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Labor für Elektronik und Meßtechnik

CAMAC – Specification of Amplitude Analogue Signals
Extension of the Specification of Amplitude Analogue Signals (EUR 5100 [1972]) and Comments of the ESONE Working Group

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K. Tradowsky*

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Abstract

This report is written as an extension of the Specification of Amplitude Analogue Signals published as Euratom Report EUR 5100 and relates to signals which are recommended for use by CAMAC compatible units. It specifies amplitude analogue signals whose rise times are shorter than 50 ns (corresponding to a 3 dB upper cutoff frequency of approximately 7 MHz). A terminated 50 Ω system with 0 to – 1 volt working range is recommended. The technical part of this recommendation has been agreed upon by the US AEC NIM Committee.

In Part B comments of the ESONE Working Group are given for explanation.

Zusammenfassung

Dieser Bericht enthält die Erweiterung der Spezifikation der Amplituden-analogen Signale, die als Euratom-Bericht EUR 5100 veröffentlicht wurde, und bezieht sich auf Signale, die für CAMAC-kompatible Einheiten empfohlen werden. Er spezifiziert Amplituden-analoge Signale mit Anstiegszeiten kürzer als 50 ns (das entspricht einer oberen 3-dB-Grenzfrequenz von ungefähr 7 MHz). Es wird ein abgeschlossenes 50-Ω-System mit einem Arbeitsbereich von 0 bis – 1 V empfohlen. Das US AEC NIM Committee hat dem technischen Teil dieser Empfehlung zugestimmt.

In Teil B des Berichtes wird die Spezifikation von der ESONE Working Group kommentiert und erläutert.

Contents

Part A CAMAC: A Modular Instrumentation System for Data Handling. Specification of Amplitude Analogue Signals. Extension of the Specification of Amplitude Analogue Signals (EUR 5100).

(Approved Text, ESONE Working Group on Analogue Signals, Harwell July 1st, 1972)

Part B Comments of the ESONE Working Group on Analogue Signals to the Extension of the Specification of Amplitude Analogue Signals (EUR 5100 [1972])

(O. Fromhein, K. Tradowsky [Chairman])

Part A

CAMAC

A MODULAR INSTRUMENTATION SYSTEM FOR DATA HANDLING

Specification of Amplitude Analogue Signals

Extension of the Specification of Amplitude Analogue Signals (EUR 5100)

ABSTRACT

This document is written as an extension of the Specification of Amplitude Analogue Signals published as Euratom Report EUR 5100 and relates to signals which are recommended for use by CAMAC compatible units. It specifies amplitude analogue signals whose rise times are shorter than 50 ns (corresponding to a 3 dB upper cutoff frequency of approximately 7 MHz). A terminated 50 Ω system with 0 to − 1 volt working range is recommended.

The technical part of this recommendation has been agreed upon by the US AEC NIM Committee.

Approved Text
ESONE Working Group on Analogue Signals
Harwell July 1st, 1972

Contents

1. INTRODUCTION

The EURATOM Report EUR 4100e defines the essential features of the CAMAC system of instrumentation. This system is primarily for on-line use with digital controllers or computers.

Representatives of European Research Laboratories, under the auspices of the ESONE Committee (Appendix 2), have agreed to recommend standard analogue signals for use with the CAMAC system.

This specification is published to ensure compatibility between CAMAC units which process analogue signals.

This specification, as far as technically feasible, applies to the processing of signals whose rise times (t_r)[1] are shorter than 15 nanoseconds ($f_c \approx 23$ MHz).

This specification may also be used for signals whose rise times (t_r) are shorter than or equal to 50 nanoseconds ($f_c \approx 7$ MHz).

The technical features of any equipment must meet the outlined specifications only within the designed frequency range.

2. INTERPRETATION OF THIS DOCUMENT

This document is the reference text describing and specifying amplitude analogue signals for use by units which conform to the CAMAC specification EUR 4100e (1972). It supersedes the recommendations in Section 7.3 of EUR 4100e (1969).

Statements which specify mandatory aspects of the standard are written in bold type and blocked in, as here, and are usually accompanied by the word "must".

The word "should" indicates a recommended or preferred practice which is to be followed unless there are sound reasons to the contrary.

