

ZERO PHASE FILTER



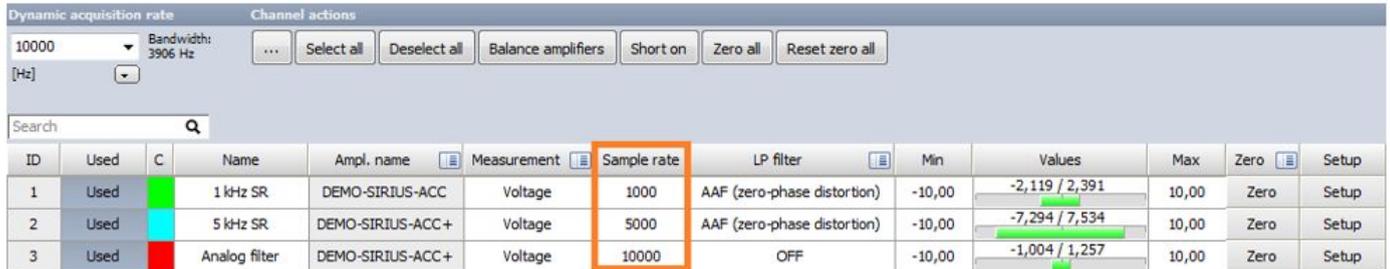
SOFTWARE USER MANUAL

ZERO PHASE FILTER V20-1



Anti-aliasing filters with zero phase distortion

Dewesoft has a possibility to set different sample rates on different channels in Channel setup.



ID	Used	C	Name	Ampl. name	Measurement	Sample rate	LP filter	Min	Values	Max	Zero	Setup
1	Used		1 kHz SR	DEMO-SIRIUS-ACC	Voltage	1000	AAF (zero-phase distortion)	-10,00	-2,119 / 2,391	10,00	Zero	Setup
2	Used		5 kHz SR	DEMO-SIRIUS-ACC+	Voltage	5000	AAF (zero-phase distortion)	-10,00	-7,294 / 7,534	10,00	Zero	Setup
3	Used		Analog filter	DEMO-SIRIUS-ACC+	Voltage	10000	OFF	-10,00	-1,004 / 1,257	10,00	Zero	Setup

Figure 1: Channels with different sample rates.

On each signal, which has sample rate less than acquisition rate, decimation is performed. With a lower sample rate, we have to take care of signal aliasing. For dynamic acquisition sample rate there is analog filter on hardware, to filter out frequencies, higher than Nyquist frequency, to avoid aliasing. Nyquist frequency is half of the sampling rate of a signal. For lower sample rates, Dewesoft uses digital anti-aliasing filters. It is possible to choose between an *Anti-aliasing filter (IIR)* and *AAF (zero-phase distortion)*.

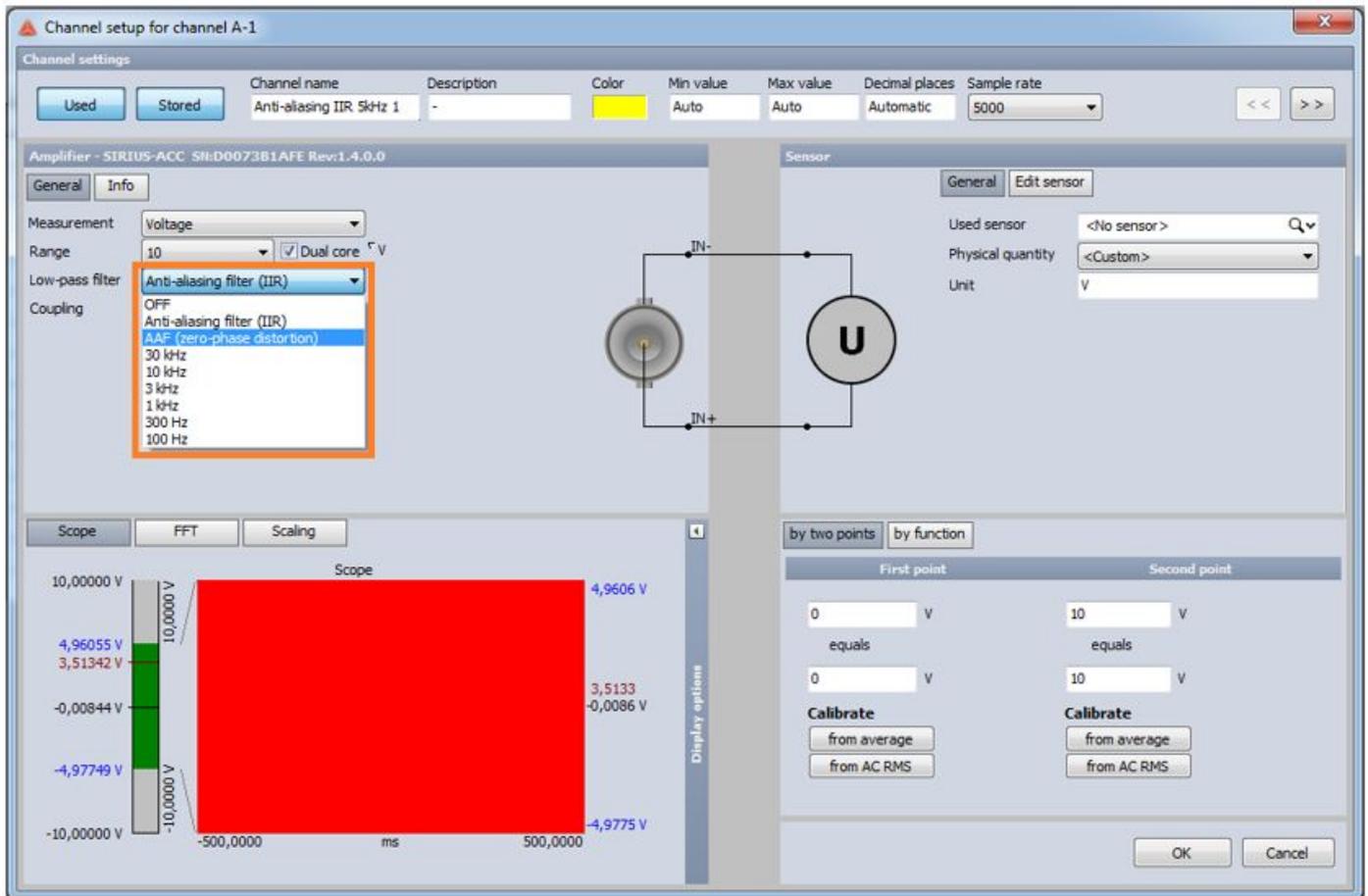


Figure 2: Anti-aliasing filter options.

