XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

SELECTED PROBLEMS OF DAQ SYSTEMS STANDARDISATION

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Abstract: Using modular DAQ systems, the precision of measurement depends not only on the quality of an AD module used, but also on the influence of disturbances. Therefore, before defining standards both for adequate EMC conditions in DAQ system cases and for the disturbance immunity of plug-in AD modules, suitable methods have to be designed and a number of measurements are to be executed. To prepare the knowledge for it, the following investigation has been made until now:
- design and verification of methods which allow the measurement of disturbing influences in DAQ systems
- design of methods for determination of disturbance immunity of AD modules and realisation of relevant equipment, a number of measurements were made
- definition of a disturbance immunity factor to compare the disturbance immunity of different types of AD modules.

Keywords: DAQ System, Standardisation, EMC conditions

1 INTRODUCTION

Precision and quality of dynamic measurements based on modular data acquisition systems are dependent both on dynamic parameters of the AD module used and the EMC conditions influencing the system. This can cause difficulties with correct use of commercially available products. For that reason, a new standard „Performance characteristics and calibration methods for digital DAQ systems„ is under preparation just now. The standardisation of stand alone waveform recorders has been documented by IEEE 1057 [1], tests of the dynamic quality of AD conversion will be covered by IEEE 1241 [2] and DYNAD. However, the list of parameters that should be standardised has to be discussed. In addition the EMC conditions in system cases and disturbance immunity of AD module used are also important parameters of the DAQ system´s quality. Some topics mentioned above were solved in a common project of the Czech Technical University - Faculty of Electrical Engineering in Prague (Czech Republic) and the Physikalisch-Technische Bundesanstalt in Berlin (Germany) [3].

2 DYNAMIC PARAMETERS OF AD MODULES

The data sheets of different ADC modules producers are characterised by great differences in specifying the parameters concerning the dynamic quality of AD modules. On the other hand, some parameters are defined differently. This complicates the comparison of different AD modules from different producers and the selection of optimal modules for particular applications.

The parameters concerning AD conversion are clearly defined in IEEE 1241 and in DYNAD. They should be declared for each AD module according to these standards and published in data sheets. However, also additional parameters describe the dynamic quality of AD modules:

- bandwidth,
- error by switching channels with a maximum voltage difference,
- crosstalk between channels.

Unfortunately, most of producers do not publish the parameters mentioned above in data sheets, and if they are published, their definitions are not often mentioned. Therefore it is necessary to define these parameters more precisely, and also to standardise testing methods.

3 EMC CONDITION IN SYSTEM CASES AND EXTERNAL DISTURBING

INFLUENCE

A disturbing magnetic field and disturbance propagating over supply lines cause a decrease in the real number of effective bits of an AD module used in modular DAQ systems [4], [5], [6]. Therefore, it is necessary to define standard EMC conditions in a system case (the maximum values both of an AC magnetic field in the AD module area and of AC components in supply voltages) and a maximum value of external disturbing magnetic field.

The real disturbing field, which influences the AD modules, have been measured. Measurements made till now were oriented towards PC systems, but the results can likewise be adopted for other modular DAQ systems. Disturbing fields influencing internal sources (power supply, main board, other plug-in modules) were investigated using a near-field probe at defined points of plug-in boards several years ago, but only the component perpendicular to the board was then measured. It was found out, that plug-in boards in adjacent slots are probably a main source of disturbing fields, above all network interface boards and graphical boards, but their disturbing fields are largely non-homogenous [6]. This is the reason, why theoretically estimated disturbance values of an AD module output, calculated for maximum values of the measured field, are several times higher than the experimental results.

That is why the average value of a disturbing field in defined areas should be measured to create a more realistic picture about the character of the disturbing field. Furthermore, additional measurements of disturbance immunity of plug-in boards showed that also the magnetic field component parallel to the board (see par. 4) can cause a significant disturbing effect. For this reason, a method for disturbing magnetic field measurement was modified. It makes it possible to measure now both the average value and the maximum value of a disturbing field in the area of the AD board analog input in all three main directions. The new testing plug-in board made from isolated material holds 10 measuring coils (see Fig. 1.) for measuring the average value of a disturbing field in their areas. Four of them (1 - 4) are determined for measurement of the component perpendicular to the board, 4 coils (5 - 8) for the component parallel with the plug-in board and perpendicular to the mother-board, and 2 coils (9, 10) for the component parallel both with the plug-in board and with the mother-board. The constants of these coils were determined using HF Helmholtz coils. The maximum values of disturbing fields in the areas of these coils and in the same direction were measured using a near-field probe as formerly.

