

INTERFERENCE ANALYSIS OF A LOW CURRENT MEASURING SYSTEM

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Abstract: Low current measurements are necessary to characterise modern electronic components and for the investigation of different physical and bioelectrical effects. The currents are mostly in the region of a few picoamperes to some femptoamperes within temperatures between – 60 °C and above 200 °C. Special difficulties are caused by several parasitic effects, influenced by the design and the applied materials of the measuring system. The presented paper separates and examines these effects. The measured results are compared with the simulations. The analysis of the results give technical conditions how to avoid these interferences and how to improve the design of low current measuring system.

Keywords: Measurement system, Interference analysis, Low current

1 INTRODUCTION

Low current measurements are necessary in different high-tech fields, e.g. to characterise modern electronic components or materials and for the investigation of different physical and bioelectrical effects [1,2 etc]. The currents are mostly in the region of a few picoamperes to some femptoamperes within temperatures between - 60°C and above 200 °C and are essentially under the limits of commonly used measuring instruments. Only a small number of commercial measuring system may be applied, but additional special difficulties are caused by several parasitic effects, influenced by the design and the applied materials of the measuring environments. In an industrial area leakage and noise currents may also modify this signal. Therefore it is necessary to separate and examine these effects. In this case one may expect information about the generation of the measured interferences and how to avoid this interferences and how to improve the design of a low current measuring system. The difficulties for the realised examinations are mainly caused by the fact, that many of the observed effects are in the literature described, but not evaluated. Therefore some simulations help to separate the observed effects although they are not to quantify. But these results are of general importance to avoid them in practice.

2 INTERFERENCES

Commonly low current measurements in the regarded region are loaded by the influence of the internal resistance of the source and the measuring system, parasitic capacitances and by leakage. These effects are well known but special examinations [4] have shown a high degree of external and internal static and dynamic influences (electromagnetic, magnetic and electrostatic interferences) arising in an industrial measuring system.

An industrial wafer prober e.g. with a thermo-chuck allows to heat or to cool the experimental surface in a short time and also to handle the probe. By further experiments with an industrial wafer prober including a thermo-chuck it was shown that the electromagnetic compatibility of the regarded system is a very important feature. But, a sufficient high electromagnetic compatibility is not only reached by a strict application of the generally given rules for system development and preparing its operation area. Additionally, interferences are also caused by non-electrical influences, like vibrations, the movement of cables or tubes. Examples of the measured effects are shown and compared with the simulations. From these results additional design rules are proposed. Internal sources of interference are mostly very critical and caused by many physical influences, like the electromagnetic induction, the thermoelectric, piezoelectric, pyroelectric or triboelectric effect. This situation will be more complicated additionally e.g. by temperature control, movement of components caused by the operator.

To reach defined test conditions and measuring results one has to ensure small temperature differences for the desired value. Therefore often Peltier-elements are added into the chuck. But, the heater and cooling system are supplied by special systems. For this purpose different control systems for

heating and cooling, like heater or chiller, respectively operating with separate mediums (air or fluid) are applied and show interactions like additional leakages, ground currents and additional sources of disturbances in the analogue systems.

For detecting critical paths of interferences (and of the sources) an industrial prober system was used with additional data logger and special test programs. The basic structure of a wafer prober is given in figure 1.