IIR filters have phase delay depending on cutoff frequency. In applications, where there is phase information needed, e.g. torsional vibration, phase delay would corrupt results (AC signals). Here comes in zero phase distortion filters, which have attenuation slope symmetrical on both sides of ideal cutoff frequency and as the name implies, they have linear phase delay. Compared to IIR filters, which have -3 dB point at cutoff frequency, here signal is attenuated for 6 dB at cutoff frequency (-6 dB point). In other words, magnitude is attenuated by half at -6 dB point (cutoff frequency). For applications described before, zero phase distortion filters are suitable as they do not cause any phase shifts and have also sharper attenuation.

Anti-aliasing IIR filters have cutoff frequency defined as $(\text{sample rate})/2.56$, since also analog filters are defined that way. For example, a channel with sample rate 1000 Hz, has -3 dB point at approximately 400 Hz. At zero phase distortion anti-aliasing filters, cutoff frequency is set to $(\text{sample rate})/2$, so attenuation of signal doesn't start too early. In terms of the previous example, cutoff frequency would be at 500 Hz.

Figure 3 shows that this is the optimal setting for cutoff frequency of zero phase distortion filters. Normalised frequency is denoted with ω , $0 \leq \omega \leq 1$, cutoff frequency is denoted with ω_c and Nyquist frequency with ω_{Nyq} . Aliasing starts at Nyquist frequency.

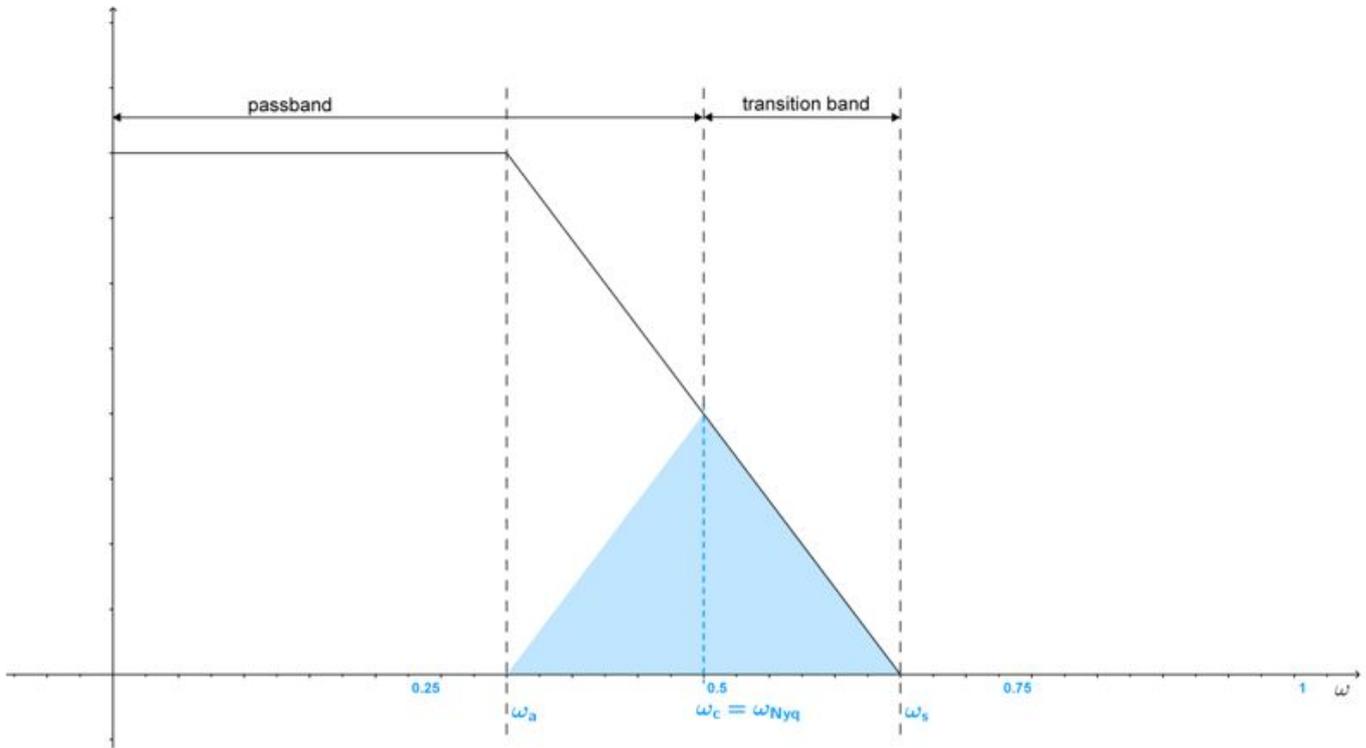


Figure 3: Magnitude response of zero phase distortion filter. Blue triangle shows aliases if .

Blue triangle represents a region with aliases when cutoff frequency, ω_c , equals Nyquist frequency. This is now the case in Dewesoft. Blue region is present in the area, where attenuation has already started. But if cutoff frequency would be set any higher, aliases would be present in signals where attenuation hasn't started yet. This implies that current settings in Dewesoft are optimal.

Transition band width is an important filter property that defines sharpness of roll-off. Noise floor begins at ω_s and roll-off start frequency is denoted with ω_a , according to Figure 3. These two frequencies are symmetrical with respect to ω_c .

Specifically, in Dewesoft, noise floor is defined at -70 dB and inside an optimally flat pass band, that's before the start of roll-off, there is $\pm 1\%$ of amplitude error.

In Advanced settings's Hardware tab, under the Digital filters section there are two options for AAF (zero-phase distortion) transition width; Auto adjust and User defined (Figure 4).

- Auto adjust

By default, the Auto adjust option is selected. Dewesoft's zero phase distortion anti-aliasing filter's edge of transition band or in other words, beginning of noise floor, is set to $\omega_s = 0.66 \cdot \text{sample rate}$, hence transition band width is equal to 16% of sample rate. Symmetrically, attenuation starts at $\omega_a = 0.34 \cdot \text{sample rate}$.