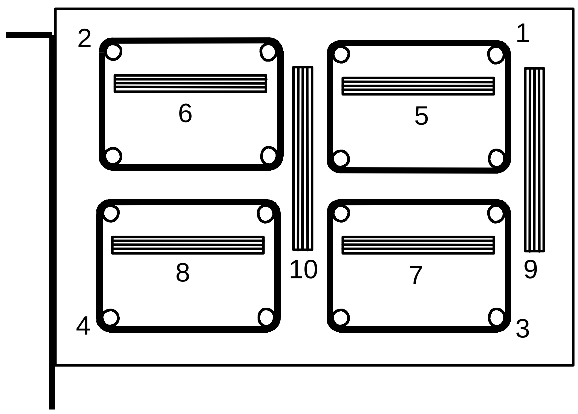


Figure 1. The testing plug-in board with 10 measuring coils

The new experiments were executed and the results measured in one desktop PC are published in Table 1 as an example (A - empty PC - the farthest slot from power supply; B - empty PC - the nearest slot to power supply; C - the graphical board in the neighbouring slot; D - the network board in the neighbouring slot [component on the side near to the testing board]; E - the network board in the neighbouring slot [component on the opposite side then the testing board]; F - the testing plug-in board between network board [component on the opposite side then the testing board] and graphical board; for C - F the measuring board was placed in the last but one slot from power supply).

In all cases also the spectrum of induced voltages was measured, but it is not possible to publish here all results of spectral analysis. However, based on all such results the standard EMC condition in a PC case could be defined.

Table 1. Values of $f_D H_D$ in the area of measuring coils in kHz.A/m, f_D is the fundamental of dist. field

		Measuring Coil									
Configuration	f_D (kHz)	1	2	3	4	5	6	7	8	9	10
A	250	4	4	9	7	1	1	7	4	3	0
B	250	11	10	14	30	7	13	5	8	36	4
C	250	4	5	9	7	6	6	10	14	8	20
D	250; 317	6	5	24	63	12	20	54	52	9	105
E	250; 317	10	2	29	48	8	18	40	28	14	81
F	250; 317	10	7	29	54	8	18	41	46	15	84

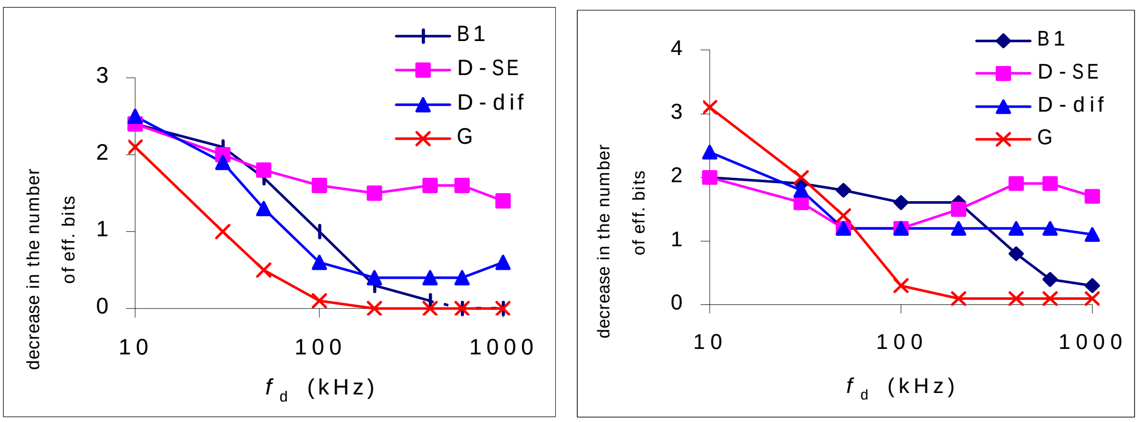
Several external sources of disturbing magnetic fields were analysed several years ago [4]. An area near pulse controlled asynchronous engine was examined as an example of an industrial environment. The main sources of disturbing fields were the power resistors used as control elements. Another source of a disturbing magnetic field was the PC monitor. There were no significant differences among tested monitors, but the graphic mode used is important. The measured values can also be used as a base for limits of a conventional EMC environment in a system case.

Also a disturbing component can arise in the output signal due to an AC component of the supply voltage. The waveform, amplitude, RMS value, and spectrum of disturbing components of supply voltages were measured in several types of PCs to know typical parameters of disturbance propagating over supply lines. This was done in PCs without plug-in boards in slots, because the inserted plug-in boards owing to blocking capacitors, make in most cases the AD component in the supply lines smaller [5].