The word "may" indicates good practice but leaves freedom of choice to the designer.

In order to claim compatibility with this specification a signal must comply with the mandatory statements in this document.

An amplitude analogue signal is one whose amplitude conveys significant information. This specification applies both to continuous and to pulse-like electrical signals. In the latter case, the amplitude may be significant during a portion of the waveform (e.g. as for peak pulse amplitude analysis) or throughout the duration of the waveform (e.g. as for pulse shape analysis).

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[1] A practical relationship between the upper 3 db cutoff frequency (f_c) and rise time (t_r) of a pulse-like signal, defined as the time interval between the 10 and 90 percentile points, is approximately given by $t_r \cdot f_c \approx 0.34$.

The standards defined below must be used for analogue signals which are input or output through connectors on the front panel of CAMAC compatible units, or at the back of CAMAC compatible units above the Dataway, unless there are strong technical reasons to the contrary.

There may, however, be special circumstances requiring some deviations from this specification to suit a specific equipment with which the CAMAC compatible unit is closely associated. In such cases, these deviations are tolerated until further CAMAC and/or IEC specifications are available for use.

3. SPECIFICATION OF AMPLITUDE ANALOGUE SIGNALS

This specification, as far as technically feasible, must apply to the processing of signals whose rise times (t_r)[1] are shorter than 15 ns ($f_c \approx$ 23 MHz).

This specification may also be used for signals whose rise times (t_r) are shorter than or equal to 50 ns ($f_c \approx$ 7 MHz).

The specification given below is summarized in Table I.

3.1. Output Characteristics

3.1.1. Output Voltage Range

The working range of an output voltage across a 50 Ω load must be 0 V to – 1 V.

3.1.2. Maximum Output Voltage

The absolute maximum range of an output voltage across a 50 Ω load must be within – 4 V to + 4 V.

The absolute maximum range of an output voltage using a current source must be – 15 V to + 15 V.[2]

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[2] This is for protection of an unterminated input as defined in EUR 5100.

3.1.3. Output Polarity

An output must provide negative polarity.

Provision may also be made for positive polarity.

3.1.4. Output Impedance

The output impedance should be 50 Ω ± 10 %.

The output impedance of a current or a voltage source may also be used.

3.1.5. Output Protection

An output must be able to withstand connection to 0 V without damage under all working conditions.

3.2. Input Characteristics

3.2.1. Input Impedance

The input impedance must be 50 Ω ± 5 % for $t_r \geqslant 3$ ns.

For 3 ns $> t_r \geqslant 1$ ns the tolerance must not exceed ± 10 %.

3.2.2. Input Voltage Range

The working range of the input voltage must be consistent with the output voltage range specification of 3.1.1.

3.2.3. Input Polarity

An input must accept negative polarity.

Provision should also be made to accept positive polarity.

3.2.4. Input Protection

An input must withstand any voltage in the range – 4 V to + 4 V.

4. CONNECTORS AND CABLES

4.1. Coaxial Connector

For coaxial connectors, the LEMO 00250 (50 Ω impedance) connector or any other type of connector whose mating conditions are compatible with it must be used.

4.2. Coaxial Cable Impedance

The characteristic impedance of coaxial cables used for these amplitude analogue signals must be 50 Ω ± 5 %.

TABLE I

AMPLITUDE ANALOGUE SIGNALS FOR CAMAC

CHARACTERISTICS	OUTPUTS	INPUTS
Working Voltage Range*	0 to – 1 V across a 50 Ω load	0 to – 1 V
Impedance	50 Ω ± 10 %†	50 Ω ± 5 % ($t_r \geqslant 3$ ns)
Impedance	50 Ω ± 10 %†	50 Ω ± 10 % (3 ns $> t_r \geqslant 1$ ns)
Maximum Voltage Range	– 4 V to + 4 V across a 50 Ω load	– 4 V to + 4 V

Notes

* Provision for positive polarity may also be made.

† The output impedance of a current or a voltage source may also be used.

Appendix 1

RELATED SPECIFICATIONS

CAMAC: A Modular Instrumentation System for Data Handling. Revised Description and Specification.

