I=0
Isup
R11=15/Isup
R11
2k94*
R2
16k5
R2.1
26k4
R2.2
26k4
R3
39k2
R3.1
30k1
R4
9k2
R4.1
5k11
R5
1k
R1
111
TC -6.5/C, +0.03/C2
TC -2.5/C, -0.04/C2
TC -1.2/C, -0.01/C2
TC +3.9/C, -0.01/C2
C1
10µ (SMD)
R7
100k (opt.)
C4
0.1u (SMD)
VD1
KD522
C2
0.1u
C3
0.022u
DA1.1
DA1.2
LT1013A
VD2
1N4007
VT1
KT961A
R8
1k
R9
1M (SMD)
R10
10k
C5
0.1u
R11
402k
VD3
LTZ1000
Heater
LTZ1000 Reference board



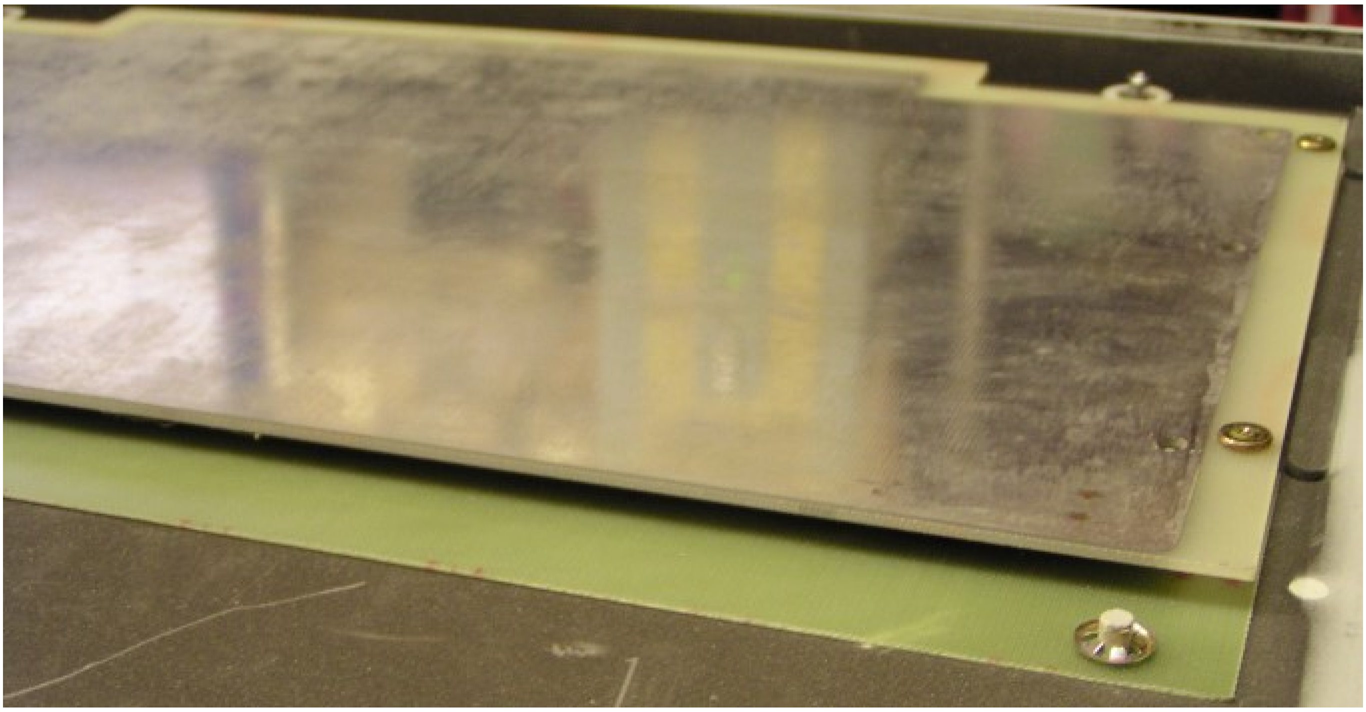


08/2012 Unsatisfactory RMS noise value (~ 2 μV) with the input to the ADC short-circuited (jumper SP501 is broken). In this case any noise from the voltage reference is not an issue.

