LINK

Low pass In-line Noise Killer

user manual

CE

Declaration of conformity

We Antec Leyden B.V., Zoeterwoude, The Netherlands, declare that the product

LINK Noise Filter (p.n. 200.0035)

to which this declaration relates, is in conformity with the following directives:

Safety (73/23/EEC)

Safety requirements for laboratory equipment (Class I, Installation cat. II, Pollution degree 2)	IEC 1010-1

Immunity (89/336/EEC)

Electromagnetic immunity	IEC 801-2/3/4 & ENV 50140
Radio frequency current injection	ENV 50141 & IEC 1000-4-6
Voltage dips and interruptions	IEC 1000-4-11

Emissions (89/336/EEC)

Electromagnetic radiation	EN 55022, Class B (CISPR 22)

Attention

Use shielded cable(s) to connect all I/O's with other devices. Thoroughly connect the shielding to common. Antec Leyden will not accept any liability for damage, direct or indirect, caused by connecting this instrument to devices which do not meet relevant safety standards.

February 21, 2007

Intended use

For research purposes only. While clinical applications may be shown, this instrument is not tested by the manufacturer to comply with the In Vitro Diagnostics Directive.

WEEE directive

All equipment of Antec Leyden which are subjected to the WEEE directive shipped after August 13, 2005 are compliant with the WEEE marking requirements. Such products are labelled with the “crossed out wheelie”, depicted on the left site.

The symbol on the product indicates that the product must not be disposed as unsorted municipality waste.

Collection & recycling information

Please ship the instrument back to the manufacturer (Antec Leyden, the Netherlands) at the end-of-life time of the product. The manufacturer will take care of the proper disposal and recycling of the instrument at its facilities.

Shipping address for the end-of-life products:

Antec Leyden
Industrieweg 12
2382NV Zoeterwoude
The Netherlands

In case of questions, or if further information is required about the collection & recycling procedure, please contact your local distributor.

ROHS directive

Our instruments are currently exempt from the RoHS directive because they fall under WEEE Annex IA categories 8 and 9, which includes medical devices and monitoring and control instruments. Nevertheless, we have taken steps to eliminate all restricted substances from our products.

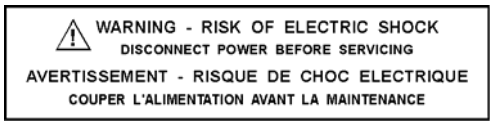
Antec Leyden is an ISO 9001:2000 certified company.

Safety practices

The following safety practices are intended to insure safe operation of the equipment.

Electrical hazards

1. Disassembly exposes potentially dangerous voltages. Therefore, disconnect the instrument from all power sources before disassembly.

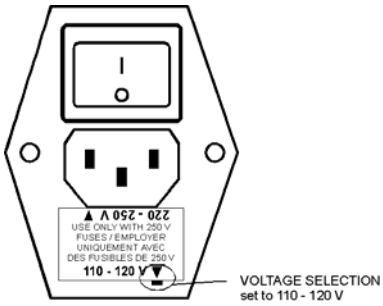


2. Replace blown fuses with size and rating stipulated on the rear panel and in this manual where listed.

WARNING - RISK OF FIRE
REPLACE FUSE AS MARKED
AVERTISSEMENT - RISQUE DE FEU
REMPLACEZ LE FUSIBLE COMME INDIQUÉ

RATED VOLTAGE	FUSE RATING	
	UL / CSA	IEC 127
115 V	0.50A 250V TL	T 0.50A 250V
230 V	0.25A 250V TL	T 0.25A 250V

3. Replace faulty or frayed power cords.
4. Check whether the voltage selector is in the correct position. If the triangle with the voltage range is pointing towards the small white block, the system is set to that line voltage. If not correct this insert has to be reversed. The fuses are mounted in the line connector. Correct values are given on the rear panel for different line sources.