Euratom Report EUR 4100e (1972), Commission of the European Communities, Luxembourg, 1972
(technically identical with: TID–25875)

CAMAC: Organisation of Multi-Crate Systems. Specification of the Branch Highway and CAMAC Crate Controller Type A.

Euratom Report EUR 4600e, Commission of the European Communities, Luxembourg, 1972
(technically identical with: TID–25876)

CAMAC: A Modular Instrumentation System for Data Handling. Specification of Amplitude Analogue Signals.

Euratom Report EUR 5100e (1972) (to be published in 1972)

Standard Instrument Modules
Report TID–20893 (Revision 3), United States Atomic Energy Commission, 1969

Appendix 2

THE ESONE COMMITTEE

The Committee comprises representatives from laboratories, institutes and organisations that have an interest in the compatibility of electronic equipment.

The Committee has a permanent Secretariat. When the Committee is not in session its business is handled by an Executive Group consisting of the secretary and one representative from each of C.E.R.N., Euratom, C.E.A. France, U.K. Nuclear Laboratories, Deutsche Studiengruppe für Nukleare Elektronik, and C.N.E.N. Italy. These representatives are nominated by their respective organisations. The Chairman of the Executive Group is also the Chairman of the ESONE Committee and is chosen annually from the nominated representatives.

A list of member laboratories is given in this Appendix. Further information about current membership and nominated representatives on the Committee and Executive Group can be obtained from the Secretary*.

This document is issued with the approval of the Executive Group. Any questions relating to the interpretation of this document should be submitted to the Secretary. Any points that cannot be cleared by him will be referred to the Executive Group for resolution.

Users of this document who wish to be informed of any future revisions should inform the Secretary.

* Address of the Secretary: Dr. W. Becker, Euratom C.C.R., I–21020 Ispra (VA), Italy
Telephone: Italy (39), Varese (332), 780131 Extension 245.
Telex Number: 38042.

Membership of the ESONE Committee

International	European Organization for Nuclear Research (CERN)	Genève, Switzerland
	Centro Comune di Ricerca (Euratom CCR)	Ispra, Italy
	Bureau Central de Mesures Nucléaires (Euratom BCMN)	Geel, Belgium
	Institut Max von Laue – Paul Langevin	Grenoble, France
Austria	Studiengesellschaft für Atomenergie (SGAE)	Wien
Belgium	Centre d'Etude de l'Energie Nucléaire (CEN)	Mol
Denmark	Forsögsanläg Risö	Roskilde
France	Centre d'Etudes Nucléaires de Saclay (CENS)	Gif-sur-Yvette
	Centre d'Etudes Nucléaires de Grenoble (CENG)	Grenoble
	Laboratoire de l'Accélérateur Linéaire, Faculté des Sciences	Orsay
Germany	Deutsche Studiengruppe für Nukleare Elektronik (SGNE), c/o Physikalisches Institut der Universität	Marburg
	Deutsches Elektronen-Synchrotron (DESY)	Hamburg
	Hahn-Meitner-Institut für Kernforschung Berlin GmbH (HMI)	Berlin (West)
	Kernforschungsanlage Jülich (KFA)	Jülich
	Gesellschaft für Kernforschung (GFK)	Karlsruhe
	Institut für Kernphysik der Universität	Frankfurt
Greece	Nuclear Research Center "Democritus"	Athens
Hungary	Hungarian Academy of Sciences, Central Research Institute for Physics	Budapest

Italy	Comitato Nazionale Energia Nucleare (CNEN)	Roma
	Comitato Nazionale Energia Nucleare, Laboratori Nazionali	Frascati
	Comitato Nazionale Energia Nucleare, Centro Studi Nucleari	Casaccia
	Centro Studi Nucleari Enrico Fermi (CESNEF)	Milano
	Centro Informazioni Studi Esperienze (CISE)	Milano
	Istituto di Fisica dell'Università	Bari
Netherlands	Reactor Centrum Nederland (RCN)	Petten
	Instituut voor Kernphysisch Onderzoek (IKO)	Amsterdam
Poland	Instytut Badań Jądrowych	Swierk/Otwocka
Sweden	Aktiebolaget Atomenergi Studsvik	Nyköping
Switzerland	Institut für Angewandte Physik der Universität	Basel
United Kingdom	Atomic Energy Research Establishment (AERE)	Harwell
	Rutherford High Energy Laboratory (RHEL)	Chilton
	Daresbury Nuclear Physics Laboratory (DNPL)	Daresbury
	United Kingdom Atomic Energy Authority, Culham Laboratory	Abingdon
	Department of Nuclear Physics, University of Oxford	Oxford
Yugoslavia	Boris Kidrič Institute of Nuclear Sciences	Vinča, Beograd