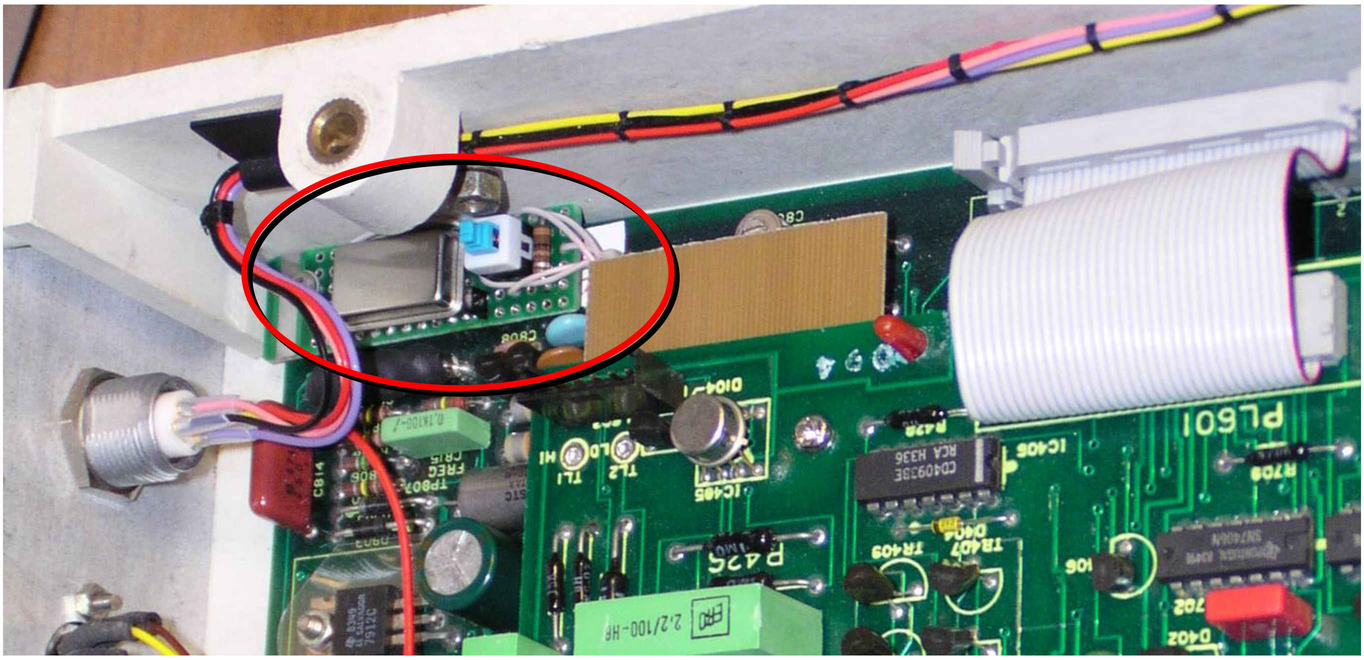
1. Replacing IC201 with an LTC1052 did not change this, so reinstalled the old ICL7650CPD).
2. Installed a socket for the integrator op-amp IC202. Replacing the regular LM301 with LME49710 and OP604 did not improve this (temporarily left LME49710 installed).
3. Adjusting the frequency of the clock with the PLL reduced the noise of the ADC to normal.

09/2012 Continuous operating time 570 hours. The drift is of the order of 0.1 ppm per day. The working temperature of the LTZ1000 chip (84 degrees Celsius) is determined by the divider (9.2 + 5.11 = 14.31): 1 kOhm. It is advisable to lower the temperature setpoint to 65 degrees Celsius, reducing the resistance of the upper arm to 13 kΩ

10/2012 Plexiglas spacers were installed between the protective electrostatic screen and the upper housing cover. As a result the capacitance between the screen and grounded conductive coating decreased from 1 nF to 230 pF. The total capacitance of the parasitic structural capacitor between the grounded chassis and the isolated measuring block of the voltmeter was reduced to 1.1 nF.