Because of limited computing power, the auto adjust option is recommended, as it has set an upper limit for number of filter's coefficients. Above described settings for transition band width (16% of sample rate) are valid up to the predefined ratio acquisition sample rate:sample rate=100:1.

What happens, when a larger ratio is used on a channel as 100? Upper limit for the number of coefficients of zero phase distortion filters is set to 1800 coefficients. When this limit is exceeded at filter design (larger ratio than 100 was used), wanted transition band width can not be reached anymore. Transition band width starts to expand according to equation

$$TBW = \frac{11.13 \cdot SRRatio}{4 \cdot N},$$

where TBW represents normalised transition band width, SRRatio is sample rate ratio, N is number of filter coefficients and scale factor 11.13 derives from some particular filter design method.

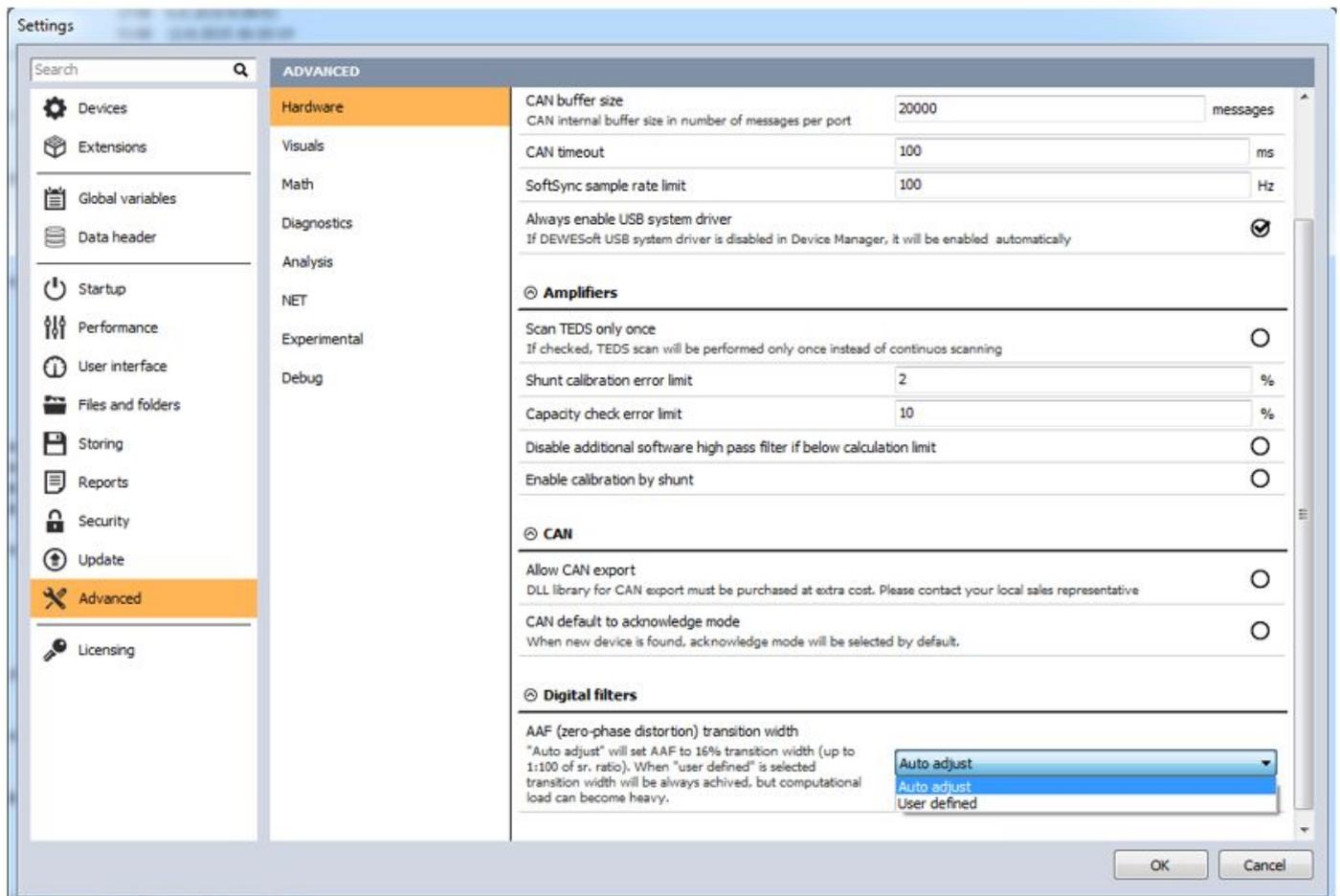


Figure 4: AAF (zero-phase distortion) ratio settings.

Let's use the upper equation; we take default SRRatio=100 and for 16% of sample rate transition band width we have TBW=0.16. This results in 1739 filter coefficients. Now consider the case, where the upper

limit is exceeded. Take a larger ratio than 100, let's say $SRRatio=125$ and the same TBW. As a result, we get 2174 filter coefficients, which is over the limit, so 1800 coefficients will be taken instead. In this case, normalised transition bandwidth is expanded to $TBW=((11.13 \cdot 125)) / ((4 \cdot 1800) \approx 0.19)$, i.e. 19% of sample rate in previously used terms. For lower acquisition sample rate dividers, we get less coefficients than limit value.

For example, if the acquisition sample rate is 20 kHz, then transition band width equals 16% of sample rate up to sample rate ratio of 100, i.e. 200 Hz sample rate. Any lower sample rate (less than 200 Hz), will result in expanded transition band width.

- User defined

With this option it is possible to set arbitrary transition band width in percentage of sample rate. Auto adjust option has this value always set to 16%. Here there is no upper limit for the number of coefficients, hence transition band width will always be exact. But at higher sample rate ratios (more than 100), calculation can be too slow because of large amount of filter coefficients.

