White Paper
thick film resistor flicker noise
2013

Introduction

Flicker noise (or 1/f noise or current noise) of thick film resistors can be very high. This week I searched for an unexpected noise source in a low noise amplifier. I searched for hours until I found the bad guy. I never expected this huge influence of a single thick film resistor.

Here a few measurements I made to estimate the flicker noise of “my” resistors

Setup

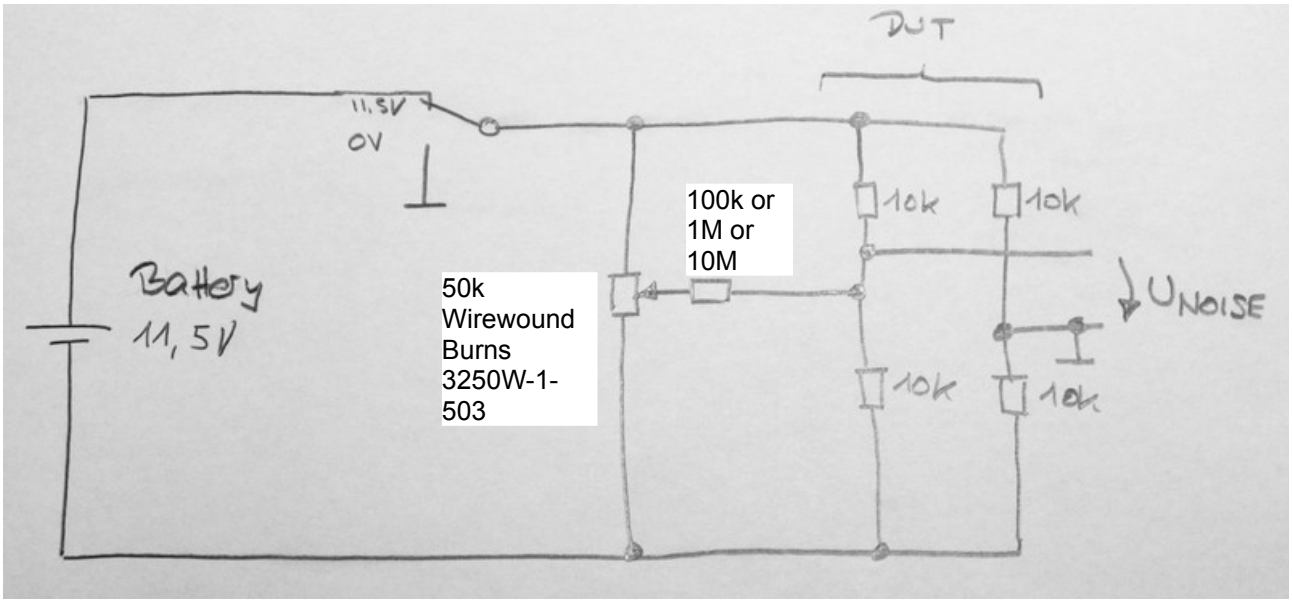
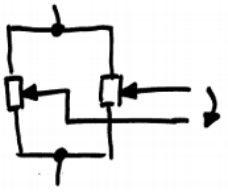


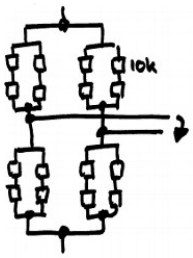
Figure 1 Schematic Test Setup

A battery supplies a resistor bridge. The offset can be adjusted to zero with a trimmer. The bridge-voltage is amplified with a low noise differential amplifier (AD8676 and INA103 or INA103 alone).