4 DISTURBANCE IMMUNITY OF AD MODULES

4.1 Enlargement of measuring system for AD modules testing

Methods were designed [4] for disturbance immunity measurements. The system for testing PC plug-in boards with ISA interface was realised earlier, and a number of measurements were executed [5]. The new Helmholtz coils were designed and manufactured, to increase the frequency range to 1 MHz, and the first measurements were executed. The results are shown with Fig. 2. In this extended frequency range it is necessary to take into consideration also the bandwidth of tested modules for different gains (see board B1 - the bandwidth is 200 kHz for G = 10 and 40 kHz for G = 100), or frequency dependence of shielding effect (see board G).



a) $f_D H_D$ = 20 kHz.A/m, G=100 b) $f_D H_D$ = 100 kHz.A/m, G=10

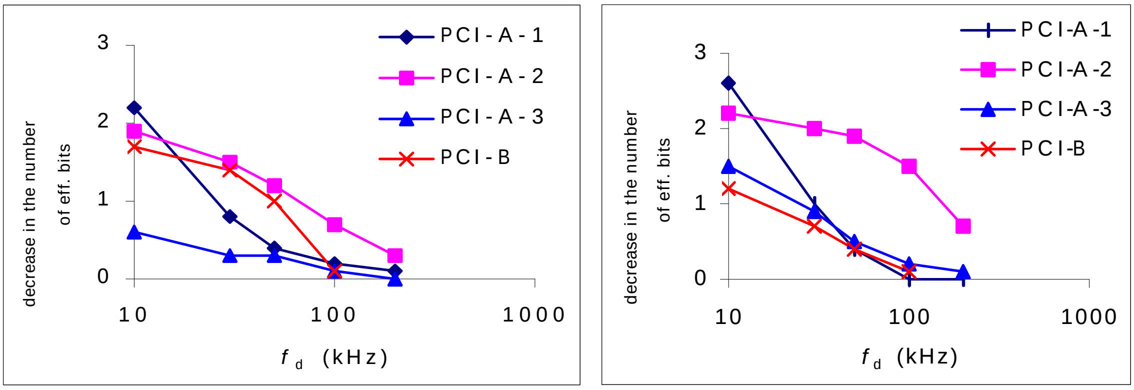
Figure 2. Frequency dependence of the decrease in the number of effective bits

The system was extended this year also for the PCI bus and PCMCIA cards. The problem of PCI boards, where no extension box can be used, was already solved. A tested PCI AD plug-in board is placed in a mother board outside of PC case where no other plug-in boards are present. Both the power supply and the hard disk are placed outside of Helmholtz coils in distance of about 0.5 m from the tested board. The results of PCI board testing are presented in Fig. 3. The influence of all three components was tested at first for the board marked PCI-A (16 bits board, bandwidth 57 kHz for

G = 10, 33 kHz for G = 100). The test for a component perpendicular to the plug-in board is marked A-1, parallel with the plug-in board and perpendicular to the mother-board is marked A-2, and parallel both with the plug-in board and with the mother-board is marked A-3. The board marked PCI-B is a 12-bits board without shielding and with a bandwidth 225 kHz.

Concerning PCMCIA cards, the PCMCIA-ISA interface is used to apply an ISA extension box also in this case.

Achieved results can constitute a base for standard methods for disturbance immunity measurements of AD modules. The parameters of a disturbing influence should be determined according to the results of a real measurement according par. 3.



a) $f_D H_D$ = 20 kHz.A/m, G=100 b) $f_D H_D$ = 100 kHz.A/m, G=10

Figure 3. Frequency dependence of decrease in the effective number of bits for tested PCI boards

4.2 Disturbance immunity factor

To describe the disturbance immunity of different types of AD boards, the disturbance immunity factor *DIF* was defined (see [5] in detail):

$$DIF_{U_R} = \frac{D}{U_D / (U_R / 2\sqrt{2})} \qquad (1)$$

where U_D is the RMS value of the disturbing component in the output signal of a tested module corresponding to the defined disturbing field,
U_R is the input range of a tested module (e.g. for declared input range ± 0,5 V is U_R = 1 V),
D is the defined value of disturbance ($D = f_D H_D$ for disturbing magnetic field, or the RMS value of the AC component of the supply voltage for disturbance propagating over supply lines)

Unfortunately, the value of the DIF_{UR} calculated according this definition is strongly dependent on the setting input range (setting gain G). To use this parameter in a standard, it should be recalculated for a basic input range, which is usually ± 5 V (U_R = 10 V). In this case.