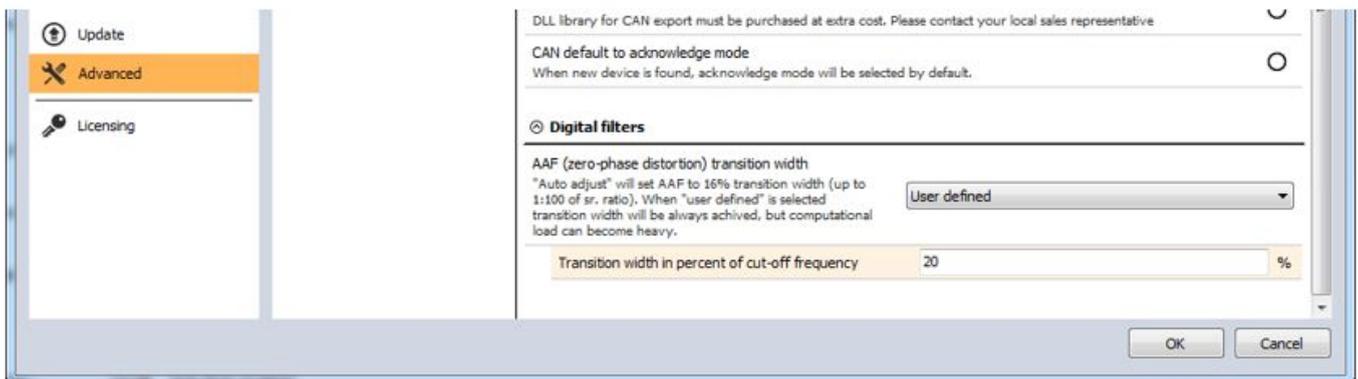


Figure 5: User defined AAF (zero-phase distortion) transition band width

Both of the upper options are limited with maximal allowable calculation delay, which means that the number of coefficients can never exceed 20% of acquisition sample rate. For example, if the Auto adjust option is selected and the acquisition sample rate is 1000 Hz, the upper limit for the number of filter's coefficients will be already at 200 and not 1800.

Below there is comparison between attenuation slope of IIR and zero phase distortion filters.

For the first example, dynamic acquisition rate was set to 10 kHz and sine sweep from 10 Hz to 10 kHz with amplitude ± 5 V and duration of 180 seconds was used on all channels.

ID	Used	C	Name	Ampl. name	Measurement	Sample rate	LP filter	Min	Values	Max	Zero	Setup
1	Used	Green	1 kHz SR IIR	SIRIUS-ACC+	Voltage	1000	Anti-aliasing filter (IIR)	-10,00	-4,950 / 4,950	10,00	Zero	Setup
2	Used	Cyan	1 kHz SR ZPD	SIRIUS-ACC+	Voltage	1000	AAF (zero-phase distortion)	-10,00	-4,950 / 4,950	10,00	Zero	Setup
3	Used	Red	Analog filter	SIRIUS-CHG	Voltage	10000	OFF	-10,00	-4,965 / 4,966	10,00	Zero	Setup

Figure 6: First example's setup.

On the first two channels we have 1000 Hz sample rate, on first there is anti-aliasing IIR filter used and on second there is zero phase distortion anti-aliasing filter set. Last, the third channel has sample rate equal to acquisition rate, 10 kHz, which means that analog filter from hardware will be used, no matter the anti-aliasing filter setting.

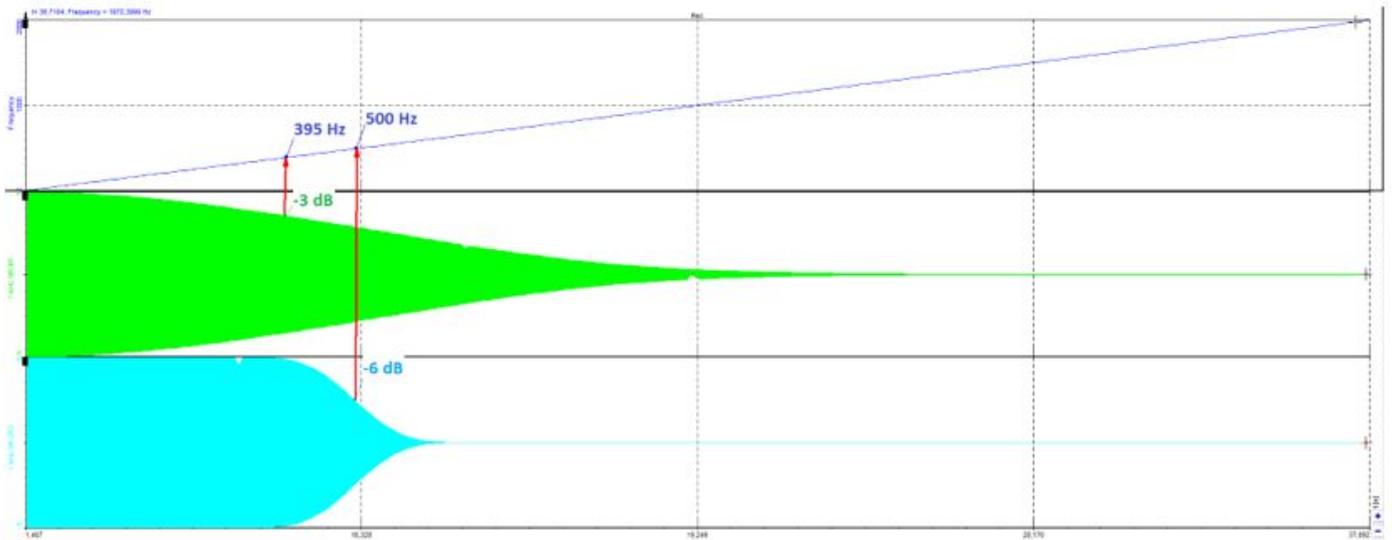


Figure 7: Comparison between IIR and zero phase distortion anti-aliasing filter at sample rate.

Green signal was filtered with IIR filter and blue signal has zero phase distortion anti-aliasing filter. Attenuation starts later at second one (blue), at approximately 340 Hz. At first one attenuation starts immediately. On Figure 7 are marked -3 dB and -6 dB points.