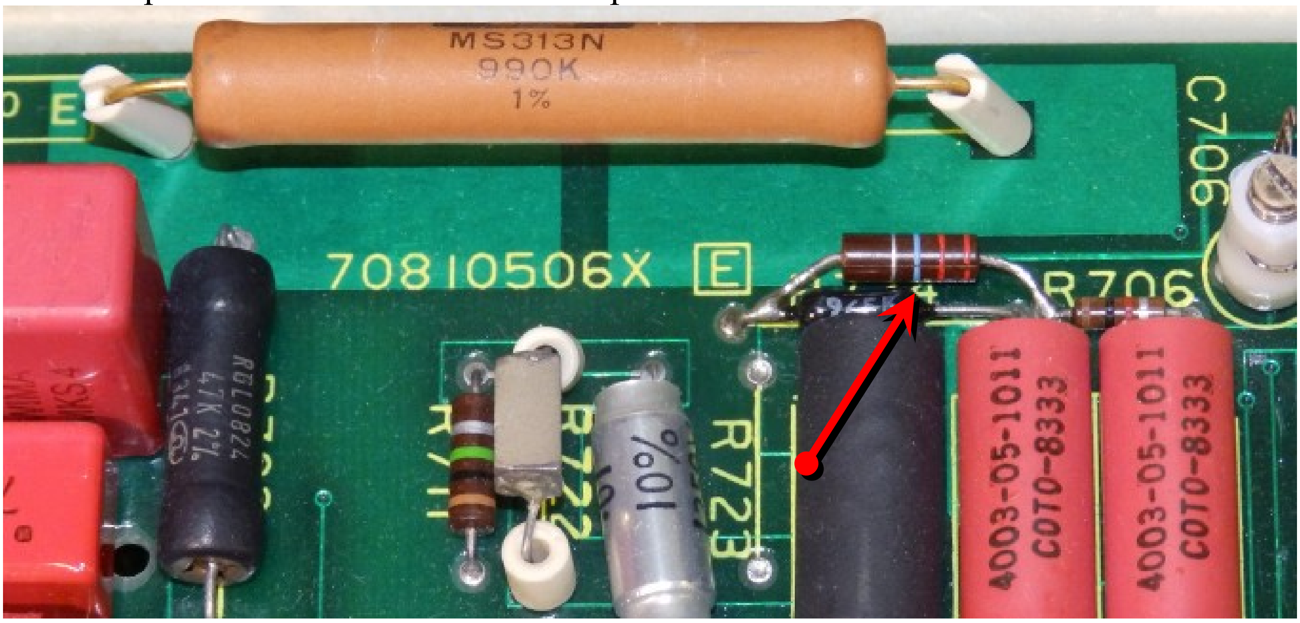


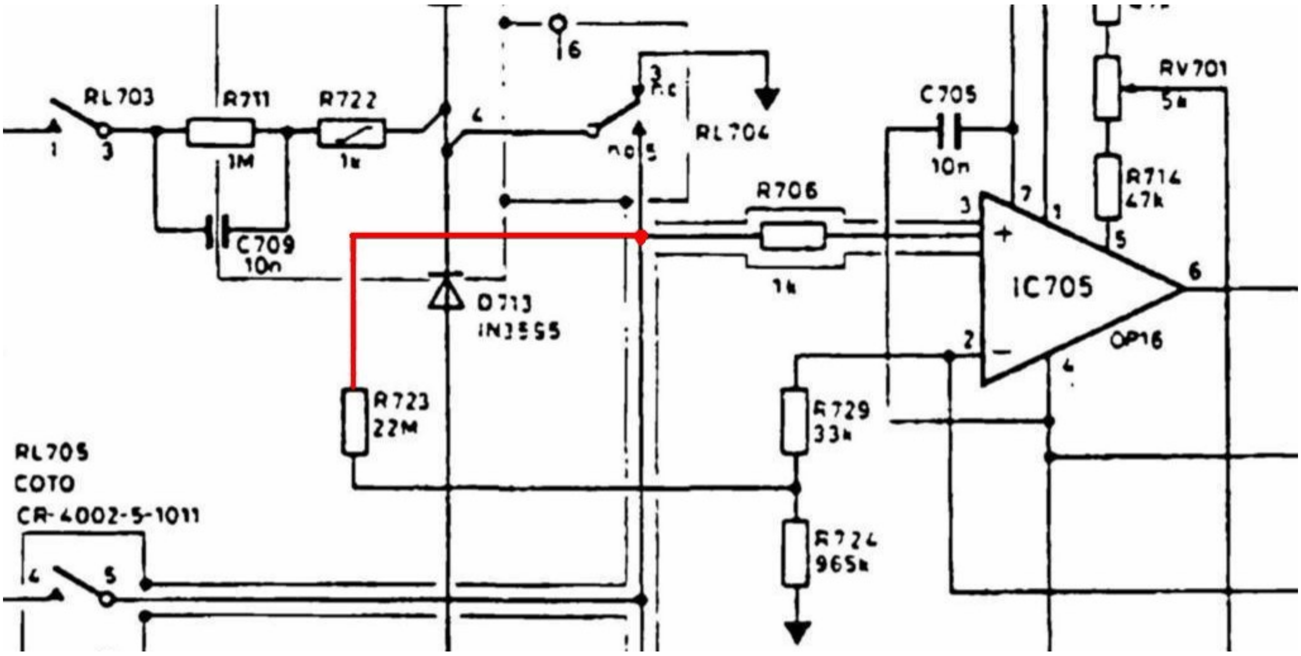
10/2012 To reduce the noise of the ADC, a mezzanine board with a clock generator wais installed at a fixed frequency of 10.48576 MHz and a button for switching to a standard oscillator with a PLL.



11/2012 The temperature set-point of the LTZ1000 chip in the voltage reference