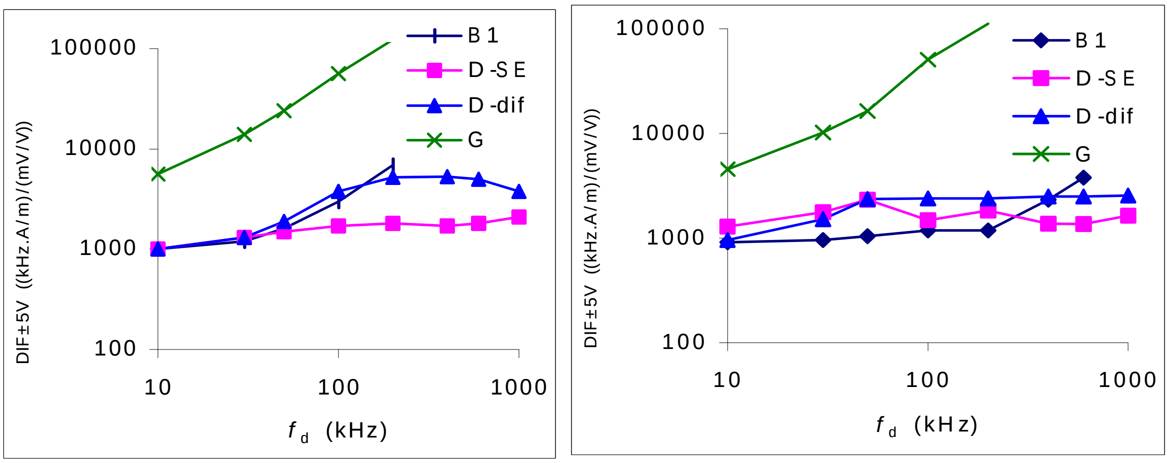
$$DIF_{\pm 5V} = DIF_{U_R}\, G = \frac{D}{U_D / (U_R / 2\sqrt{2})}\, G = \frac{10}{2\sqrt{2}}\,\frac{D}{U_D}\, G \qquad (2)$$

where $G = 10/U_R$ for this purpose.

This parameter is theoretically independent on the input range. Therefore it should be convenient to apply high gain for *DIF* measurement to increase a disturbing effect and then recalculate the parameter DIF_{UR} to the basic range ± 5 V ($DIF_{\pm 5V}$). However, in real case there is a certain small dependence on the setting range (e.g. different loops for different ranges, in which the disturbing voltage is induced etc.). Therefore the DIF_{UR} for several low-voltage ranges should be measured, then recalculated to the $DIF_{\pm 5V}$, and the most pessimistic result (minimum value) should be used as a typical parameter for a tested board. In the case, when the input bandwidth is dependent on the set gain, the gain, by which the measurement was originally made, must be mentioned. The calculated values of

$DIF_{MF,\pm5V}$ for the boards mentioned above (see Fig. 2) are displayed in Fig. 4. In Fig. 4a were the value calculated from measured results for the gain G = 100, in Fig. 4b for the gain G = 10. It is perceptible that the results are near the same except for the board B, where the input bandwidth is dependent on the set gain.

The results for tested PCI boards mentioned above (see Fig. 3) are also very interesting. The calculated values of $DIF_{MF,\pm5V}$ are displayed in Fig. 5. The test for the component perpendicular to the mother-board is marked A-1, for the component parallel both with the plug-in board and with the mother-board is marked A-2. The *DIF* for the component perpendicular to the plug-in board increases with frequency faster than the component parallel with the plug-in board and perpendicular to the mother-board The board marked PCI-B is a 12-bits board without shielding and with the bandwidth 225 kHz.



a) G=100 b) G=10

Figure 4. Frequency dependence of the $DIF_{MF,\pm5V}$ for ISA boards

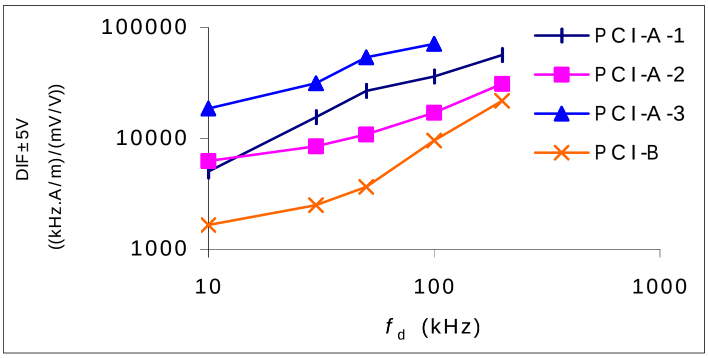


Figure 5. Frequency dependence of the $DIF_{MF,\pm5V}$ for tested PCI boards

If the $DIF_{\pm5V}$ and ideal resolution (*n*) is known, a decrease in the number of effective bits can be calculated by use of it for all input ranges. The used equation can be derived from the well known formula for the number of effective bits of an ideal ADC under disturbing influence (see [5] in detail).