Spare parts and service availability

Antec Leyden provides operational spare parts of the instrument and current accessories for a period of five years after shipment of the final production run of the instrument. Spare parts will be available after this five years period on an ‘as available’ basis.
Antec Leyden provides a variety of services to support her customers after warranty expiration. Repair service can be provided on a time and material basis. Qualified chemists on both contractual and as-needed basis can provide technical support and training.

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C H A P T E R 1

LINK, Low-pass In-line Noise Killer

Introduction

The LINK is an active, fourth order (four-pole) noise filter to improve detection in liquid chromatography. It has been developed as a stand-alone unit and is applicable with any detector that supplies an analogue signal. The improvement in S/N ratio depends on the frequency of the signal vs. the noise. In a realistic experimental set-up consisting of an optimised LC-EC system for biogenic amines, up to a factor of 600 improvement in S/N ratio has been obtained.

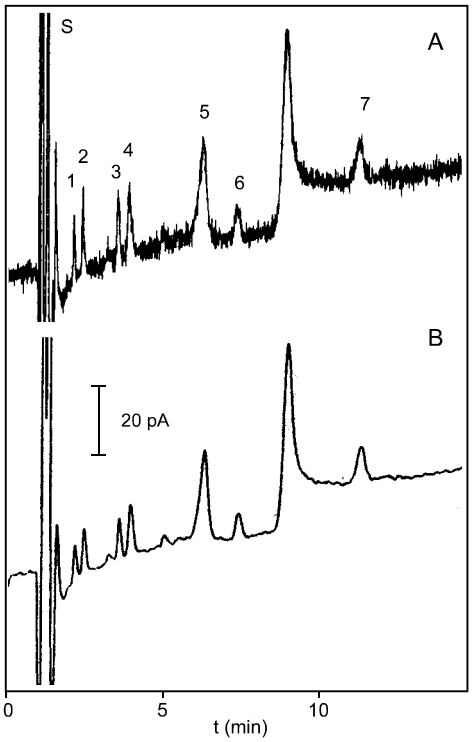


Fig. 1. Chromatogram of 1 nmol/l (20 fmol) (1) adrenaline, (2) DHBA, (3) DHPG, (4) dopamine, (5) VMA, (6) DOPA and (7) MHPG. Raw (A) and filtered (B) signal recorded simultaneously on a 2 channel integrator, LINK cut-off frequency is 0.055 Hz (B).

Noise filters

If noise frequencies in LC-EC differ from the frequency of the signal, filtering can be applied to specifically attenuate noise and improve the signal-to-noise (S/N) ratio. No matter how 'advanced' a filter is, it is only possible to apply low pass filtering if noise frequencies are higher than the frequency of the signal. Prerequisite for a 'good' noise filter for data acquisition in liquid chromatography is that it improves the S/N ratio without significant distortion of the signal of interest. This is particularly difficult if the frequency of the signal is close to the frequency of the noise.
Several designs of low-pass filters have been described. In most detectors a passive RC low-pass filter is applied as a standard. It is a 'passive' filter, meaning that such a filter consists of resistors R and capacitors C.
An active higher order filter can be considered (also mathematically) as a number of 1st order RC filters in series. In a 4th order filter the signal coming from the first filter is filtered again in a second, third and fourth filter. During these steps, loss of signal occurs simply because of all the resistors that are applied. Operational amplifiers, which are 'active' components, are applied in each stage to restore the signal to its original value.

S/N ratio

The theoretical improvement in S/N ratio can be calculated if the frequencies of signal and noise are known.

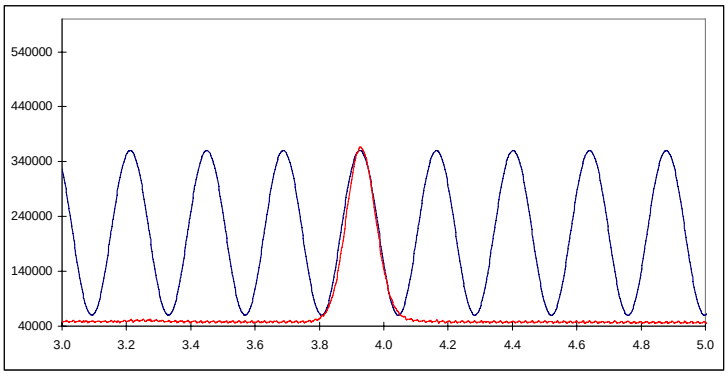


Fig. 2. Overlay of a chromatographic peak (W = 15 s, f = 1/15 = 0.07 Hz) with 0.07 Hz sine.