Samples built with two trimmers: K, L, N, R



Sample with 16 resistors: T



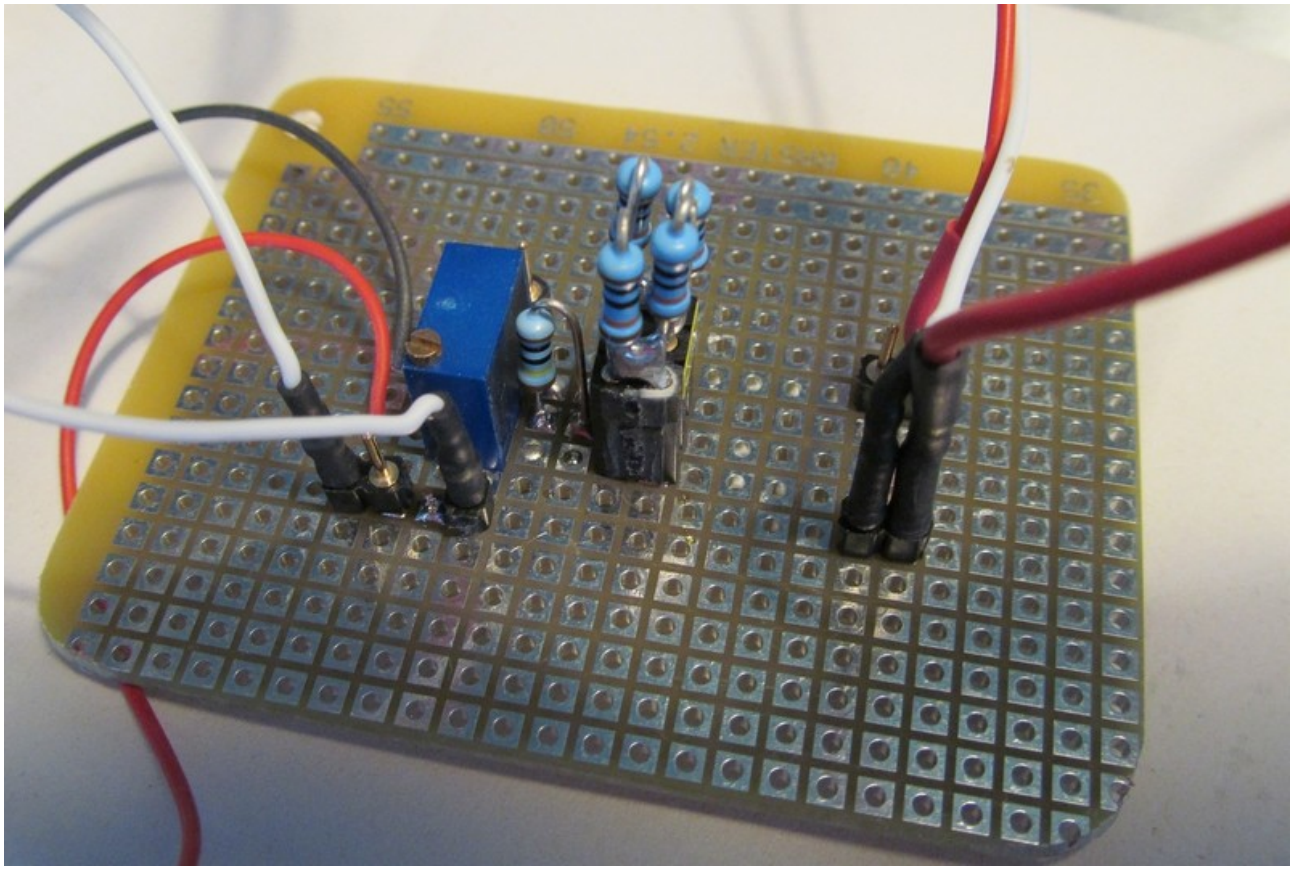


Figure 2 Circuit-board

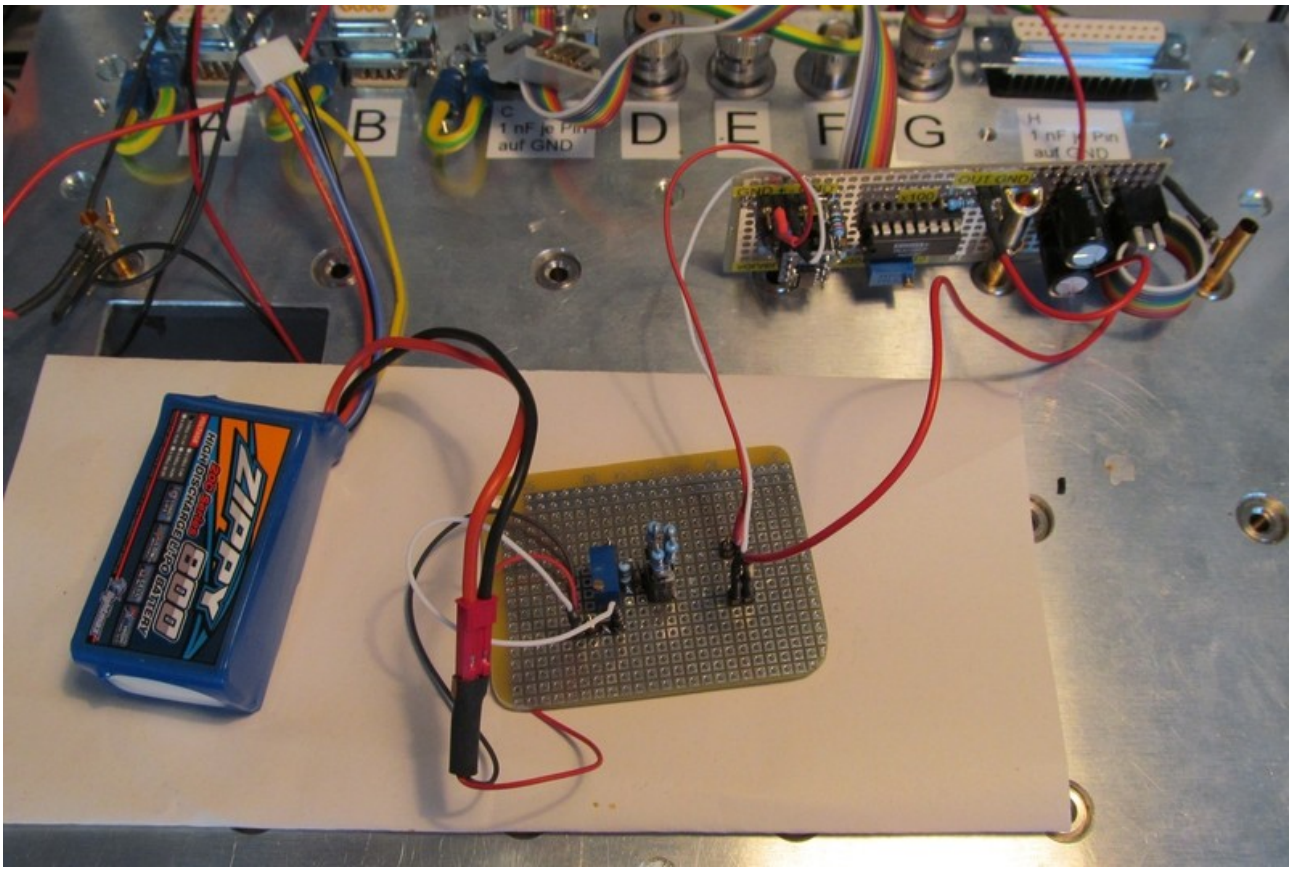


Figure 3 Battery, circuit-board and low noise amplifier in shielded box.