module was reduced to 65 degrees Celsius by reducing the upper arm resistance to 13 kΩ (S5-61 12 kΩ 0.01% -0.2…+ 0.3 ppm/°C in series with 1 kΩ 0.05% -3.3 ppm/°C).

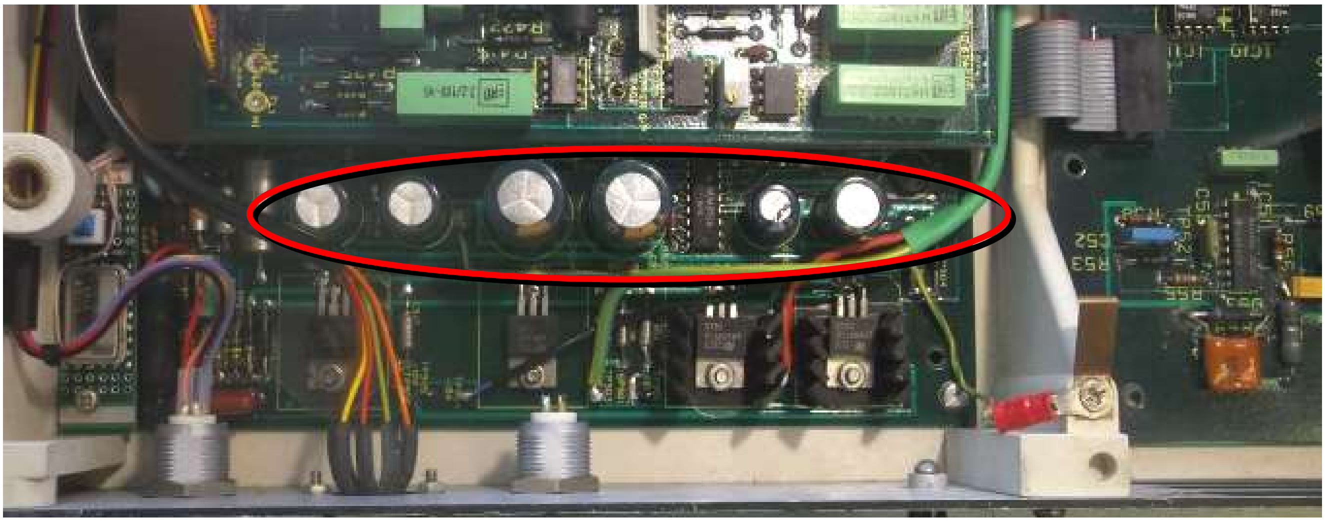
12/2012 To reduce interference, R723 in the ACV circuit was moved to the same location as it occupies in the final revision of the printed circuit board.