In a simplified model, the frequency of a chromatographic peak in LC can be calculated from the peak width (W) as f = 1 / W (Fig. 2). For a passive, first

order low-pass filter the output voltage over the capacitor is given as a function of the input voltage by:

$$\frac{V_o}{V_i} = \frac{1}{\sqrt{1 + [\, f \; 2\pi RC \,]^2}} = \frac{1}{\sqrt{1 + [\, f \,/\, f_c \,]^2}} \qquad (1)$$

where f is the frequency of the input signal, fc the cut-off frequency, and Vo/Vi (output resp. input voltage) is the amplitude response.
There are several higher order filter characteristics, such as the Bessel, Chebyshev and Butterworth. Electronically they differ in the choice of components (R and C) used to design the filter. The resulting filter characteristics differ in attenuation slope, phase shift, overshoot and ripple. In our simplified model, the amplitude response of an n^{th} order filter is calculated by

$$\frac{V_o}{V_i} = \frac{1}{\sqrt{1 + [\, f \,/\, f_c \,]^{2 \cdot n}}} \qquad (2)$$

where n is the order of filtering.

Amplitude response

The behaviour of a 1^{st} and 4^{th} order filter with a cut-off frequency of 0.05 Hz is illustrated in Fig. 3. If a noise frequency of 0.2 Hz is assumed, the amplitude response (= ratio output and input voltage, Vo/Vi) is 0.243 for the first order filter, which means that only 76% of the noise is suppressed. For a 4^{th} order filter the amplitude response is 0.004 which means that 99.6% of the noise is suppressed.
A peak width of 25 s corresponds to a frequency of 0.02 Hz. The amplitude response of a 0.02 Hz signal is 0.928 and 1.0 for a 1^{st} and 4^{th} order filter respectively. This means that the S/N ratio improves a factor of 3.8 and 256 for a 1^{st} and 4^{th} order filter respectively. Peak deformation is negligible in both cases since more than 92% of the signal is passed.

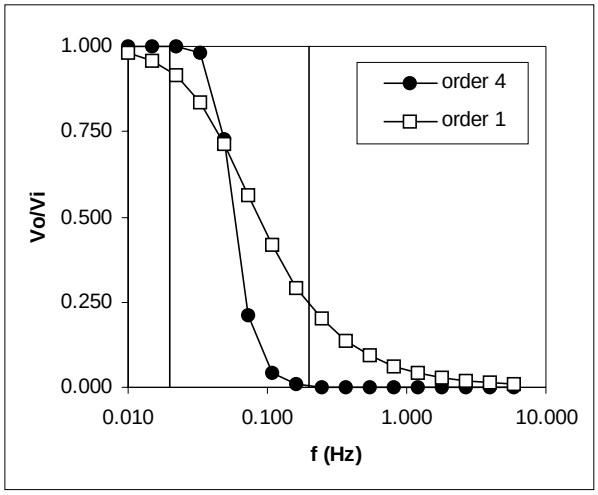


Fig. 3. Amplitude response for a first and fourth order filter at a cut-off frequency of 0.05 Hz (RC=3.18 s). The vertical lines indicate the noise frequency of 0.2 Hz and the signal frequency at 0.02 Hz.

The performance of a higher order filter is best illustrated if the difference in frequency of signal and noise is small. In Table I the frequency response is given for a 0.2 Hz noise frequency and a 0.05 Hz signal frequency. At a filter setting (cut-off frequency) of 0.07 Hz, the signal passes for more than 96% whereas the noise is attenuated to 1.5%, resulting in a factor of 64 improvement of S/N ratio. With a first order filter under similar conditions, only a factor of 1.5 improvement in S/N ratio can be expected.