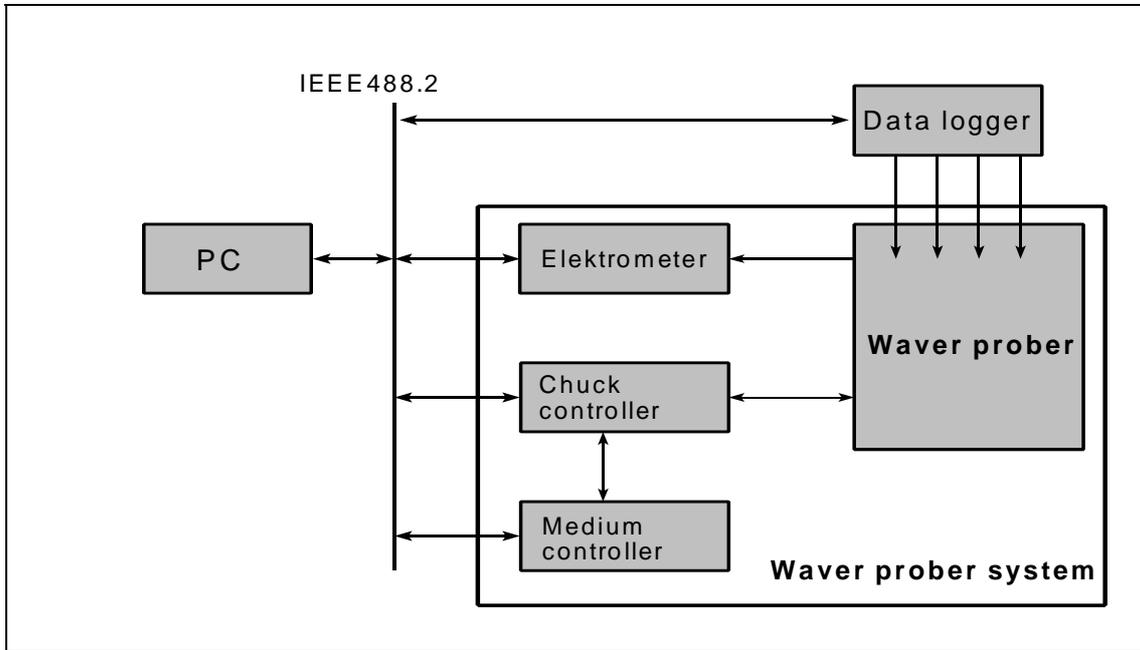


Figure 1. Measurement system with wafer prober

Additional sensors for temperature are adapted to special points in the wafer system, for example on the wafer layer and in the medium. Then the leakage current through the wafer layer is measured and recorded over the time for interesting temperature cycles. The different test modes are demonstrated in figure 2.

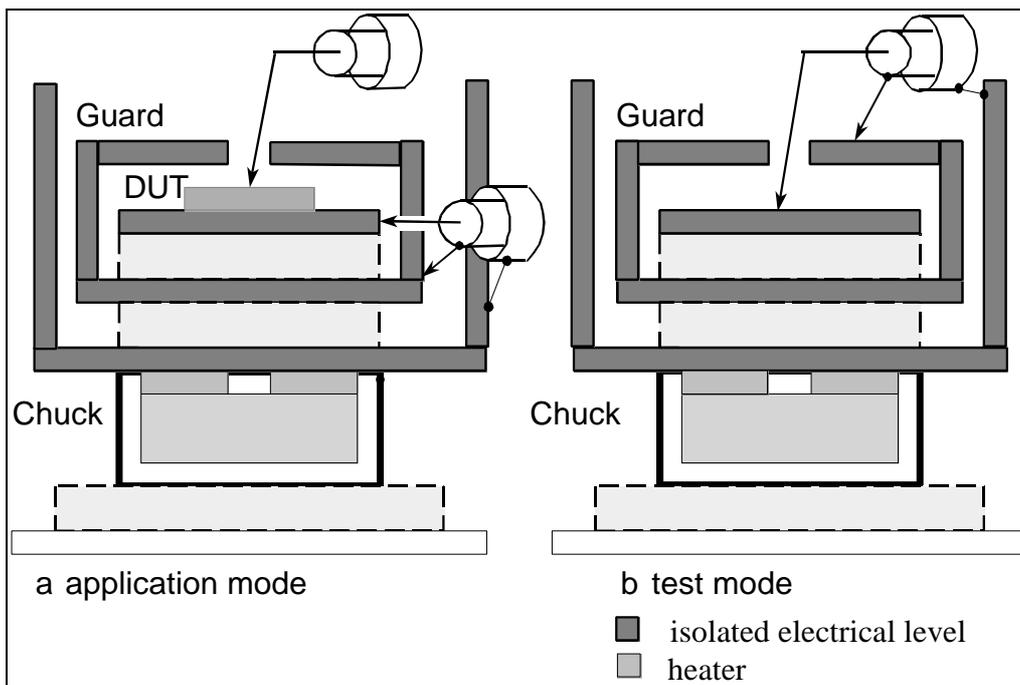


Figure 2. Measurement in application mode (a) and in test mode (b)

The main problem of testing is, that all measured interferences are the result of the interaction of different effects. The developed method to simulate the system and its components give the possibility to separate the effects step by step, excluding all other functional and parasitically influences. In this way one is able to detect the significance of any special effect out of the sum of all interferences and one is able better to interpret the results of measurements. The following task is to discuss the remaining uncertainty and to compare the theoretical results with the measured data.