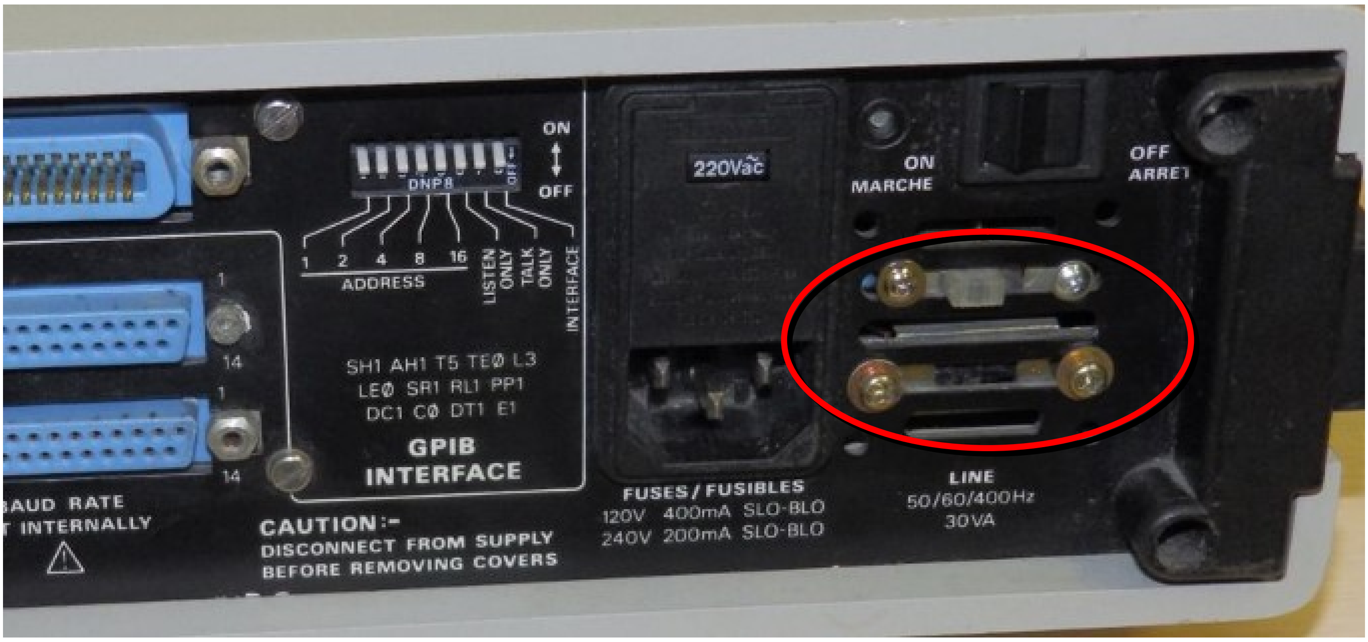
07/2013 Replaced OP97 with OP07EZ because 2 times less low-frequency noise. Replaced C303-C306 in the voltage reference, the places of soldering were varnished. The AUXILIARY connector on the back of the enclosure was re-purposed for monitoring +7 V (LTZ1000), +10 V and -10 V (voltage reference) in tests of long-term stability.

02/2014 Installed additional bypass capacitors in the +5V floating logic power supply to reduce switching emissions. Electrolytic capacitors of isolated power supply are replaced with low-ESR ones.