Table I. Amplitude response and theoretical improvement in S/N ratio for a fourth order filter.

fc (Hz)	signal 0.05 Hz	noise 0.2 Hz	S/N
0.200	1.000	0.707	1.4
0.100	0.998	0.062	16.0
0.080	0.989	0.026	38.6
0.070	0.968	0.015	64.5
0.060	0.901	0.008	111.2
0.050	0.707	0.004	181.0
0.040	0.379	0.002	236.9
0.020	0.026	0.000	255.9

Application

The LINK has been applied for the analysis of a standard mixture of biogenic amines. Fig. 4 shows the chromatogram at 3 different filter settings. It can be seen that the best S/N ratios are obtained for peaks with higher retention times (peak 7, Fig. 4).

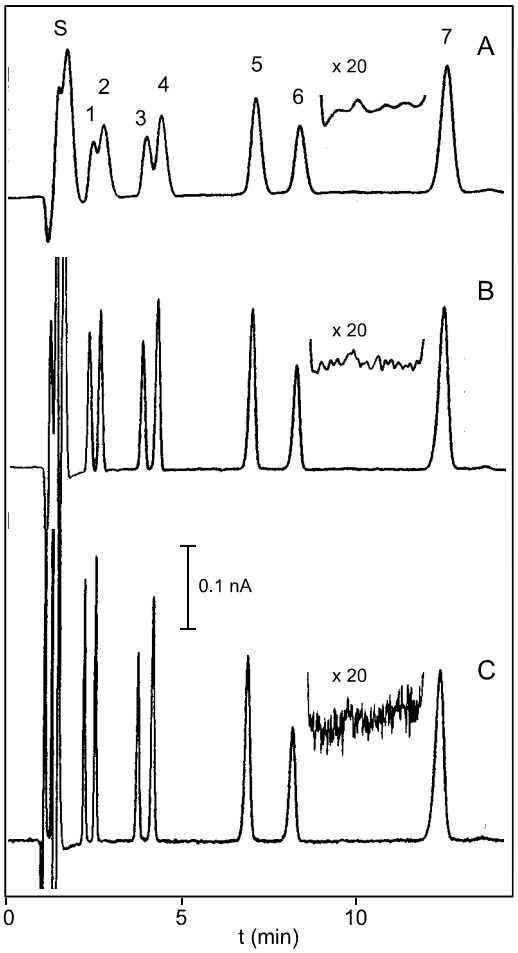


Fig. 4. Chromatogram of 10 nmol/l (200 fmol) (1) adrenaline, (2) DHBA, (3) DHPG, (4) dopamine, (5) VMA, (6) DOPA and (7) MHPG. The LINK is used with a cut-off frequency of (A) 0.020 Hz, (B) 0.055 Hz and (C) 0.300 Hz. Inset shows the noise at increased sensitivity of a factor 20.

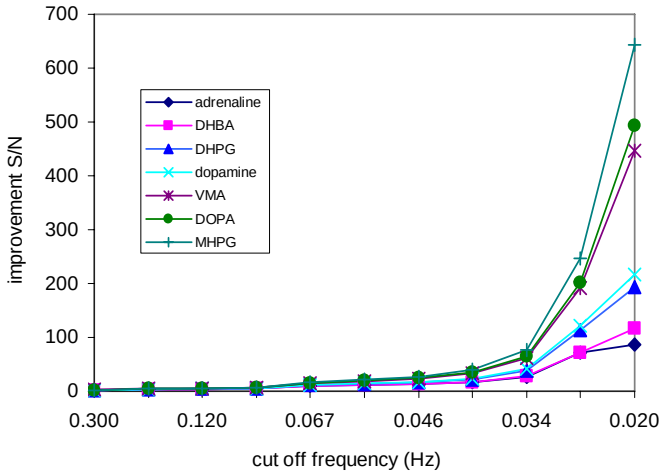


Fig. 5. Improvement in S/N ratio for lower cut-off frequencies. Best results are obtained for peaks with larger peak widths (see also Fig. 4). Up to a factor 600 improvement (vs. raw signal) has been obtained for MHPG.