$$n_{ef}^{/} = \frac{1}{6.02}\,20\log\frac{U_R}{2\sqrt{2}\sqrt{U_q^2+U_N^2}} - \frac{1.76}{6.02} \qquad (3)$$

where U_R is the ADC range used, U_N is the RMS value of the output noise caused by a disturbance, and U_q is the RMS value of the quantisation noise. After modification, the decrease in the number of effective bits for a defined value of disturbance D (e.g. $D = f_D H_D$ for disturbing field), number of bits n, gain G, and disturbance immunity factor $DIF_{\pm 5V}$ for basic input range ± 5 V can be calculated from

$$\Delta n_{eff} = n - 1.66 \log \left[\frac{2}{3.2^{2n}} + \left(\frac{D}{DIF_{\pm 5V} . G} \right)^2 \right] + 0.292 \qquad (4)$$

for all input ranges. The calculated decrease is of course only valid in an ideal case, when only the one influence affects the AD module. When several influences affect the module, the dependence is more complicated. In spite of this imperfection this way makes it possible to define, by which condition the specified parameters are valid and how it changes by disturbing influence transitions.

The determination of the *disturbance immunity classes* (DI classes) of AD modules should be the next step of standardisation. They can be defined based on knowledge of:

- the $DIF_{\pm 5V}$ determined according par. 2.2 for the number of AD modules, the defined
- standard EMC condition (disturbing limits) in a system case estimated according to par.2.1,
- in relation to the decrease in the number of effective bits calculated according to (4).

The four DI classes could be proposed as the first idea:

A	16 bit AD board:	$\Delta n_{eff} < 0.5$ for gain G = 2 and $\Delta n_{eff} < 1$ for gain G = 5
B	16 bit AD board:	$\Delta n_{eff} < 0.5$ for gain G = 1 and $\Delta n_{eff} < 1$ for gain G = 2
	12 bit AD board:	$\Delta n_{eff} < 0.5$ for gain G = 20
C	12 bit AD board:	$\Delta n_{eff} < 0.5$ for gain G = 5 and $\Delta n_{eff} < 2$ for gain G = 20
D	12 bit AD board:	$\Delta n_{eff} < 0.5$ for gain G = 5 and $\Delta n_{eff} < 2$ for gain G = 20

5 CONCLUSION

Using modular DAQ systems, low disturbance or even ideal EMC conditions are not a realistic case, thus the precision of measurements depends not only on the quality of an AD module used, but also on the influence of both the internal EMC conditions in the system case and an external disturbing field. Main important factors are the disturbing magnetic field and non-ideal supply voltages. This has been confirmed by measurements made till now. That is why standardisation must take into account both EMC conditions in a DAQ system case and disturbance immunity of plug-in AD modules.

To prepare the knowledge for this standardisation, the following investigation has been made until now and other have to be made in the near future:

The tasks, which have been finished	What will be necessary to do
a method which makes it possible to measure the disturbing influences in PC DAQ systems has been designed and verified	to execute more measurements for PC, to enlarge this methods for notebooks, IPC, Compact PCI, and IPCI, and execute necessary measurements
a method for determination of disturbance immunity of AD modules has been designed, the relevant equipment for PC DAQ systems with ISA bus was realised, and a number of measurements were done	to realise the relevant equipment for PC DAQ systems with PCI bus, for PC Card (it is developed now), Compact PCI, and IPCI, to execute necessary measurements
a method for definition of the disturbance immunity classes of AD modules has been designed	to define the disturbance immunity classes of AD modules for individual types of systems

ACKNOWLEDGEMENT

The results of the project No. 101/98/1508 „*New methods for testing of systems for dynamic measurement*“ which is supported by the Grant Agency of the Czech Republic and of the research project J04/98:210000015 „*Research of New Methods for Physical Quantities Measurement and Their Application in Instrumentation*“ were used in this paper.

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