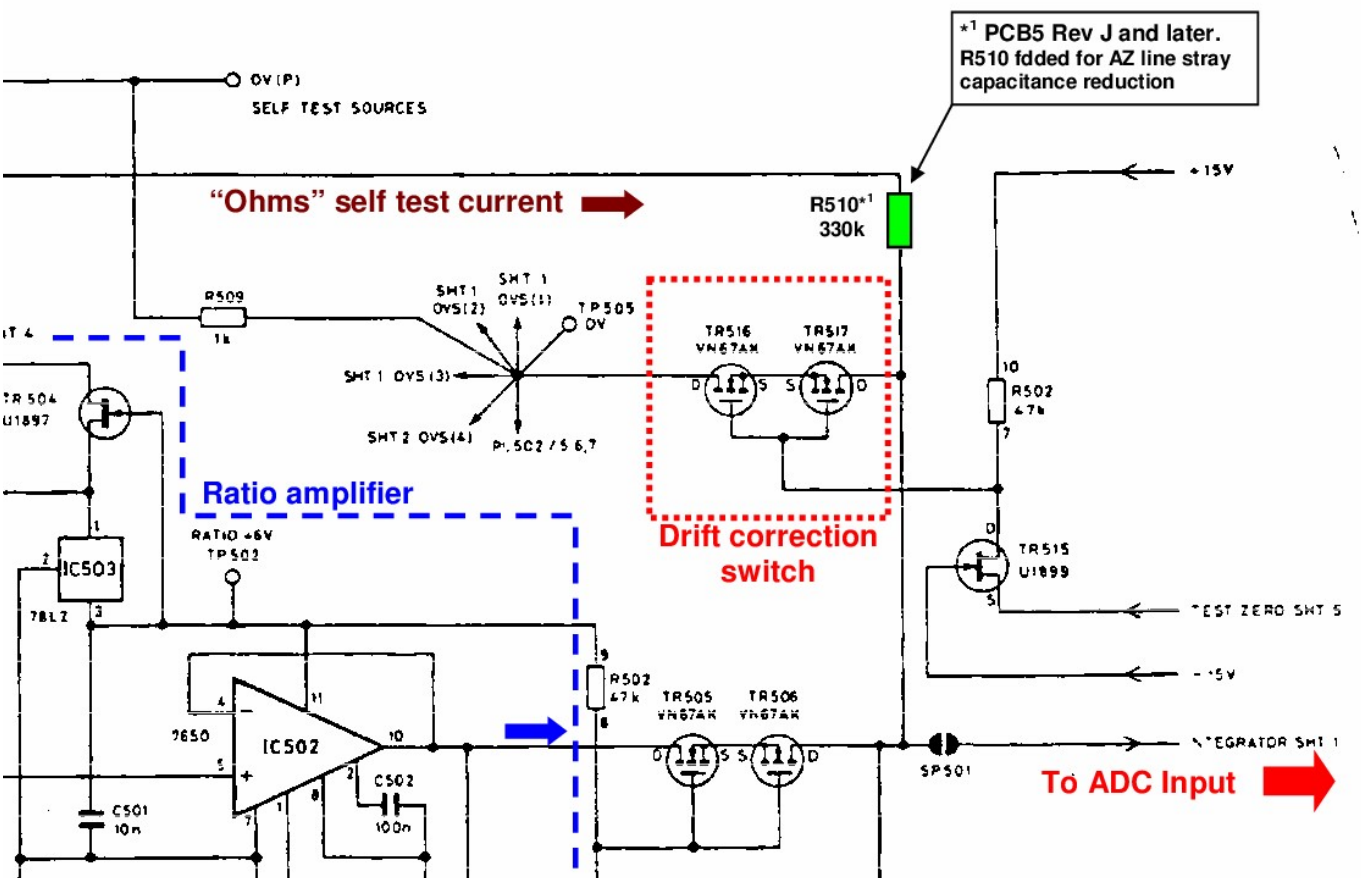
A slide switch was installed on the rear wall case to cut the supply to the heater circuit of the VFD so it could be turned off when not needed so as to increase its service life.

A slide switch on the rear wall of the housing was installed between the chassis of the device the internal shield (sputtered) from the grounded midpoint of the earthed line power filter. Used only in case of emergency when power supply of the device from a 2-wire network without protective ground in order to avoid the risk of ½ mains potential on the internal screen.