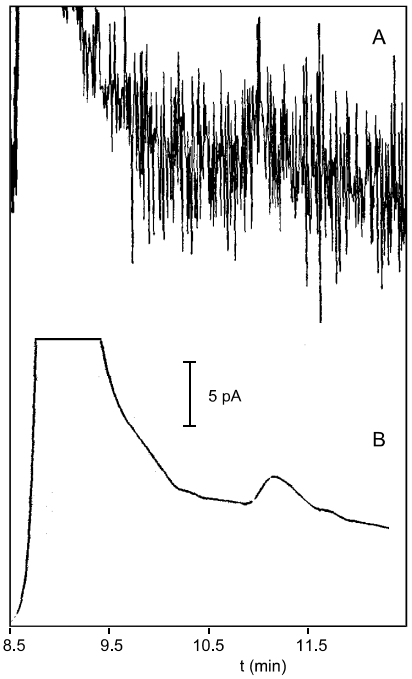


Fig. 6. Chromatogram of 0.1 nmol/l (2 fmol) MHPG (t=11.3 min). The LINK is used with a cut-off frequency of 0.020 Hz (B). Signal is recorded simultaneously on a 2 channel integrator. S/N ratio is improved by a factor of 600 compared to the raw signal (A).

C H A P T E R 2

Using the LINK

Practical issues

There are some issues to be kept in mind when using the LINK. To **optimise for the best S/N ratio**, use the lowest acceptable cut-off frequency. Filter settings are given as cut-off frequencies or peak width. The peak width in seconds is the filter setting resulting in more than 80% of the original (unfiltered) peak height. This is not necessarily the best setting for your analysis therefore optimisation is advised.
After optimisation, **do not change the cut-off frequency setting** during analysis of a calibration sequence. Use the same settings for analysis of samples and calibration standards.
The S/N improvement depends on the composition of the **frequency spectrum**. Improvement up to a factor 100 may be obtained compared to a standard RC filter. HPLC pumps with a high pump frequency give the best results because low frequency pump fluctuations are difficult to suppress. As high frequency noise is easily suppressed, remaining noise components are in the same frequency range as chromatographic peaks.
The LINK accepts max. +/-10V input voltage, also +/-1V or +/-100 mV input can be used. It must be realised however, that the LINK generates a noise level lower than 30 µV. To fully exploit this, **use the highest output voltage possible** (up to +/-10V). For the same reason it is advised to **switch your detector to the highest sensitivity, without peaks running off-scale.**
The offset can be used to zero the output voltage. Before using this function, first auto zero the detector.
The LINK has been developed as a stand-alone unit and is applicable with **any detector** supplying an analogue signal.

LINK front panel

Fig. 7. Front panel of the LINK.

Table II. LINK settings

Offset	Adjustment of zero output level (use after auto zero of the detector)
Peak width in seconds	For peaks with corresponding peak width, filter setting results in more than 80% of the original (unfiltered) peak height, lower cut-off frequencies may be used
Cut-off frequency	Lower cut-off frequency results in better noise attenuation

LINK rear panel

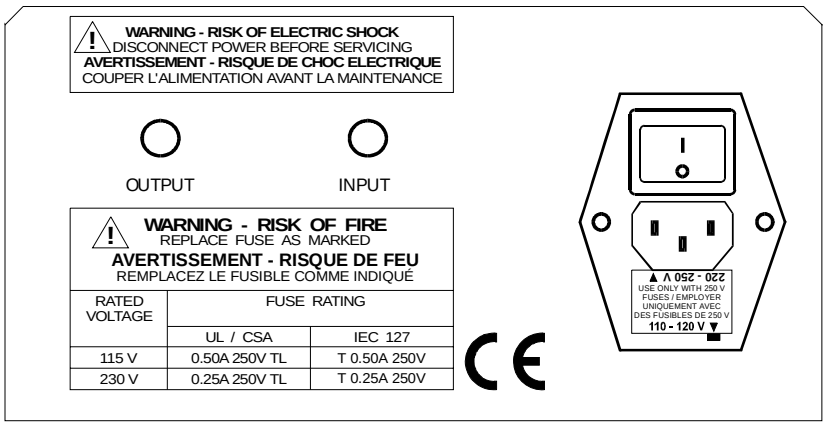


Fig. 8. Rear panel of the LINK.