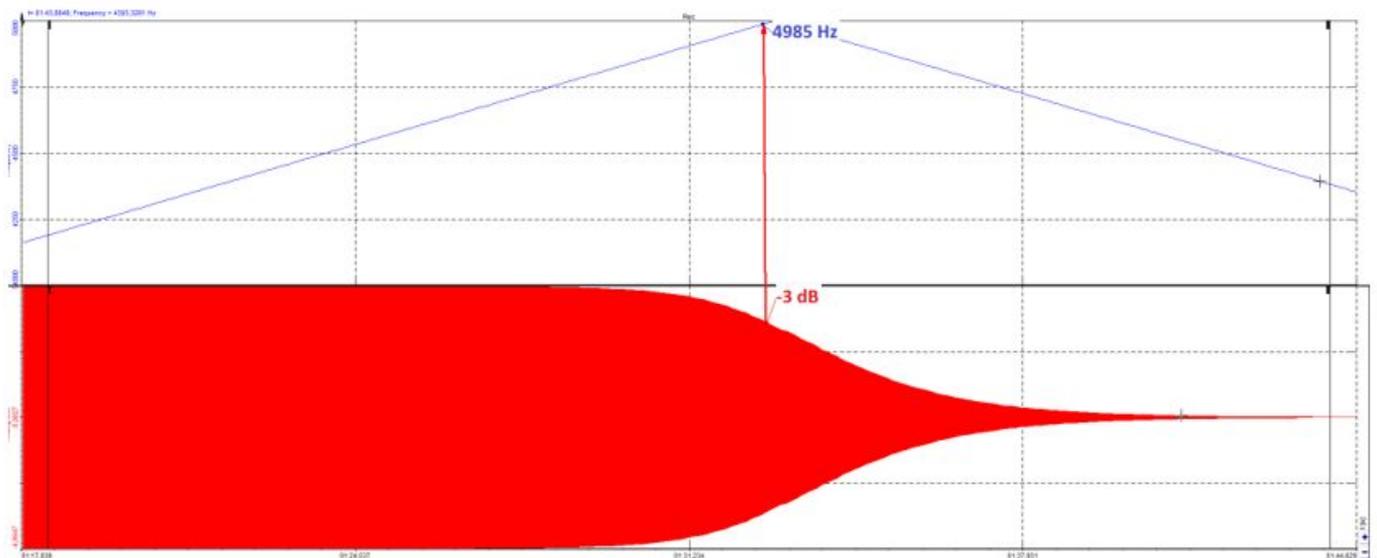


Figure 8: Signal with 10 kHz sample rate.

Sample rate of signal on Figure 8 is equal to acquisition rate, therefore no decimation is needed and digital anti-aliasing filter is not used (no matter what your anti-aliasing filter setting is, in this example it is set on OFF). Here is used an analog filter, -3 dB point is at approximately 5000 Hz, attenuation starts at around 4600 Hz.

For the second example, dynamic acquisition rate was set to 20 kHz and sine sweep from 100 Hz to 20 kHz with amplitude ± 5 V and duration of 180 seconds was used on all channels.

ID	Used	C	Name	Ampl. name	Measurement	Sample rate	LP filter	Min	Values	Max	Zero	Setup
1	Used	Green	10 kHz SR IIR	SIRIUS-ACC+	Voltage	10000	Anti-aliasing filter (IIR)	-10,00	-5,008 / 5,003	10,00	Zero	Setup
2	Used	Cyan	10 kHz SR ZPD	SIRIUS-ACC+	Voltage	10000	AAF (zero-phase distortion)	-10,00	-5,008 / 5,003	10,00	Zero	Setup
3	Used	Red	Analog filter	SIRIUS-CHG	Voltage	20000	OFF	-10,00	-5,008 / 5,003	10,00	Zero	Setup

Figure 9: Second example's setup.

Similar to the first example, the first two channels have 10000 Hz sample rate, first has anti-aliasing IIR filter used and second has zero phase distortion anti-aliasing filter. Last, the third channel has sample rate equal to acquisition rate, 20 kHz, so analog filter from hardware will be used.

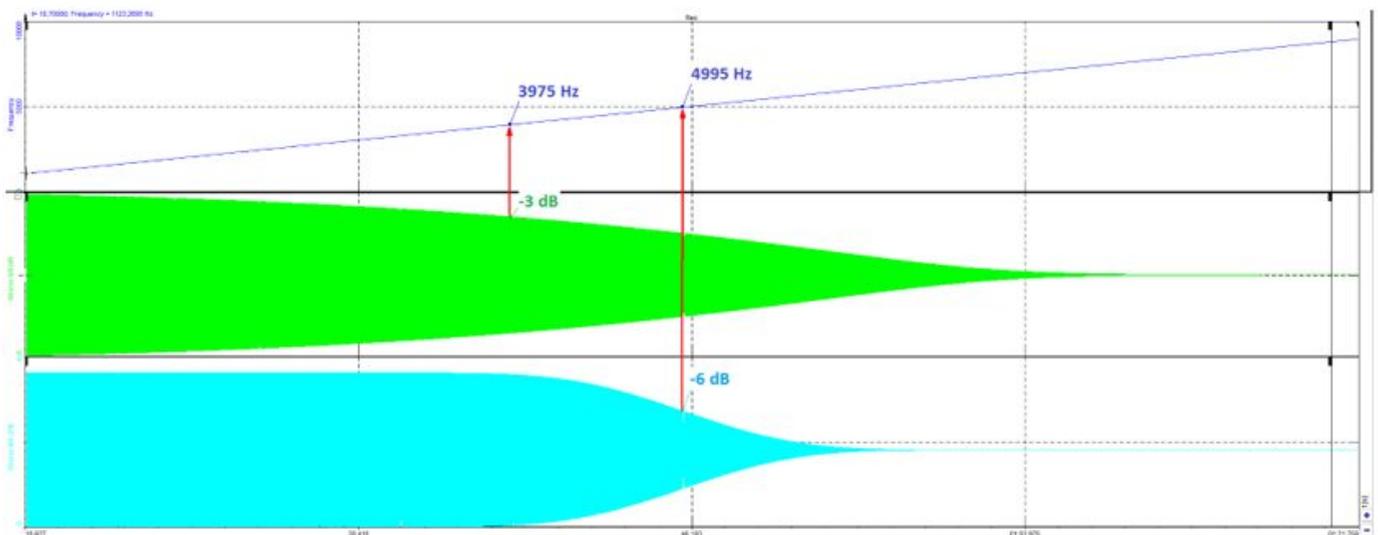


Figure 10: Comparison between IIR and zero phase distortion anti-aliasing filter at sample rate.

Green signal was filtered with IIR filter and blue signal has zero phase distortion anti-aliasing filter. Attenuation starts later at second one (blue), at approximately 3400 Hz. At first one, attenuation starts a lot earlier (start is cropped out of Figure 10). On Figure 10 are marked -3 dB and -6 dB points.