To limit the parasitic currents in a chuck a structure shown in figure 2 is used. In application mode contains an active guard to eliminate the parasitic effects of the surroundings. But, by using of external standard measurement devices only a reduction of surrounding effects for static signals and in a captured status of the probe system is reached.

Generally a temperature control is desired. Therefore, the integration of a temperature sensor and a heater is necessary. Mostly, an electrical heater is used. Important for the design of the heater-cooler system are the acceptable maximal settling time and a guaranteed high precision for the whole region of the operation temperature. The additional electrical circuits interact through parasitic components (components with only mechanical function). Therefore save used high-resistance insulating materials.

But the material, the design of the heater and the temperature dependence of the resistance limits the insulation between the heater and the test layer. Therefore a leakage current, strongly arising with the temperature, is unavoidable. Physical limits are soon reached for current measurements in the region of a few fA (fig. 3 and 4). Additionally, in the case of discrete temperature control significant current spikes are induced into the measuring circuitry (fig. 4).

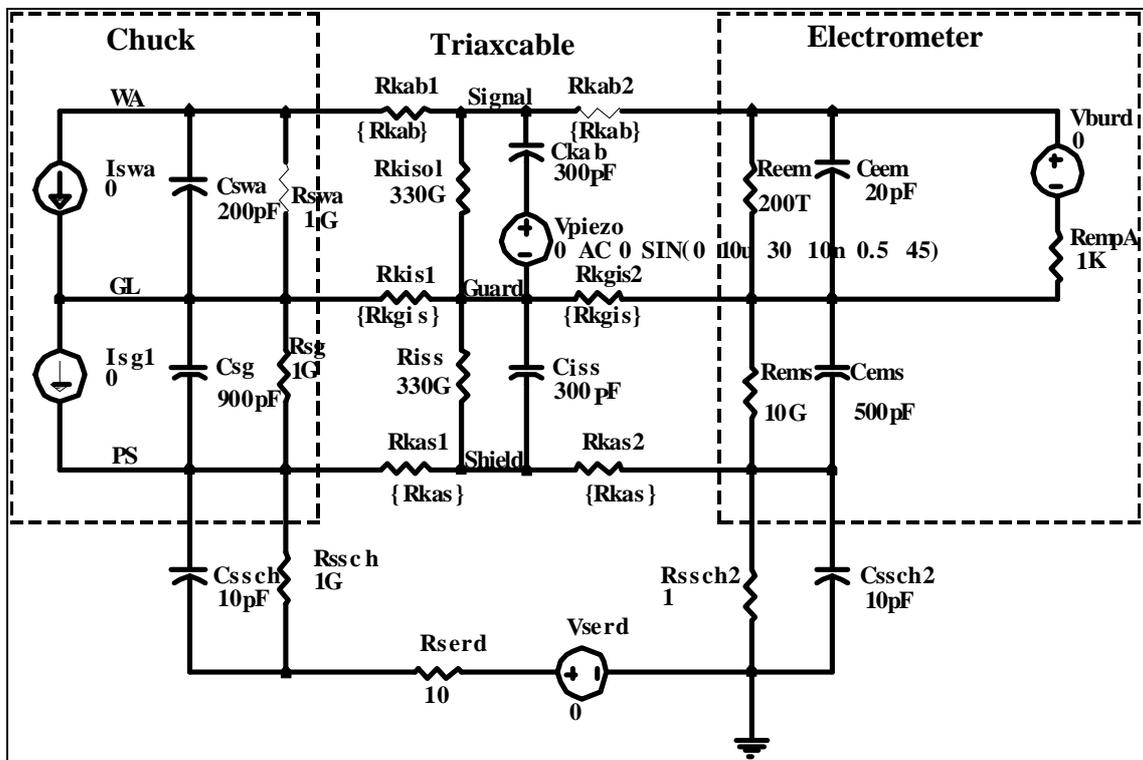


Figure 3. Electrical model of thermo-chuck

A successful way examine the different problems is to develop special model for every single effect. Any physical effect may be assumed as an action of an electrical source and components in each case. Figure 3 shows a PSPICE model for capacitive and galvanic coupling of heating circuit and test layer. All possible interferences are concentrated only in a few electrical sources. In a simulation step there is only one of them active. So we can see the influence of a separate effect to the measurement signal on the test layer. By comparing the results of several interferences one is able to classify the absolute amount and its importance for the resulting noise level. The result is a quantitative analysis for the sensitivity against different interference sources. With the different methods, which are implemented in PSPICE (like DC-, AC-, transient analyse), one is able to analyse the static and dynamic behaviour of the test object. One problem is, to define a suitable stimulating function, nearby the real physical interference source. In the discussed case it was sufficient, to take a simple behavioural description.