Table III. LINK connectors

Input	Connection to detector (max. +/-10 V)
Output	Connection to integrator or recorder (max. +/-10 V)

C H A P T E R 3

Specifications LINK

Filter type	fourth order (four pole), low-pass
Attenuation slope	24 db/oct (80 db/decade)
Cut-off frequencies	0.300, 0.171, 0.120, 0.086, 0.067, 0.055, 0.046, 0.040, 0.034, 0.030 and 0.020 Hz (11 settings)
Offset	+/- 35 mV
Max. output voltage	+/- 10 V
Max. output noise	< 30 µV peak to peak noise (input short-circuited)
Output gain	0 dB
Max. input voltage	+/- 10 V
Mains	110 or 220 V AC, selectable
Power consumption	10 W
Dimensions and weight	20 (w) x 20 (d) x 10 (h) cm, 1.75 kg

C H A P T E R 4

Installation and maintenance

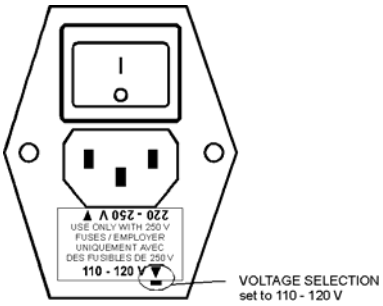
Unpacking

Upon arrival inspect the *transport box* for possible damage. Immediately inform the transport company in case of damage, otherwise she may not accept any responsibility. Keep the transport box as it is designed for optimum protection during transport and it may be needed again. Carefully unpack the system and inspect it for completeness and for possible damage. Contact your supplier in case of damage or if not all marked items on the checklist are included.
Prior to shipment, the LINK has been inspected and tested to ensure the best possible performance. The results of the electronic tests are included.

Installation

Please follow the next steps:

1. Unpack the LINK, inspect for possible damage and make sure that all marked items on the checklist are included.
2. **Check whether the voltage selector is in the correct position.** If the triangle with the voltage range is pointing towards the small white block, the system is set to that line voltage. If not correct this insert has to be reversed.



The fuses are mounted in the line connector. Correct values are given on the rear panel for different line sources.

⚠ WARNING - RISK OF FIRE REPLACE FUSE AS MARKED AVERTISSEMENT - RISQUE DE FEU REMPLACEZ LE FUSIBLE COMME INDIQUÉ		
RATED VOLTAGE	FUSE RATING	
	UL / CSA	IEC 127
115 V	0.50A 250V TL	T 0.50A 250V
230 V	0.25A 250V TL	T 0.25A 250V

3. Connect the LINK 'input' to your detector and the 'output' to your data system, integrator or recorder.
4. Use the highest detector output voltage possible (up to +/-10V).
5. Switch your detector to the most sensitive range setting, without peaks running off-scale.
6. Switch 'on' the LINK by the mains switch on the rear panel.
7. Optimise for best S/N ratio by using the lowest cut-off frequency possible.

Maintenance

The LINK requires no special maintenance. Use a cloth wetted with water only to clean the LINK, do not use organic solvents.
Replace blown fuses with fuses of proper type and rating as stipulated on the rear panel and specified in the installation section of this manual. The fuse holder is integrated in the mains connector. Ensure that the instrument is never put in operation with fuses of a different type. This could cause fire.

⚠ WARNING - RISK OF FIRE REPLACE FUSE AS MARKED AVERTISSEMENT - RISQUE DE FEU REMPLACEZ LE FUSIBLE COMME INDIQUÉ		
RATED VOLTAGE	FUSE RATING	
	UL / CSA	IEC 127
115 V	0.50A 250V TL	T 0.50A 250V
230 V	0.25A 250V TL	T 0.25A 250V