Similar as before, sample rate of signal on Figure 11 is equal to acquisition rate. Analog filter is used, -3 dB point is at approximately 10000 Hz, attenuation starts at around 8900 Hz.

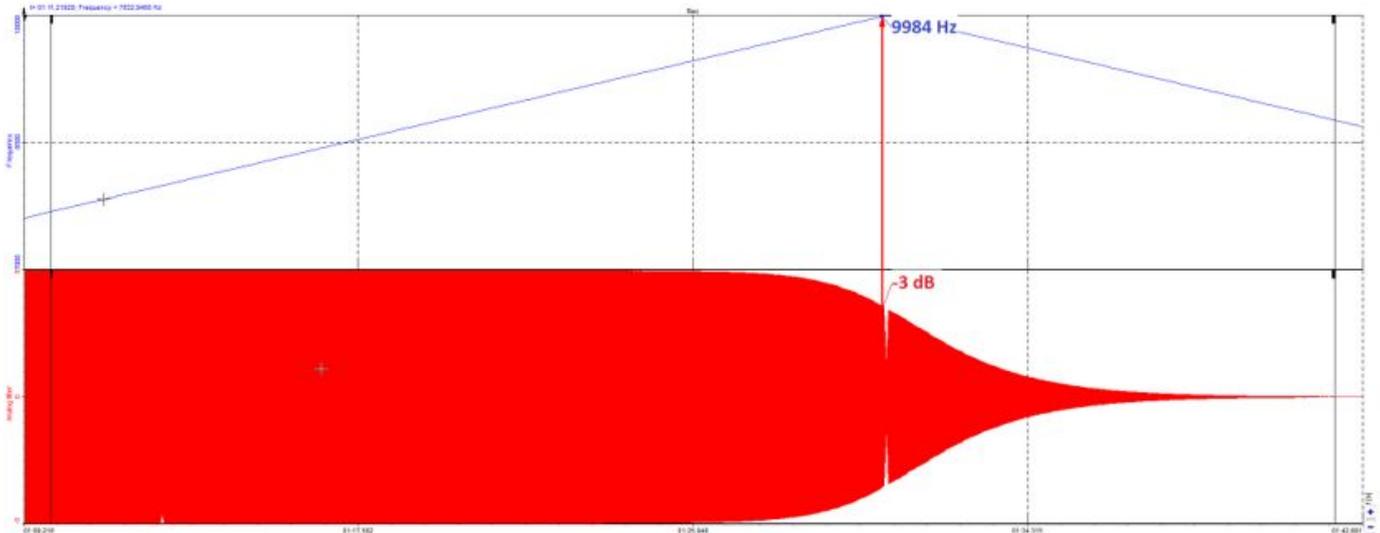


Figure 11: Signal with sample rate.

With the next example, phase shift of anti-aliasing IIR filters will be pointed out.

Dynamic acquisition rate was set to 10 kHz and sine sweep from 10 Hz to 10 kHz with amplitude ± 5 V and duration of 180 seconds was used on all channels.

ID	Used	C	Name	Ampl. name	Measurement	Sample ...	LP filter	Min	Values	Max	Zero	Setup
1	Used		Analog filter	SIRIUS-ACC	Voltage	10000	OFF	-10,00	-4,758 / 4,750	10,00	Zero	Setup
2	Used		5kHz SR ZPO	SIRIUS-ACC	Voltage	5000	AAF (zero-phase distortion)	-10,00	-4,757 / 4,752	10,00	Zero	Setup
3	Used		5kHz SR IIR	SIRIUS-ACC	Voltage	5000	Anti-aliasing filter (IIR)	-10,00	-4,752 / 4,758	10,00	Zero	Setup
4	Used		1kHz SR ZPO	SIRIUS-ACC	Voltage	1000	AAF (zero-phase distortion)	-10,00	-4,751 / 4,758	10,00	Zero	Setup
5	Used		1kHz SR IIR	SIRIUS-ACC	Voltage	1000	Anti-aliasing filter (IIR)	-10,00	-4,752 / 4,757	10,00	Zero	Setup

Figure 12: Phase comparison example.

In order to compare phase shifts between channels with different sample rates, for each type of filter we have two channels, one with 5000 Hz sample rate and another with 1000 Hz sample rate. For reference there is also a channel with sample rate equal to acquisition rate, 10 kHz, so analog filter from hardware will be used.

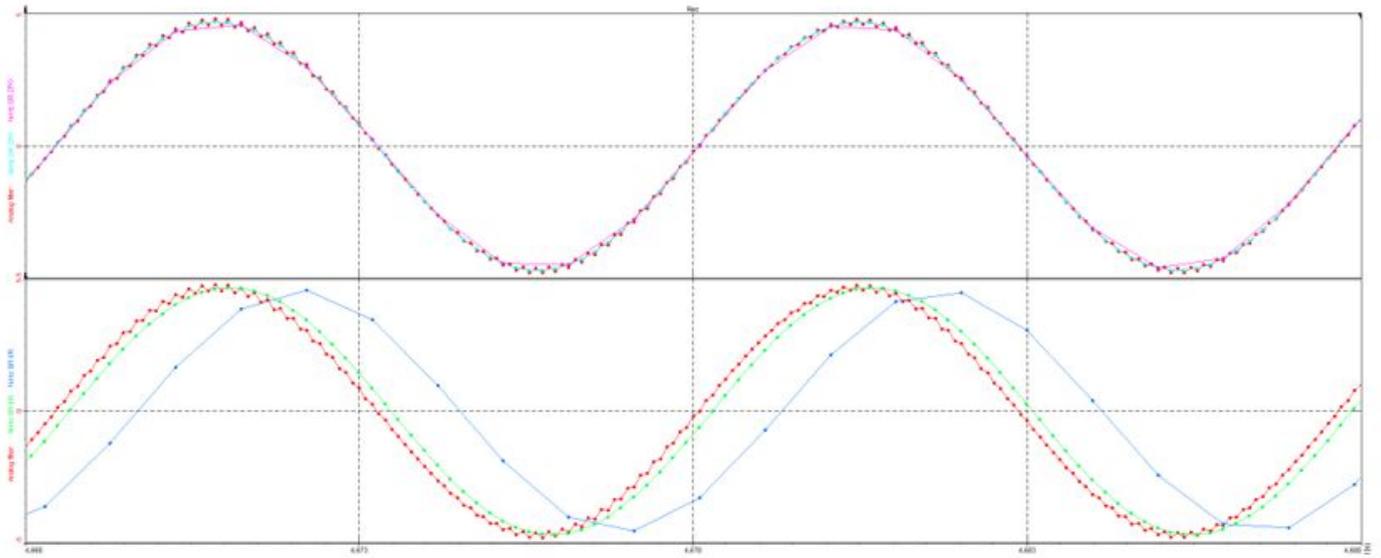


Figure 13: Phase comparison at 100 Hz.