Affiliated Laboratory

Canada	TRIUMF Project University of British Columbia	Vancouver

Part B

Comments

of the ESONE Working Group on Analogue Signals to the Extension of the Specification of Amplitude Analogue Signals (EUR 5100 [1972])

O. Fromhein

K. Tradowsky, Chairman

Contents

1. Introduction

The Executive Group decided to omit the "fast analogue signal" part (Chapter 4.3., Preliminary Issue, September 1970) in EUR 5100 (1972) after there had been a controversy on the polarity of the signals. The result was that the proposed negative polarity for all signals has been changed in order to come to a compromise with our American colleagues. Therefore the Working Group on Analogue Signals was asked to publish an extension of EUR 5100 (1972) dealing with the so-called "fast analogue signals".

But after signals with shorter rise times have been left out of EUR 5100 (1972) the paper was not covering all signals of interest and therefore the problem was not totally solved. Questions of some manufacturers and the cooperation with the US AEC NIM Working Group on Analogue Signals led to the decision of the ESONE General Assembly in Paris in 1971 to publish specifications on "fast analogue signals" as soon as possible. The Working Group had a strong cooperation with the American Working Group and achieved a complete technical agreement. The main new part in the extension is the introduction of fixed rise times, which was absolutely necessary to define the range in which each paper must be used. Therefore the rise time range has been introduced in EUR 5100 (1972) just before it was published.

The Working Group held the following meetings:

Karlsruhe on 21st and 22nd February, 1972

Participants:

Barthel, H.	GFK, Karlsruhe
Fischer, P. M.	GFK, Karlsruhe
Friese, T.	HMI, Berlin
Fromhein, O.	GFK, Karlsruhe
Guillon, H.	CEN, Saclay
Hagelberg, R.	CERN, Genève
Kurz, R.	KFA, Jülich
Manfredi, P. F.	CESNEF, Milano
Sattler, E.	EURATOM, Geel
Tradowsky, K., Chairman	GFK, Karlsruhe
Urban, H.-J.	Universität Freiburg

Received comments for the topics from:

Proposal of the AEC NIM Working Group on Analogue Signals	
Iselin, F.	CERN, Genève

Harwell on 28th – 30th June, 1972

Participants:

Barthel, H.	GFK, Karlsruhe
Bisby, H.	AERE, Harwell
Friese, T.	HMI, Berlin
Fromhein, O.	GFK, Karlsruhe
Kurz, R.	KFA, Jülich
Sattler, E.	EURATOM, Geel
Tradowsky, K., Chairman	GFK, Karlsruhe

Received comments for the topics from:

Manfredi, P. F.	CESNEF, Milano
Porat, D. (Chairman of the AEC NIM Working Group on Analogue Signals)	SLAC, Stanford, Cal.
Thielmann, R.	Universität Marburg

Preliminary papers were titled "Fast Analogue Signals" or "Broadband Analogue Signals". The expression "Fast Analogue Signals" is not well enough defined, so that it was decided to avoid this expression in the official text. On the other hand the expression "Broadband Analogue Signals" has different meanings. Nuclear physicists very often interpret it as the band from D.C. to an upper cutoff frequency, but in other fields it is unterstood as a band with a center frequency where the band is small compared with the center frequency. So the Working Group decided to use only the text on the cover page.

2. Comments to the Abstract

The Working Group decided – following a proposal of the Chairman – to bring the main technical ideas into the abstract. This was done to give technical information to a reader of one of the international abstracts, (e.g. INIS, Nuclear Science Abstracts, Electrical and Electronics Abstracts) where the abstract will be cited if given.

3. Comments to 1. Introduction

The Working Group decided to omit the word "Nuclear" in "European Nuclear Research Laboratories", for there are now Laboratories in the ESONE Committee not only working in the Nuclear Research field.