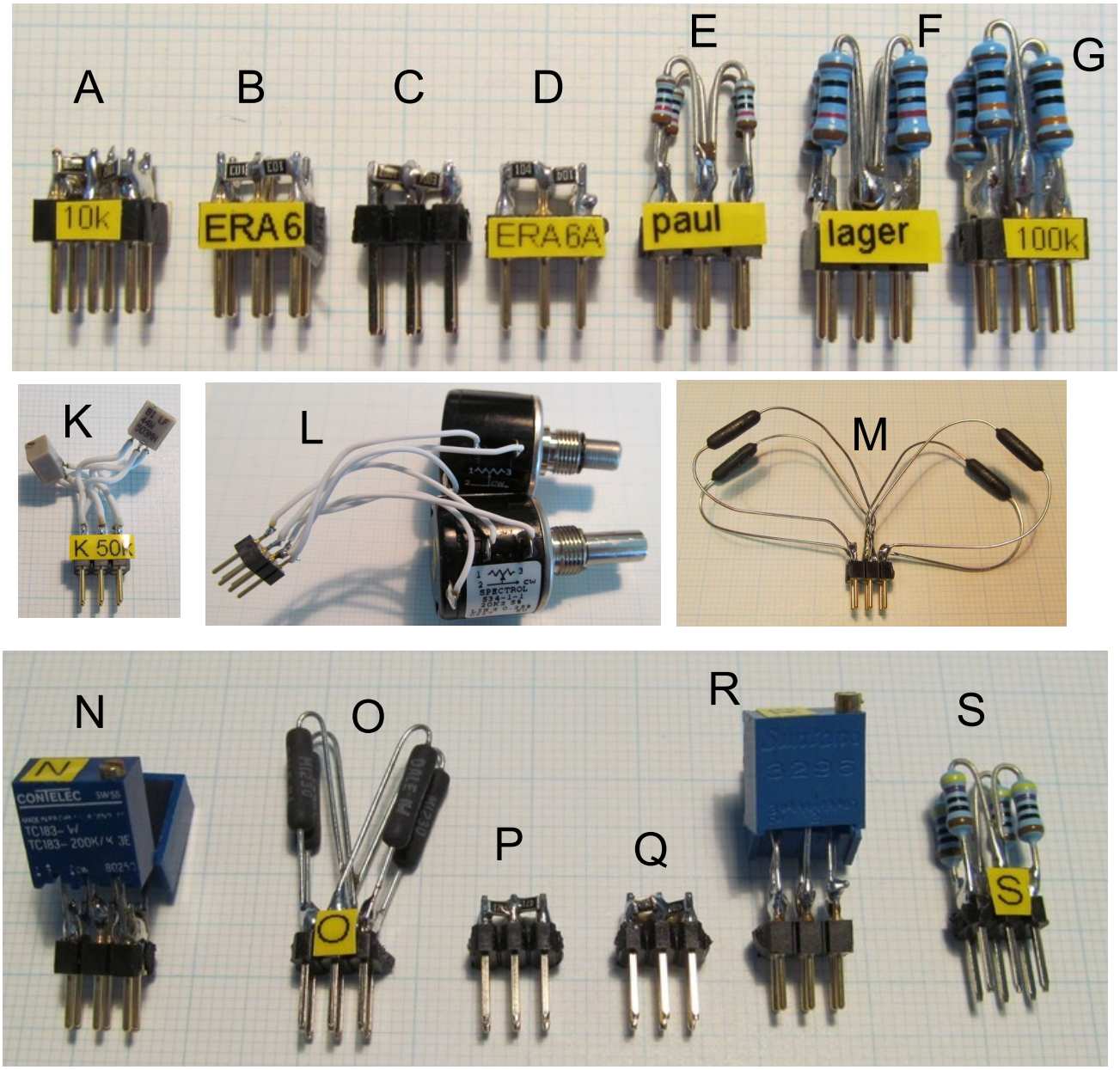


Figure 4 Samples, DUT

A	10k, Resistor Set Constructiva AG SMD-RCS-x 0805 100 ppm
B	10k, Panasonic, ERA-6AED103V, thin-film
C	100k, Resistor Set Constructiva AG SMD-RCS-x 0805 100 ppm
D	100k, Panasonic, ERA-6AED104V, thin-film
E	10k, paul's stock
F	10k, unknown type, guess 0207 thin-film
G	100k, unknown type, guess 0207 thin-film
K	50k cermet trimmer, 44WR50KLFT7 BI Tech (25k upper part, 25k lower part)
L	20k wire trimmer, spectrol model 534 (10k upper part, 10k lower part)
M	10k wire-wound resistor Vishay RS01A10K00FE12
N	200k cermet trimmer Contelec 183W swiss
O	470 wire-wound vishay RS01A470R0FE12
P	470 ,Panasonic, ERA-6AED471V, thin-film
Q	470 ,Resistor Set Constructiva AG SMD-RCS-x 0805 100 ppm
R	1k trimmer cermet Suntan 3296
S	470, unknown type, guess 0207 thin-film
T	10k, Resistor Set Constructiva AG SMD-RCS-x 0805 100 ppm, 16 Resistors