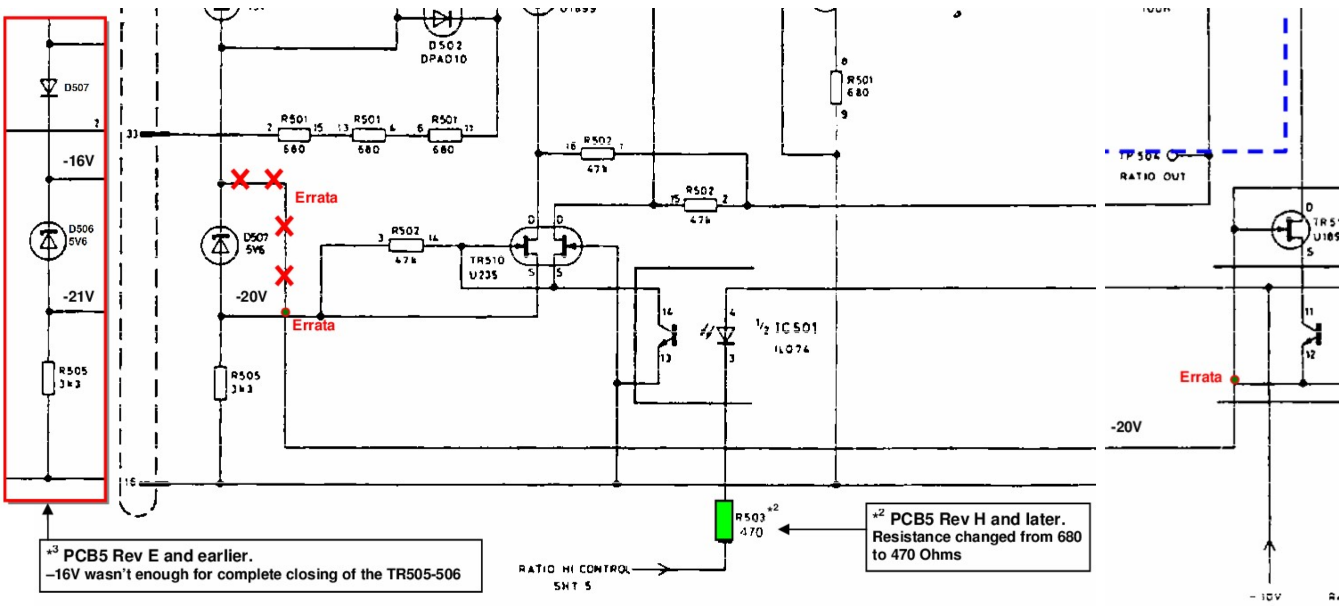


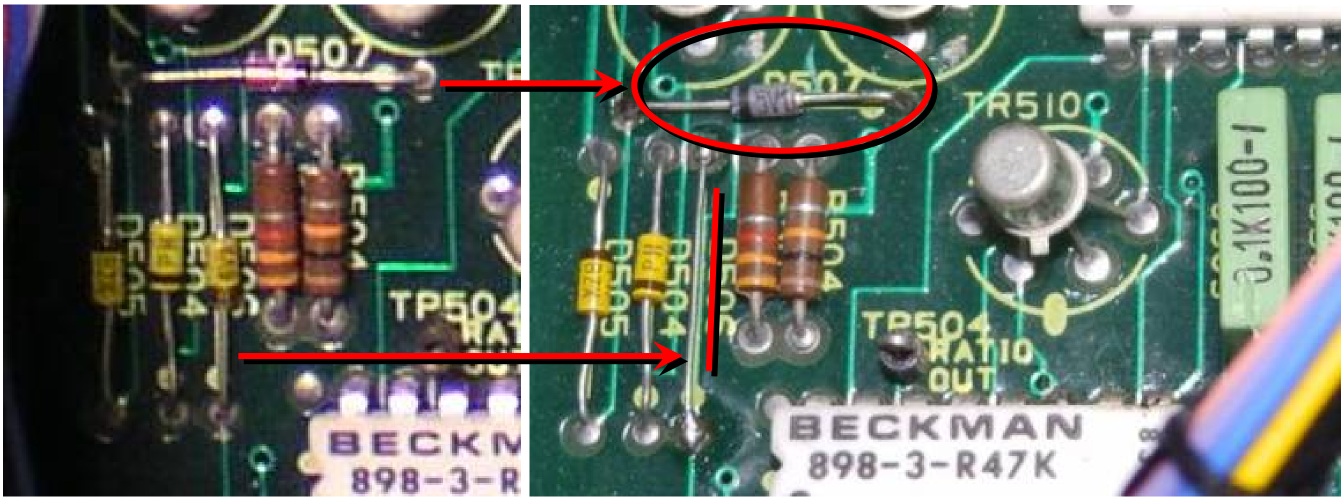
08/2015 The connection of the GUARD circuit was changed to match the final revision of the schematics. Electro-static screens now connect to the 0VP power zero. GUARD is disconnected from electrostatic screens and inter-winding screens of the power transformer.