4. Comments to 2. Interpretation of this Document

According to an American proposal the Working Group agreed to add the words "blocked in" in the explanatory part in order to be consequent with the procedure of blocking the must-statements.

5. Comments to 3. Specification of Amplitude Analogue Signals

The need for the interaction of information handling systems between CAMAC units led to the necessity of specifying amplitude analogue signals which convey the significant information in a well defined form. Whatever characteristic of a signal is chosen to transmit some information, we can restrict our consideration to the following very general communication system.

This system will include a transmitter, this may be a transducer generating an electrical signal as a response of a physical effect, a transmission system over which the signal is transmitted, this may be a transmission line, a filter etc., and a signal processor which produces at its output the desired information.

Since the transmission systems are restricted in the available bandwidth, there evolve limitations in the transmitted signal. In the design of transmission networks the frequency concept is widely used, whereas the rise time concept is often preferred in describing the responses in the time domain. Both concepts are related to each other depending on what criterion is chosen. Conclusions as to which bandwidth requirements are needed must agree with the transient analysis.

If the output has to be a reproduction of the input with high fidelity the required system bandwidth will be much greater compared with an output which contains only the most significant energy share. The output signal will then be a distorted replica of the input, but it may be good enough for further evaluation.

Besides other definitions we refer to the frequency bandwidth of a low-pass system as being the frequency interval between zero and the 3 db cutoff points. In particular, the rise time is defined here as the time interval between 10 and 90 per cent of the final value of the output unit step response. Unfortunately both characteristics show no general relation, that means, changing the transmission system a different relationship will result.

The following examples demonstrate the situation for a unit step input function at the output of an ideal low-pass filter and a Gaussian type low-pass filter.

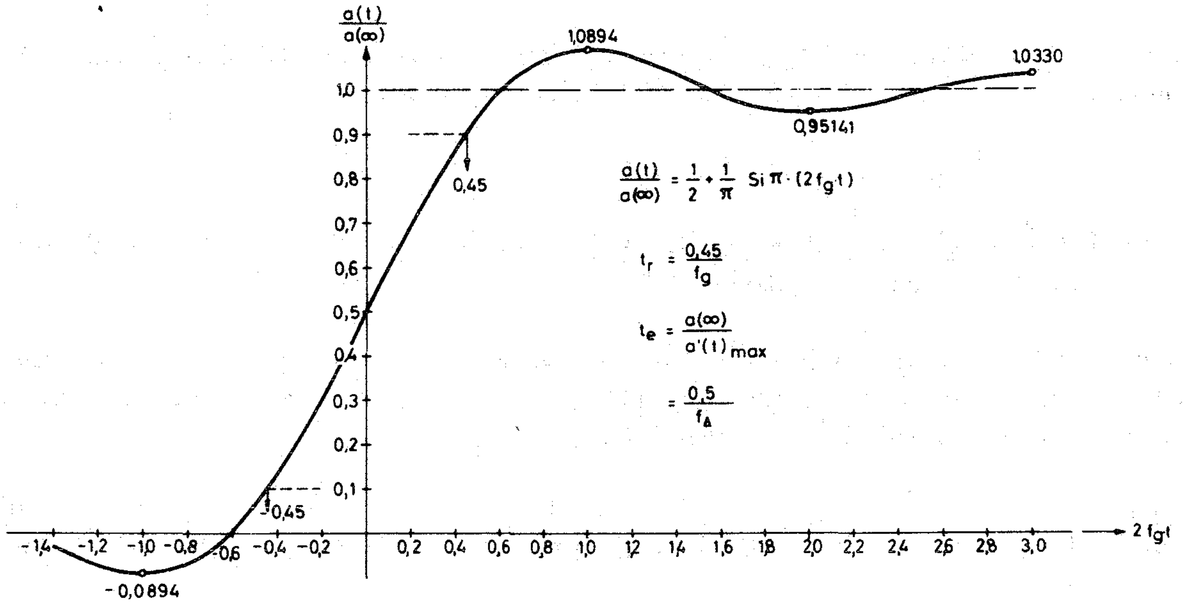

Fig. 1 Unit Step Response of an Ideal Low-Pass Filter

The response of the ideal low-pass filter is:

$$a(t) = a_0\,[0.5 + 1/\pi \cdot \mathrm{Si}(\pi \cdot 2f_g t)]$$

with f_g being the cutoff frequency point.