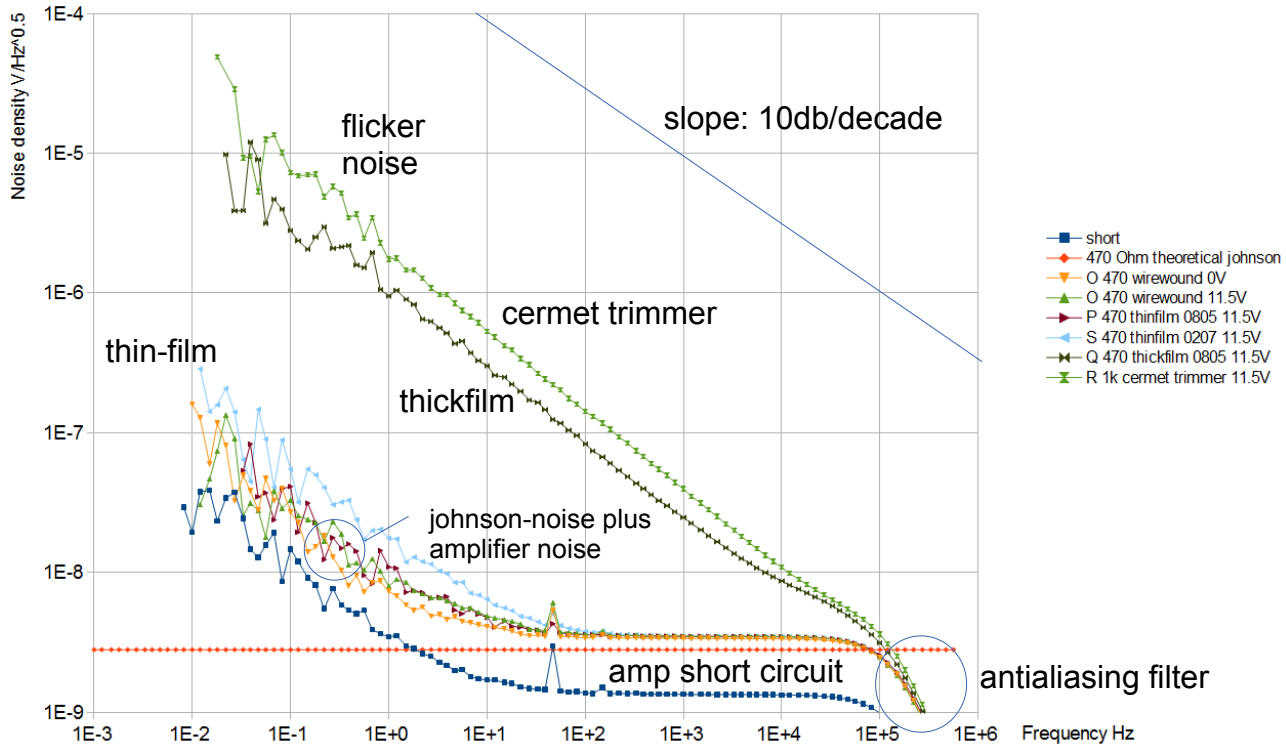


Figure 5 470 Ohm resistors

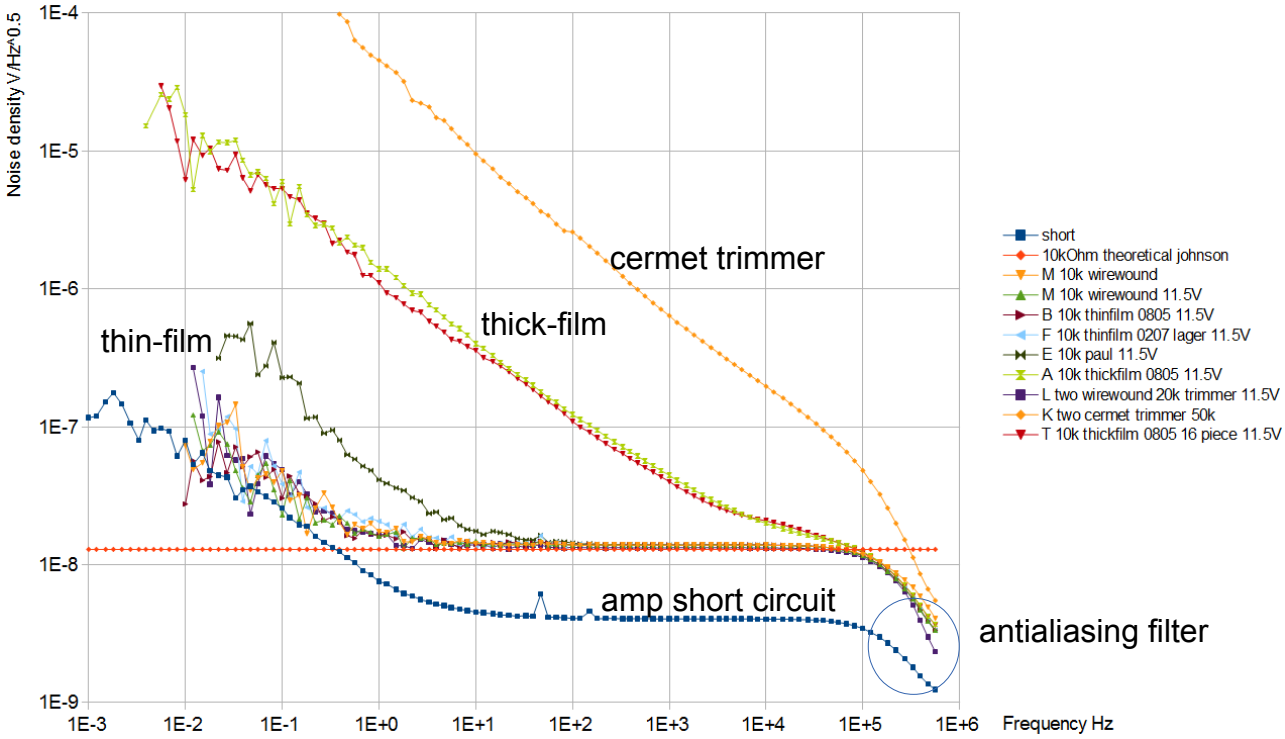


Figure 6 10k Ohm resistors

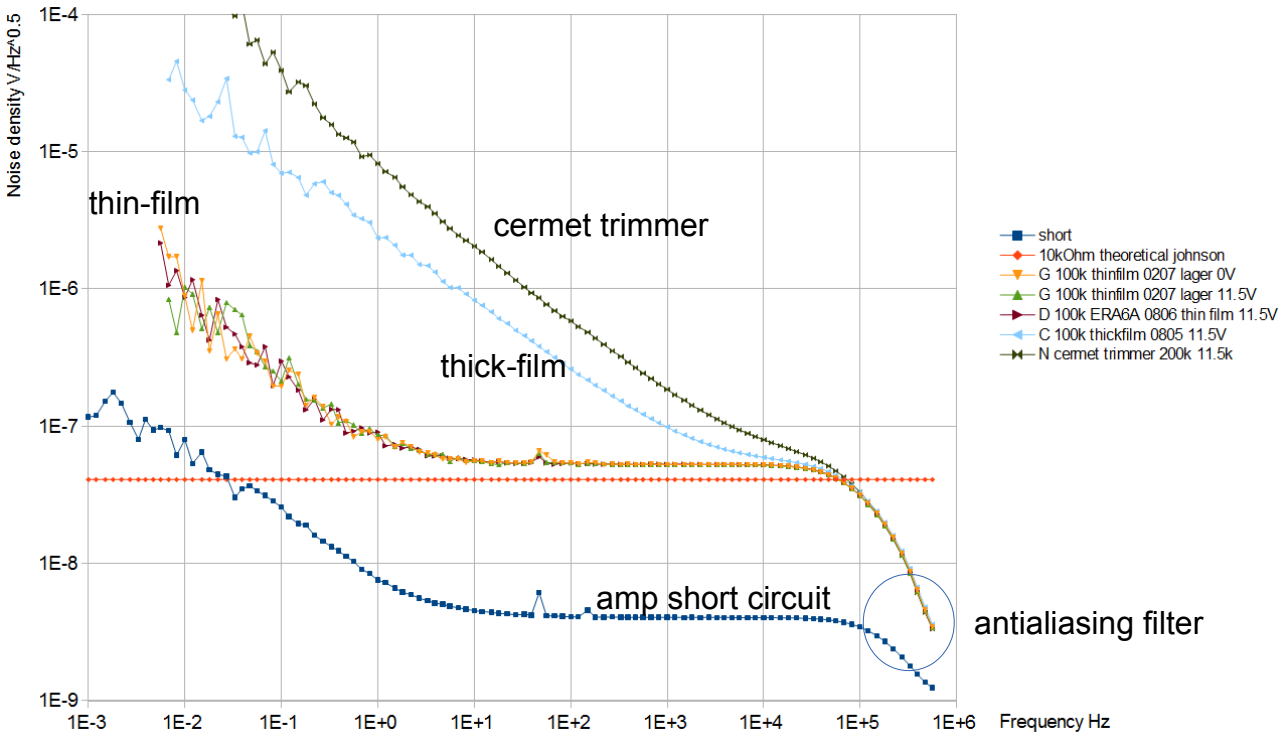


Figure 7 100k Ohm resistors

The measured noise consist of:

- Amplifier voltage noise (see first graph in diagram)
- Amplifier current noise times resistance
- Johnson-noise of the resistor (see second graph in diagram, theoretical value)
- Flicker-noise due to current flowing trough the resistor

The third graph shows the noise without applied voltage (0V). Should be amplifier noise plus amplifier current noise times resistance plus johnson noise.

Thin-film resistors do have very low flicker-noise. There is nearly no difference with or without applied voltage.

At low frequencies the flicker-noise of thick-film resistors can be about 100 times higher than the noise of thin-film resistors. The flicker-noise of the cermet trimmers can be about 1000 times higher than the noise of thin-film resistors. If you increase the voltage, it gets even worse because flicker noise of resistors is proportional to the applied voltage.