08/2015 Added resistor R510 (330 kOhm) to PCB5 board as shown in the final version of the schematics. This is needed to reduce the impact of the capacitance of conductors for the duration of transients during auto-correction zero ADC.

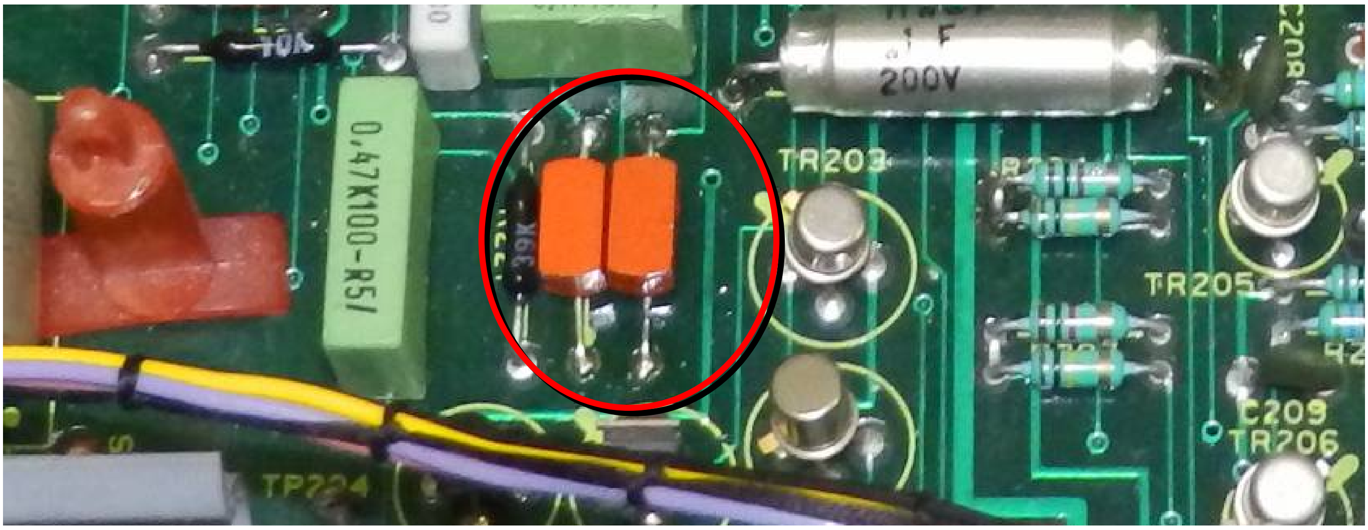


08/2015 The circuit for switching on the D505 and D507 on the PCB5 board is adjusted to create a potential of minus 20 V, thus completely shutting off TR505, 506, 508, 509 and preventing the influence of interference over the input of the RATIO on the measurement results at the main input. The diagram corresponds to the last revision.





08/2015 Removed board with voltage regulators LM78L08 and LM79L08 and re-installed the original Zener diodes in the supply circuits of IC201.



In just 4 years, about 230 tests were conducted and the same number of graphs were constructed.