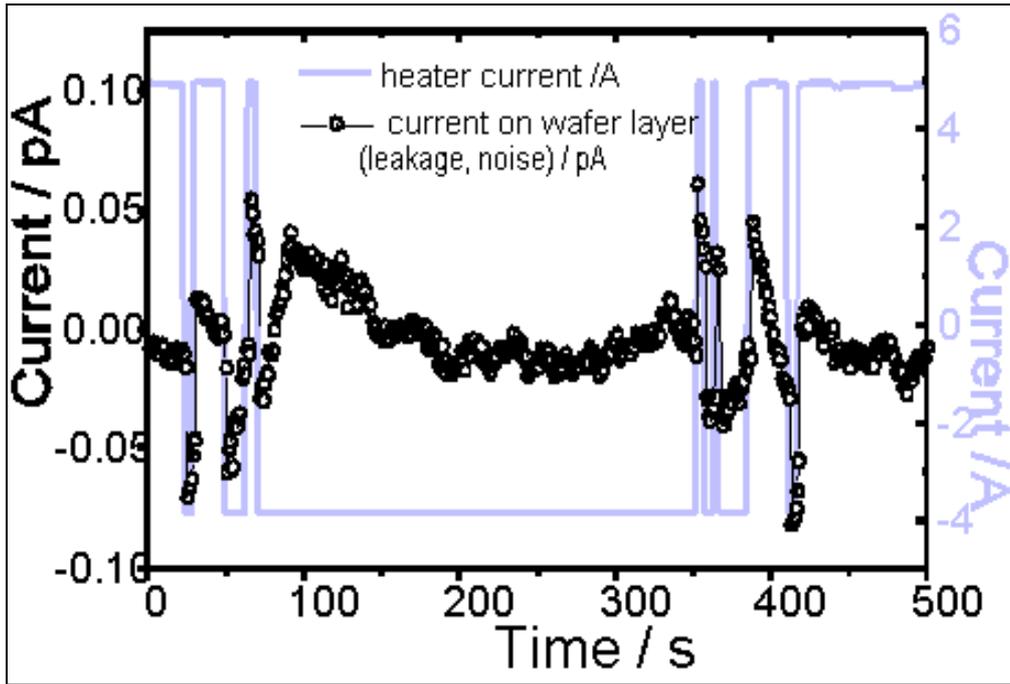


Figure 4. Measured interference current forced by heater

Fig. 4 shows a current, measured by active filtering and an integration time of one power-line cycle (plc). Of course, smaller steps of the heater current generate smaller spikes on the test layer, but they are not insignificant. But this method, fig. 4 shows the effect of the capacitive coupling, is sufficiently good. There is also shown, that by the high insulation resistance and the unavoidable capacitance (smaller than one nanofarad) causes a relative high time constant. This effects also a high measuring time. To eliminate this problem it is on principle necessary to find other system structure to reduce the power level and to use a heater controller without steps.