To calculate the flicker-noise of a single resistor, take the value in the graph and multiply with $U_{applied}$ * 2 / 11.5V.

If you combine 4 resistors to build one resistor, flicker-noise should be reduced by factor 2.

Recommendation

If noise is a matter, use thin film resistors. For example ERA-6AED 0805 resistors, 0.5 %, 25 ppm, from mouser. 0.02 CHF each @ 100 piece. Available in E96, values between 10 Ohm and 1 MOhm.

Avoid trimmers (cermet) if possible. Avoid wire-wound trimmers as well as they have a minimal step size and the value can change between two steps randomly.

To adjust something, use multiple fix value resistors in parallel. Measure the needed value with a trimmer, place the first to big fix value resistor. Measure again with a trimmer, place the second fix value resistor and so on.

Further reading

- Resistor Current Noise Measurements Frank Seifert, April 14, 2009

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Additional measurements 2016

I was interested in the flicker noise of high value resistors. An optimized setup was used:

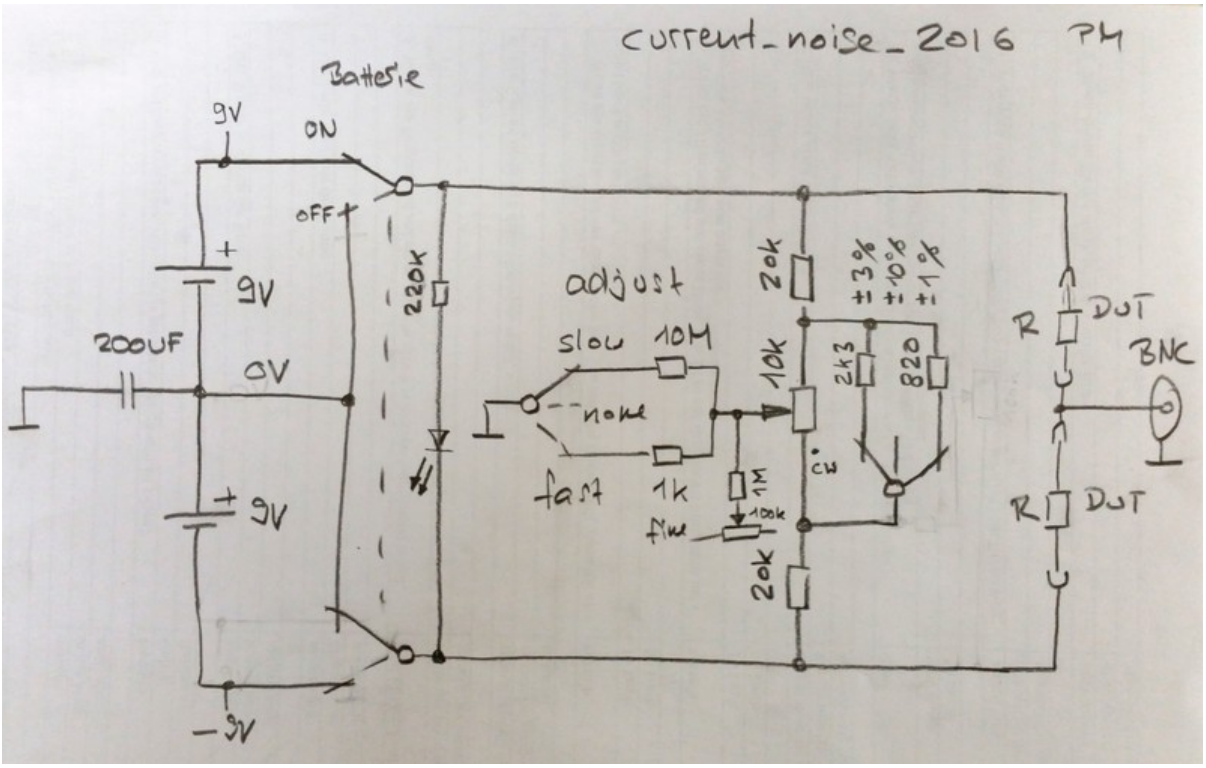

Figure 8 Schematic current_noise_2016

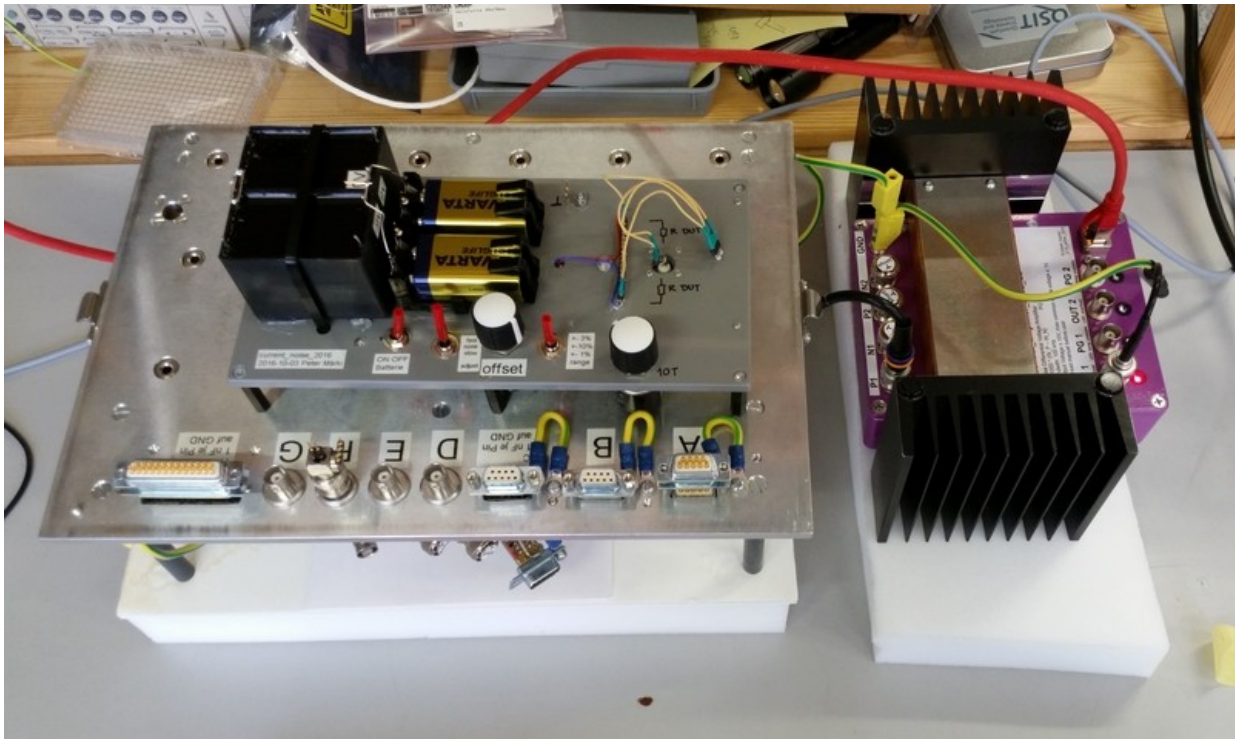

Figure 9 current_noise_2016

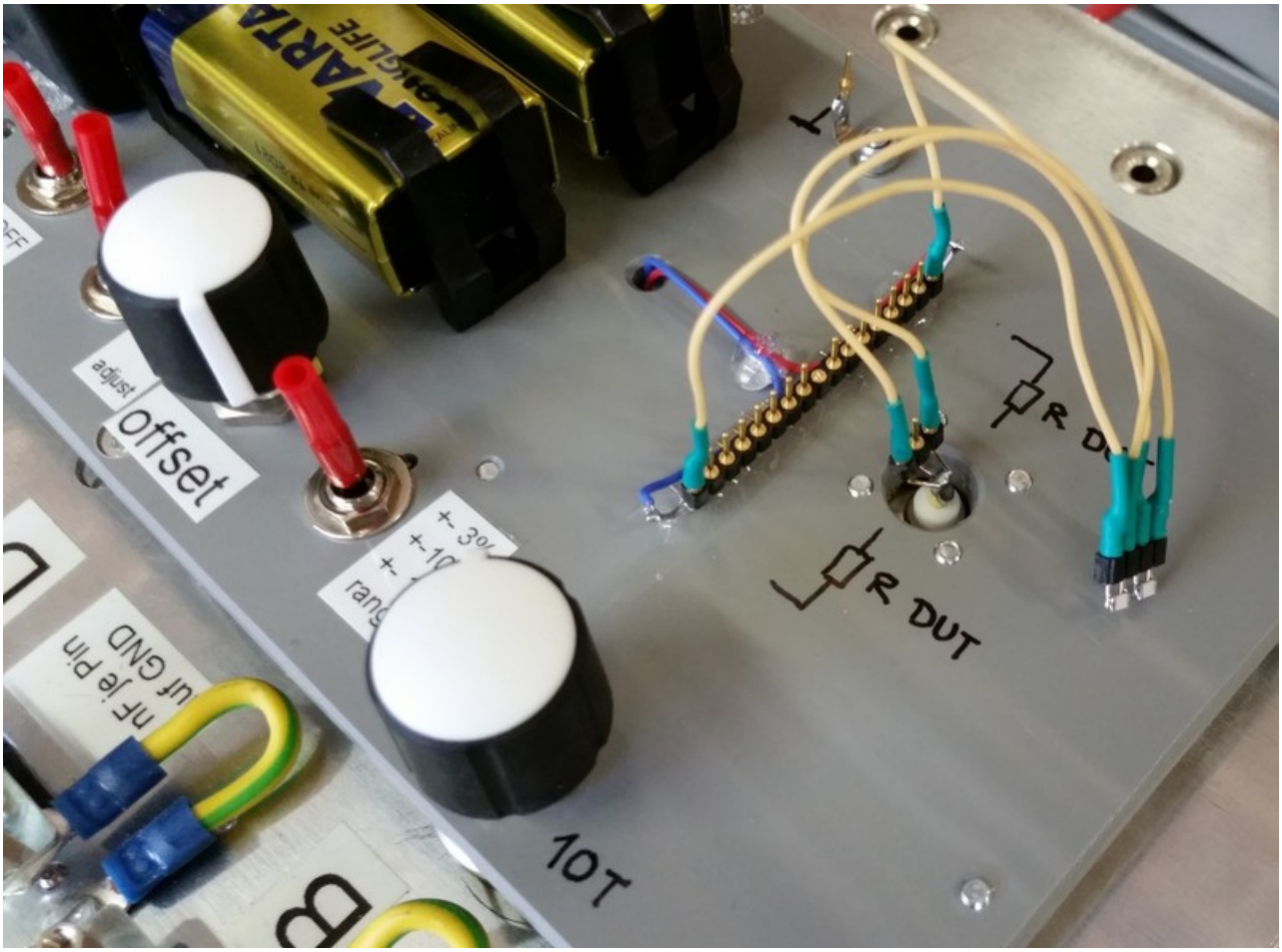

Figure 10 current_noise_2016 detail

Only the noise voltage of a half bridge is measured. The amplifier (differential_amplifier_2015_dc) has less voltage and less current noise than the one I used before.

I measured the noise with battery switched off (johnson noise plus amplifier noise) and then the noise with battery switched on. I then choose a frequency decade where the signal was nice and calculated the difference in this decade. Then I calculated the noise index Vrms noise / V DC over one resistor. Noise index = Uadditional_noise (in one decade) / Ubattery (18V) * 2 * 2^0.5.