Fragment of approximate two periods on Figure 13 is taken around sweep's frequency of 100 Hz. On upper graph there are channels with zero phase distortion anti-aliasing filter applied, and on bottom are channels with IIR anti-aliasing filter. On both graphs there is also channel without software filter (red) for reference. There is quite a noticeable difference in phase shift between channels with different types of filters used.

Both channels with zero phase distortion anti-aliasing filter (cyan and pink) are completely aligned, between each other and with the reference channel. We can't say that for channels which have anti-aliasing IIR filters used. Channel with 5000 Hz sample rate and IIR anti-aliasing filter (green) is already shifted from the reference channel (red). With 1000 Hz channel (blue) this shift only expands.

As the name suggests, zero phase distortion anti-aliasing filters don't introduce any phase shifts between signals with different sample rates as that happens with anti-aliasing IIR filters.

Sweep signal that was used in the previous example on all channels had some higher frequency orders added (50th and 100th order). In Figure 14, there is one period shown at frequency around 16 Hz.

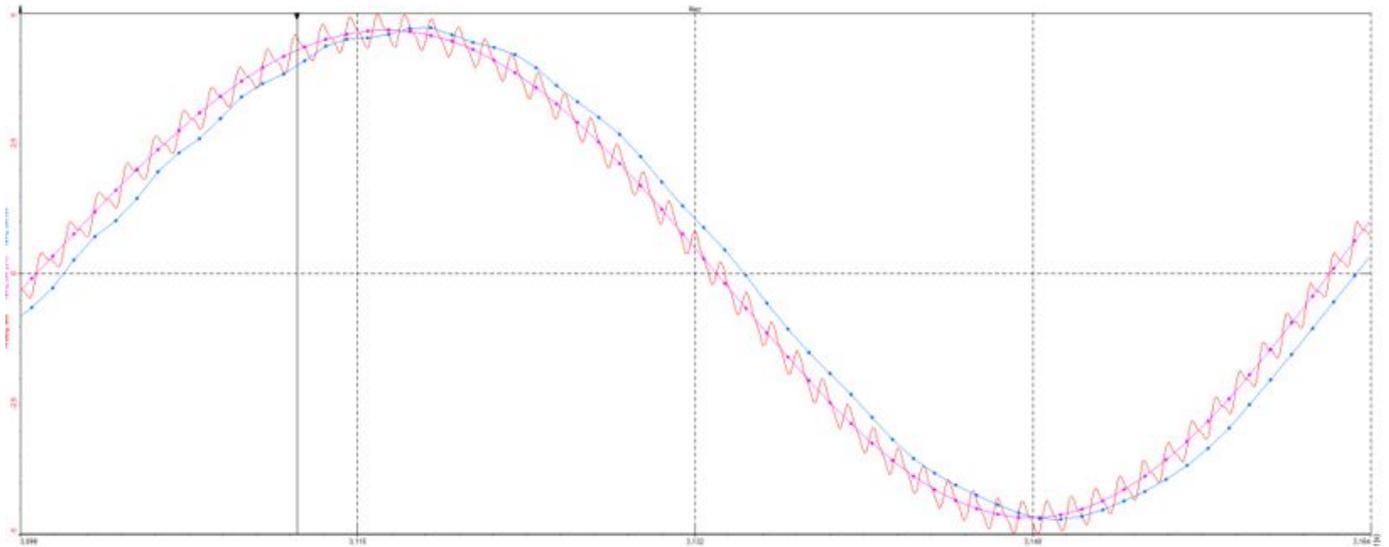


Figure 14: Filtered out higher frequencies.

Red signal on graph is reference signal (without filter). Other two both have sample rates set to 1000 Hz. Pink channel has zero phase distortion anti-aliasing filter and blue channel has IIR anti-aliasing filter used. At that moment, captured on Figure 14, previously mentioned higher frequencies are at around 800 Hz and 1600 Hz. Zero phase distortion anti-aliasing filter nicely filters out these higher orders and outcome is a smooth sine curve, aligned with the reference channel. Because of IIR filter's lower attenuation, we can still see some bumps on the blue signal. They are in effect form 50th frequency order, which is not yet completely filtered out. Zero phase distortion anti-aliasing filters have steeper cutoff slope, hence there is no more effect seen from 50th order.

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Every instrument needs to be calibrated at regular intervals. The standard norm across nearly every industry is annual calibration. Before your Dewesoft data acquisition system is delivered, it is calibrated. Detailed calibration reports for your Dewesoft system can be requested. We retain them for at least one year, after system delivery.

Support

Dewesoft has a team of people ready to assist you if you have any questions or any technical difficulties regarding the system. For any support please contact your local distributor first or Dewesoft directly.

Dewesoft d.o.o.
Gabrsko 11a
1420 Trbovlje Slovenia

Europe Tel.: +386 356 25 300

Web: <http://www.dewesoft.com>

Email: support@dewesoft.com

The telephone hotline is available Monday to Friday from 07:00 to 16:00 CET (GMT +1:00)

Service/repair

The team of Dewesoft also performs any kinds of repairs to your system to assure a safe and proper operation in the future. For information regarding service and repairs please contact your local distributor first or Dewesoft directly on <https://dewesoft.com/support/rma-service>.

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Safety instructions

Your safety is our primary concern! Please be safe!

Safety symbols in the manual



Warning

Calls attention to a procedure, practice, or condition that could cause the body injury or death



Caution

Calls attention to a procedure, practice, or condition that could possibly cause damage to equipment or permanent loss of data.

General Safety Instructions



Warning

The following general safety precautions must be observed during all phases of operation, service, and repair of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the product. Dewesoft GmbH assumes no liability for the customer's failure to comply with these requirements.