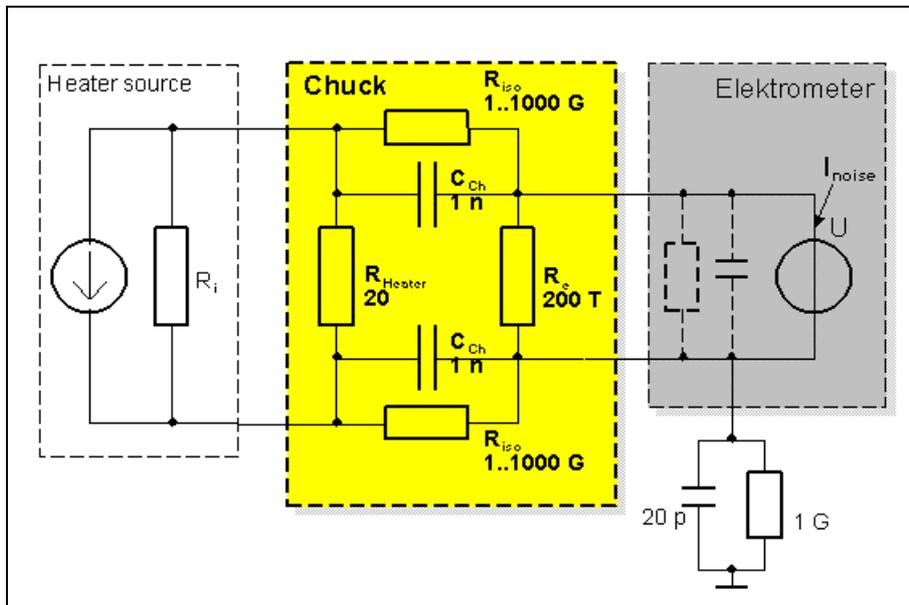


Figure 5. Electrical model for coupling of heater and layer

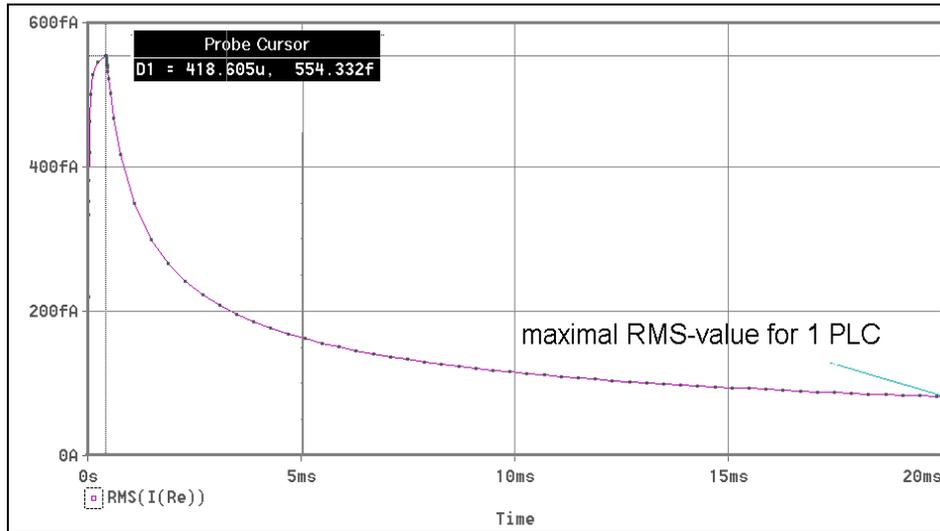


Figure 6. Simulated leakage current on test layer

The simulation of the leakage to ground has received good results. For wafer prober it is very important to control a lot of special conditions of measurements. Therefore one has to enclose any different and powerful subsystems with their own controller unit into the examinations. And of course, they have an electrical effect of interference into the test signal.

For example, one subsystem of the investigated wafer prober system with its supply was connected to a different phase. In this case the resulting interference was very remarkable. Ignoring this fact, a very high noise level is caused by the power line. The ground potential is then not ideal; line resistance and the resulting noise voltage can not be neglected. It was good to demonstrate the (known) possibility to avoid this problem by a good equalisation line (see fig. 7, signed elements).