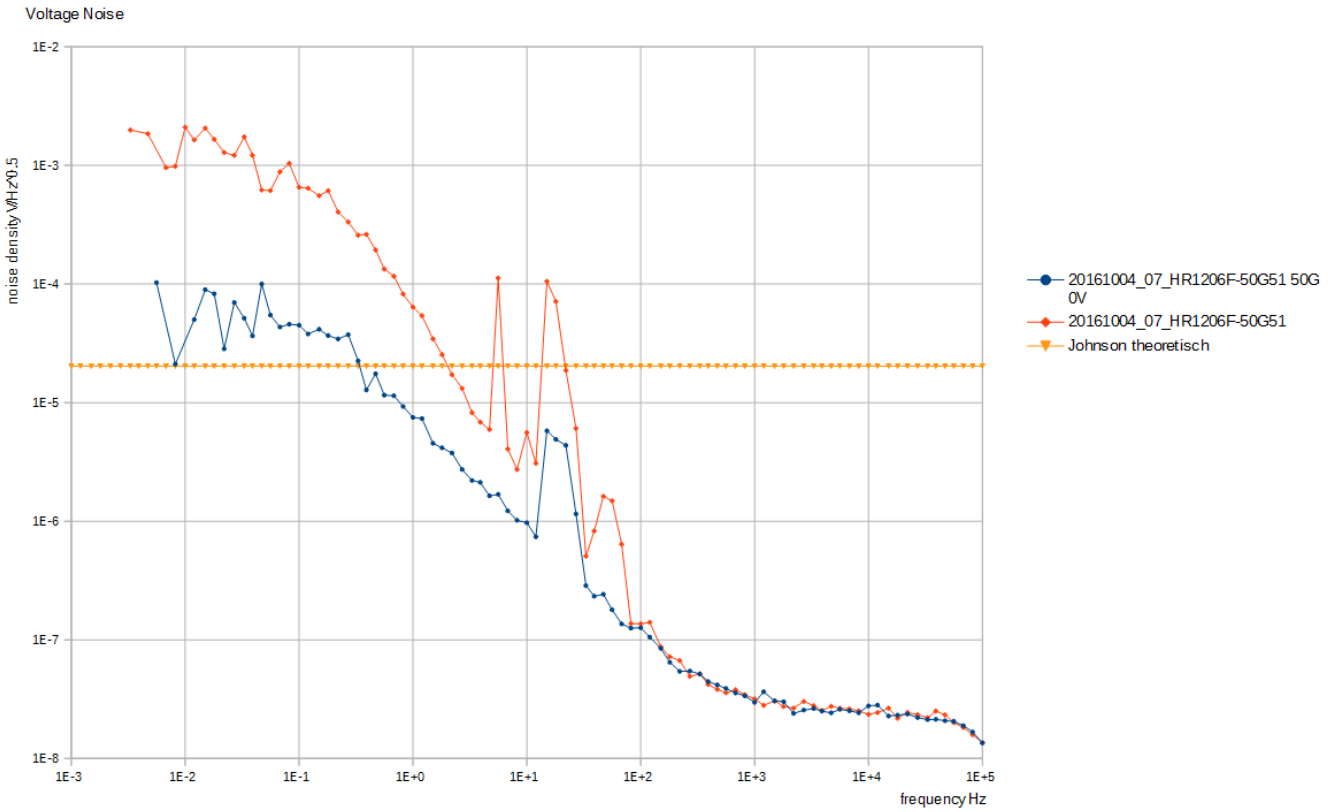

Figure 11 one example of the measurements. 50 GOhm resistors.

In this example you can see peaks between 1 Hz and 100Hz. They are due to vibrations of the setup.

The setup was very sensitive to vibrations with this high value resistors. Above 0.1 Hz the noise decreases. This is due to the capacitive load of the cabling and the amplifier.

Between 10 mHz and 100 mHz the blue line (noise without DC voltage over resistors) is flat and a bit higher than the expected johnson noise. The increase of the noise is caused by the current input noise of the amplifier. I choose the range between 10 mHz and 100 mHz: Without battery: 1.76E-5 Vrms, with battery: 3.55E-4Vrms. Difference: 3.5E-4Vrms. Noiseindex: 5.2E-5V/V.

Some people calculate the noise index in dB: 20 log (uV/V).

I did not see measurements of that high resistor values somewhere else up to now.

Sample		Widerstandswert Widertand Ohm	Noise Index Noise Vrms/V	Noise Index uV/V dB
20161004_01_MCT06030C1005	MCT0603	1.0E7	3.1E-6	9.83
20161004_02_P2010H4295CNT_42.9M	P2010	4.3E7	4.5E-7	-6.94
20161004_03_SMM02040C1005FB30_10M	WMM0204	1.0E7	4.3E-7	-7.33
20161004_04_MMB02070C1005FCT_10M	MMB0207	1.0E7	3.4E-7	-9.37
20161004_05_RK1_4CT52R226G_22M	RK1	2.2E7	2.0E-5	26.02
20161004_06_RGP0207CHJ100M_100M	RGP0207	1.0E8	4.0E-7	-7.96
20161004_07_HR1206F-50G51_50G	HR1206	5.0E10	5.2E-5	34.32
20161004_08_ERA-8AED105V_1M	ERA-8A	1.0E6	2.9E-8	-30.75
20161004_09_RG3216P-1004-BT1_1M	RG3216	1.0E6	2.4E-8	-32.4
20161004_10_MCU0805C1005FP5_10M	MCU0805	1.0E7	2.2E-6	6.85
20161005_11_CRHV1206AF100MFKE_100M	CRHV1206	1.0E8	1.8E-6	5.11
20161004_12_CRHV1206AF1G00FKE_1G	CRHV1206	1.0E9	3.7E-6	11.36
20161004_13_HVF1206T1008JE_10G	HVR1206	1.0E10	2.0E-5	26.02
20161004_14_ERA6AED105V_1M	ERA6A	1.0E6	2.0E-8	-33.98
20161004_15_ERA6AED104V_100k	ERA6A	1.0E5	2.5E-8	-32.04
20161004_16_ERA6AED104V_10k	ERA6A	1.0E4	1.9E-8	-34.42
20161004_17_ERA6AED105V_10M_10st	ERA6A 10x	1.0E7	2.5E-8	-32.04