All accessories shown in this document are available as an option and will not be shipped as standard parts.

Environmental Considerations

Information about the environmental impact of the product.

Product End-of-Life Handling

Observe the following guidelines when recycling a Dewesoft system:

System and Components Recycling

Production of these components required the extraction and use of natural resources. The substances contained in the system could be harmful to your health and to the environment if the system is improperly handled at its end of life! Please recycle this product in an appropriate way to avoid unnecessary pollution of the environment and to keep natural resources.



This symbol indicates that this system complies with the European Union's requirements according to Directive 2002/96/EC on waste electrical and electronic equipment (WEEE). Please find further information about recycling on the Dewesoft web site www.dewesoft.com

Restriction of Hazardous Substances

This product has been classified as Monitoring and Control equipment and is outside the scope of the 2002/95/EC RoHS Directive. However, we take care of our environment and the product is lead-free.

General safety and hazard warnings for all Dewesoft systems

Safety of the operator and the unit depend on following these rules.

- Use this system under the terms of the specifications only to avoid any possible danger.
- Read your manual before operating the system.
- Observe local laws when using the instrument.
- DO NOT touch internal wiring!
- DO NOT use higher supply voltage than specified!
- Use only original plugs and cables for harnessing.
- You may not connect higher voltages than rated to any connectors.
- The power cable and connector serve as Power-Breaker. The cable must not exceed 3 meters, the disconnect function must be possible without tools.
- Maintenance must be executed by qualified staff only.
- During the use of the system, it might be possible to access other parts of a more comprehensive system. Please read and follow the safety instructions provided in the manuals of all other components regarding warning and security advice for using the system.
- With this product, only use the power cable delivered or defined for the host country.
- DO NOT connect or disconnect sensors, probes or test leads, as these parts are connected to a voltage supply unit.
- Ground the equipment: For Safety Class 1 equipment (equipment having a protective earth terminal), a non-interruptible safety earth ground must be provided from the mains power source to the product input wiring terminals.
- Please note the characteristics and indicators on the system to avoid fire or electric shocks. Before connecting the system, please read the corresponding specifications in the product manual carefully.

- The inputs must not, unless otherwise noted (CATx identification), be connected to the main circuit of category II, III and IV.
- The power cord separates the system from the power supply. Do not block the power cord, since it has to be accessible for the users.
- DO NOT use the system if equipment covers or shields are removed.
- If you assume the system is damaged, get it examined by authorized personnel only.
- Adverse environmental conditions are Moisture or high humidity Dust, flammable gases, fumes or dissolver Thunderstorm or thunderstorm conditions (except assembly PNA) Electrostatic fields, etc.
- The measurement category can be adjusted depending on module configuration.
- Any other use than described above may damage your system and is attended with dangers like short-circuiting, fire or electric shocks.
- The whole system must not be changed, rebuilt or opened.
- DO NOT operate damaged equipment: Whenever it is possible that the safety protection features built into this product have been impaired, either through physical damage, excessive moisture, or any other reason, REMOVE POWER and do not use the product until the safe operation can be verified by service-trained personnel. If necessary, return the product to Dewesoft sales and service office for service and repair to ensure that safety features are maintained.
- If you assume a more riskless use is not provided anymore, the system has to be rendered inoperative and should be protected against inadvertent operation. It is assumed that a more riskless operation is not possible anymore if the system is damaged obviously or causes strange noises. the system does not work anymore. The system has been exposed to long storage in adverse environments. the system has been exposed to heavy shipment strain.
- Warranty void if damages caused by disregarding this manual. For consequential damages, NO liability will be assumed!
- Warranty void if damage to property or persons caused by improper use or disregarding the safety instructions.
- Unauthorized changing or rebuilding the system is prohibited due to safety and permission reasons (CE).
- Be careful with voltages >25 VAC or >35 VDC! These voltages are already high enough in order to get a perilous electric shock by touching the wiring.
- The product heats during operation. Make sure there is adequate ventilation. Ventilation slots must not be covered!
- Only fuses of the specified type and nominal current may be used. The use of patched fuses is prohibited.
- Prevent using metal bare wires! Risk of short circuit and fire hazard!
- DO NOT use the system before, during or shortly after a thunderstorm (risk of lightning and high energy over-voltage). An advanced range of application under certain conditions is allowed with therefore designed products only. For details please refer to the specifications.
- Make sure that your hands, shoes, clothes, the floor, the system or measuring leads, integrated circuits and so on, are dry.
- DO NOT use the system in rooms with flammable gases, fumes or dust or in adverse environmental conditions.
- Avoid operation in the immediate vicinity of high magnetic or electromagnetic fields, transmitting antennas or high-frequency generators, for exact values please refer to enclosed specifications.
- Use measurement leads or measurement accessories aligned with the specification of the system only. Fire hazard in case of overload!

- Do not switch on the system after transporting it from a cold into a warm room and vice versa. The thereby created condensation may damage your system. Acclimatise the system unpowered to room temperature.
- Do not disassemble the system! There is a high risk of getting a perilous electric shock. Capacitors still might be charged, even if the system has been removed from the power supply.
- The electrical installations and equipment in industrial facilities must be observed by the security regulations and insurance institutions.
- The use of the measuring system in schools and other training facilities must be observed by skilled personnel.
- The measuring systems are not designed for use in humans and animals.
- Please contact a professional if you have doubts about the method of operation, safety or the connection of the system.
- Please be careful with the product. Shocks, hits and dropping it from already- lower level may damage your system.
- Please also consider the detailed technical reference manual as well as the security advice of the connected systems.
- This product has left the factory in safety-related flawlessness and in proper condition. In order to maintain this condition and guarantee safety use, the user has to consider the security advice and warnings in this manual.

EN 61326-3-1:2008

IEC 61326-1 applies to this part of IEC 61326 but is limited to systems and equipment for industrial applications intended to perform safety functions as defined in IEC 61508 with SIL 1-3.

The electromagnetic environments encompassed by this product family standard are industrial, both indoor and outdoor, as described for industrial locations in IEC 61000-6-2 or defined in 3.7 of IEC 61326-1.

Equipment and systems intended for use in other electromagnetic environments, for example, in the process industry or in environments with potentially explosive atmospheres, are excluded from the scope of this product family standard, IEC 61326-3-1.

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