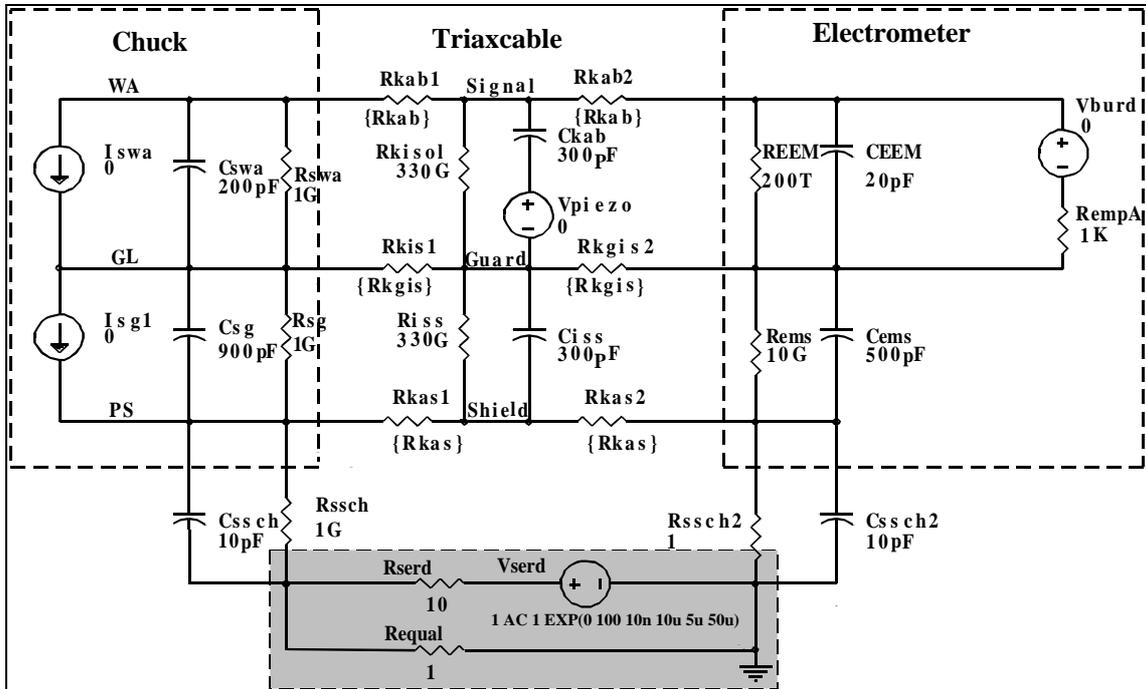


Figure 7. Electrical model for solving the earth problem

Another known but often-neglected problem is the triboelectric effect in high-impedance systems and cables. Mechanical stimulation (vibration, pressure) forces an undesired electrical charge. Therefore in such applications one has to use special low-noise cables. But nevertheless it is necessary to

realise special constructions to eliminate additional cable vibrations. This includes also a careful handling by the user.

The influence of the triboelectric effect shows fig. 8. The problem of this effect for any measurements is the very low generated noise frequency and its relative high amplitudes. Therefore it is not possible (or not practicable) to reduce this interference simply by normal integration time of any plc. The user has to avoid any vibration or - in the other case - have to respect the necessary long stabilisation time.

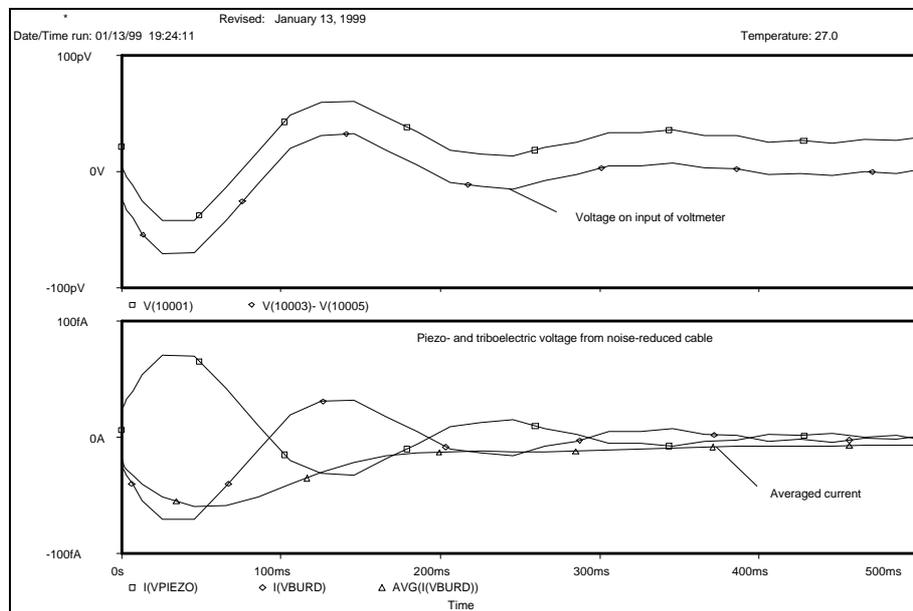


Figure 8. Results of simulation of model for piezoelectric and triboelectric noise

3 CONCLUSIONS

It was shown that many effects influence the measurements in the low current region. The simulations have shown that every cause leads to remarkable disturbances. The measurements have confirmed the simulations. By these results, the physical causes of electrical interferences could be discussed and investigated more exactly in the order of their importance. In this way one can define weighted rules to reduce the physical effects or to avoid interference signals, respectively to reduce the sensibility of the measured signal. In consequence the proposed measures to avoid this measuring errors have to be respected consequently. Rules for the design, for the choices of suitable materials and for the measuring environment are derived.

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