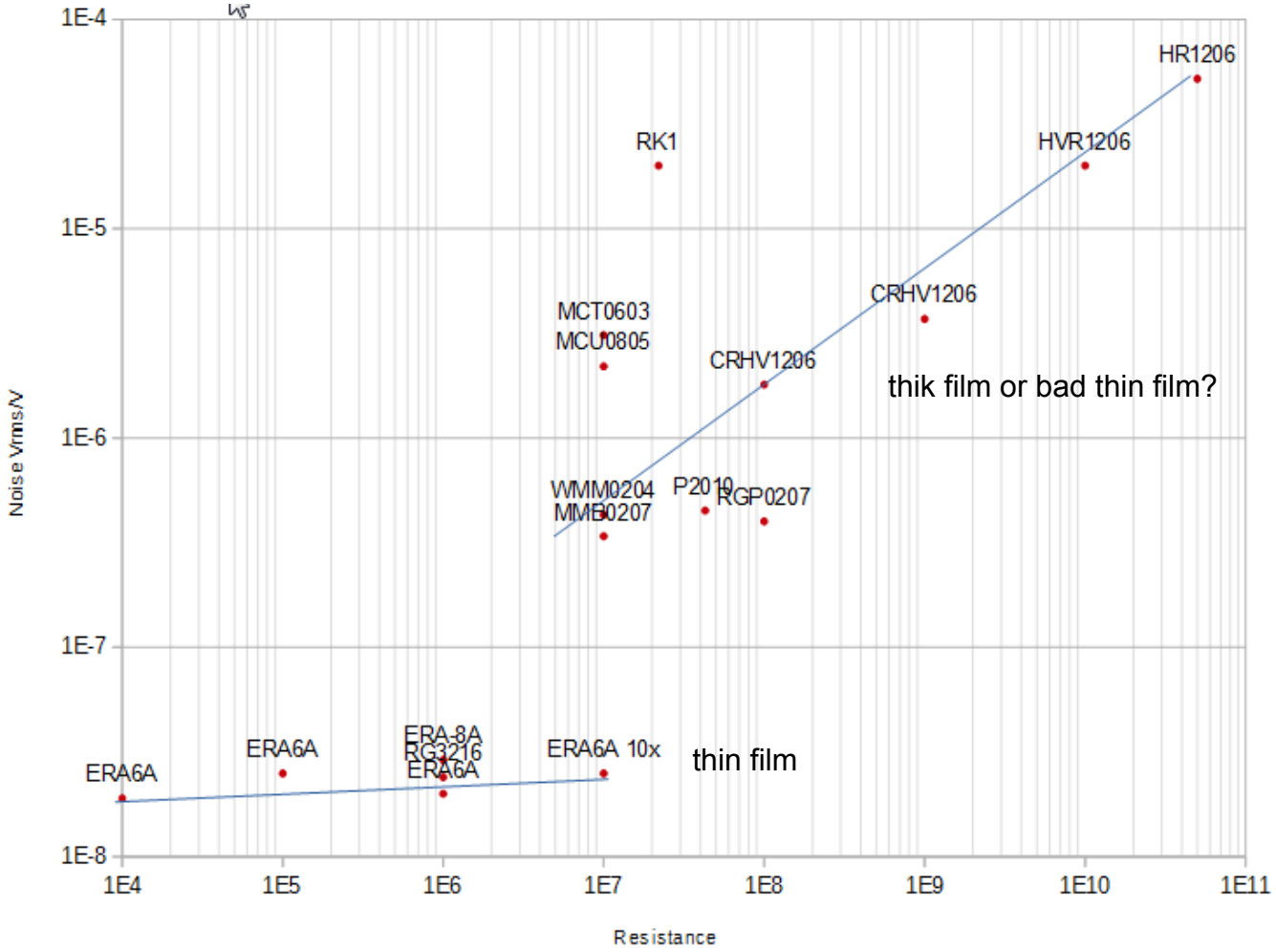

Figure 12 Results

Below 1E-7 are only thin film resistors.

Take care: not all as “thin film” declared resistors are thin film.

Example 1:

MCT06030C1005
Datasheet: Revision: 26-Oct-15

VISHAY

MCS 0402, MCT 0603, MCU 0805, MCA 1206 - Professional

www.vishay.com

Vishay Beyschlag

Professional Thin Film Chip Resistors

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DESCRIPTION

Production is strictly controlled and follows an extensive set of instructions established for reproducibility. A homogeneous film of metal alloy is deposited on a high grade ceramic substrate (Al_2O_3) and conditioned to achieve the desired temperature coefficient. Specially designed inner contacts are deposited on both sides. A special laser is used to achieve the target value by smoothly cutting a meander groove in the resistive layer without damaging the ceramics. For the high and low ohmic range, optimized Cermet products provide comparable properties. The resistor elements are covered by a protective coating

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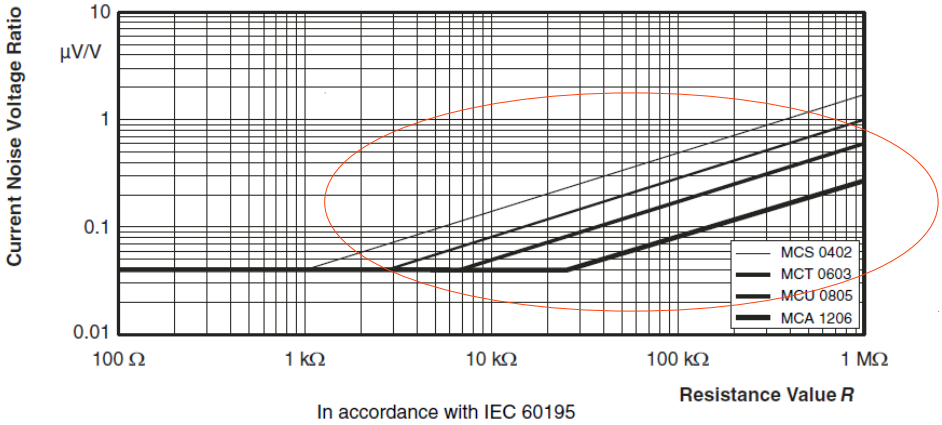
10/700 Pulse

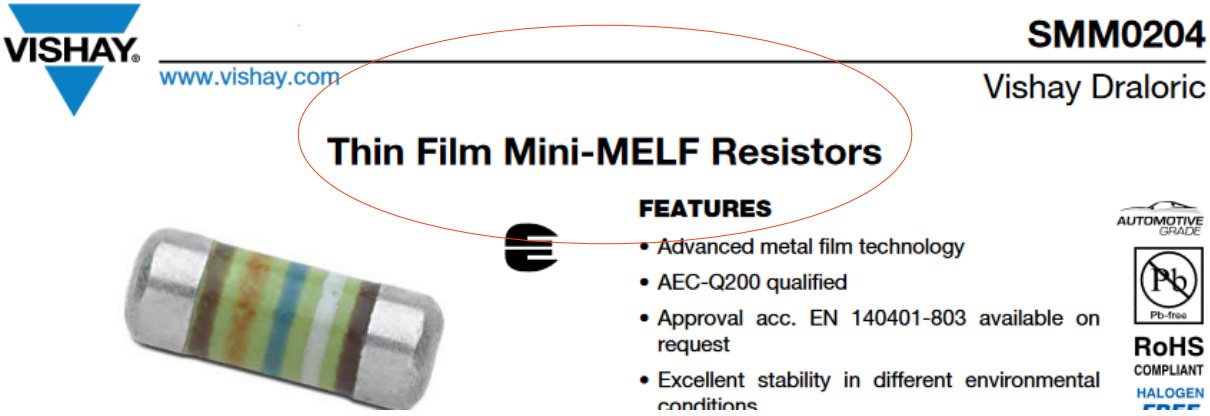


In accordance with IEC 60195

Thinfilm? No! At least not the ones with high resistance value. This datasheet is very unfair!

Example 2:
Revision: 21-Jul-16 Document Number: 20004

SMM02040C1005FB30



I could not find any hints why this title could be wrong.

But look at my measurements. I completely lost my confidence.

What I learn:
Some datasheet writers simply do not tell the truth.
Thin film resistors in size 0805 are available only up to 1 MOhm. Not higher.

An exeption, I guess, could be the CNS020-10MP from vishay/sfernice, but quite bulky. I have to test later.

If you find mistakes in this document: please give me a short feedback.