The evaluation yields the relation:

$$f_g \cdot t_r = 0.45$$

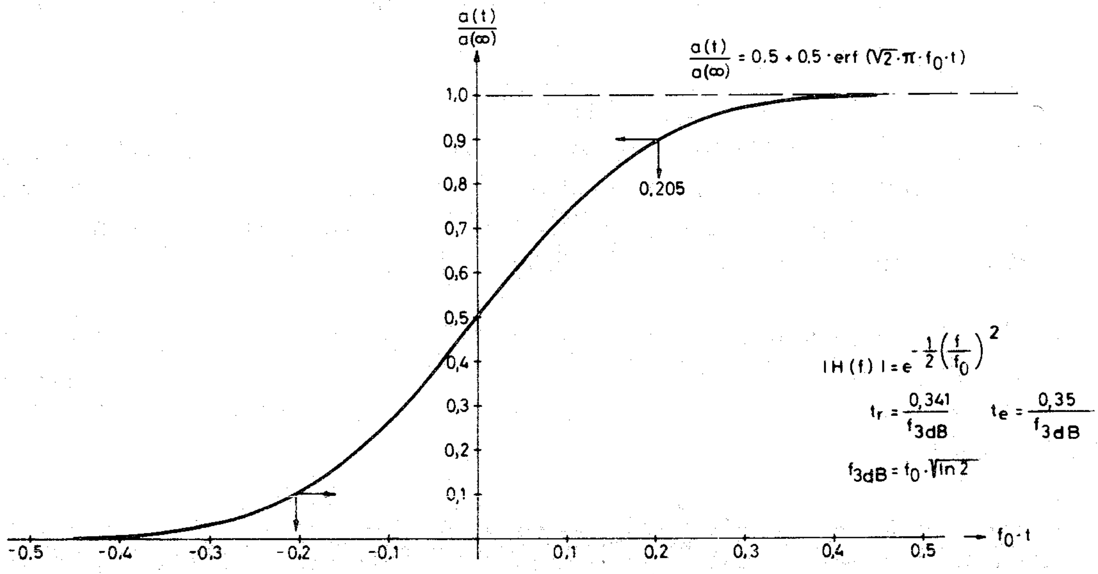

Fig. 2 Unit Step Response of a Gaussian Low-Pass Filter

The response of the Gaussian low-pass filter is:

$$a(t) = a_0\,[0.5 + 0.5 \cdot \mathrm{erf}(\sqrt{2} \cdot \pi \cdot f_0 \cdot t)]$$

with f_0 being the standard deviation. The relation between rise time and 3 db cutoff frequency is found to be

$$f_{3db} \cdot t_r = 0.34$$

We note that the output pulse has a nonzero rise time which is inversely proportional to the filter bandwidth besides a here not considered time delay.

We understand that these examples are of purely academic interest, since practical transmission systems are restricted by the causality principle. But these examples give at least some insight, what the consequences will be for similar transfer functions.

A practical example is an n-stage RC amplifier. It can be shown that the relation between 3 db bandwidth and 10 to 90 per cent rise time given for a Gaussian low-pass filter can be applied within a few per cent of error for RC amplifiers. The larger n is the better is the approximation by a Gaussian type function and therefore the better is the application of the above mentioned relation.

For practical purpose this relationship has been referred to in the Specification of Amplitude Analogue Signals.

But it must be noted, that if high fidelity transmission is required the bandwidth specified must be determined by particular rise time considerations. This idea may be underlined by the next example where the input function is a ramp function with rise time T for simplicity sake measured from 0 to 100 per cent of the final value. The response to this input function of an ideal low-pass filter with different cutoff frequencies is shown in the next figure. The result is selfexplainable and is in agreement with those mentioned previously.

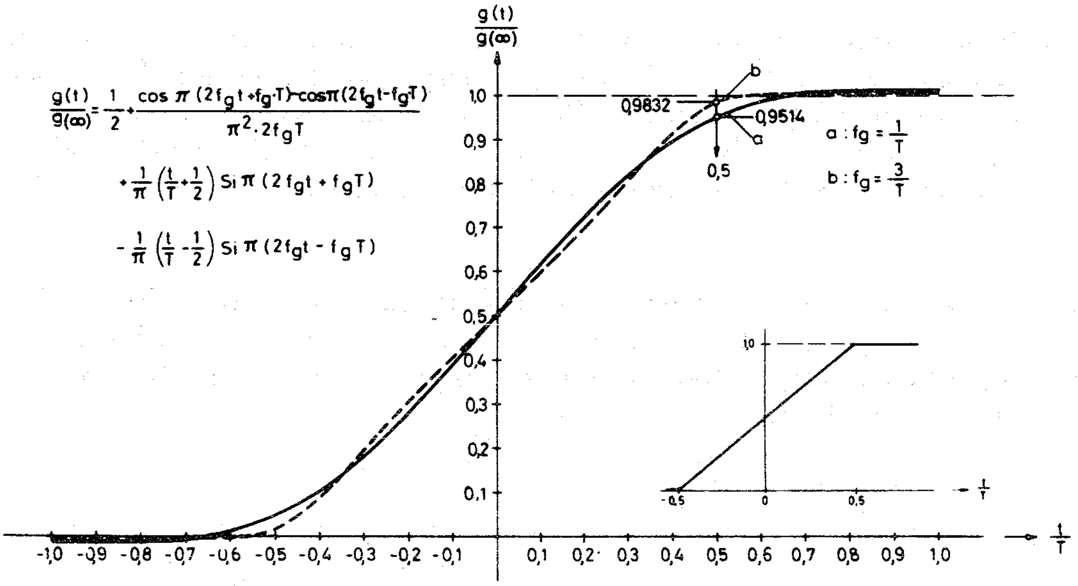

Fig. 3 Responses of an Ideal Low-Pass Filter to a Ramp Input Function

6. Comments to 3.1.1. Output Voltage Range

In comparison with the Report EUR 5100 the extension for the broadband signals does not refer to an equivalent circuit of the signal source, but to the output voltage across a definite load impedance, which is in any case the 50 Ω load.

This arrangement originates from the consideration that the signal source should have an output impedance of 50 Ω with a tolerance of ± 10 %. Claims were made that the signal source may also have an output impedance of a current or a voltage source, which means an impedance much larger or less compared with the 50 Ω load. The decision what is finally implemented is left to the designer. It should be noted that some complications may occur if an overall 50 Ω system is not used. For the application of broadband signals the 50 Ω load (input impedance) is specified with a must and therefore the output voltage range must be expressed in connection with the 50 Ω load. Exactly for this reason the tolerance of the input impedance is given in much greater detail with respect to rise times.

7. Comments to 3.1.2. Maximum Output Voltage

In the statement of the maximum output voltage range it is said that the absolute maximum range of an output voltage across a 50 Ω load must be – 4 V to + 4 V. The range itself can easily be understood if we realize that a load impedance may be connected with a voltage source with an output impedance of 50 Ω or much less or much larger than 50 Ω The main danger arises if the output impedance of a current source is drastically decreased for some faulty reason. Using a voltage source the highest voltage range may happen to be – 2 V to + 2 V across a 50 Ω load. The maximum range is chosen to be twice as large. The equal range with respect to the zero level is selfexplainable, if we note that the polarity must be negative and that provision may also be made to provide for positive polarity.

8. Comments to 3.1.4. Output Impedance

It was the purpose of the specification to recommend a terminated 50 Ω system, even if the use of a voltage or a current source is allowed. If perfect matching is provided no difficulties should arise. But if the output impedance is not 50 Ω reflections will occur. Because of discontinuities reflections will appear at the source and will interfere at the output with the desired signal. In order to prevent reflections the advisable technique is to arrange an overall terminated 50 Ω system.

A terminated 50 Ω system is also a good practice dealing with rise times in the order of a few nanoseconds. The step response of the combination of load impedance (R_L) and a parallel parasitic capacitance (C) fed by a 50 Ω (R_S) source yields a rise time of about 1 ns if the parasitic capacitance is kept below 20 pF.

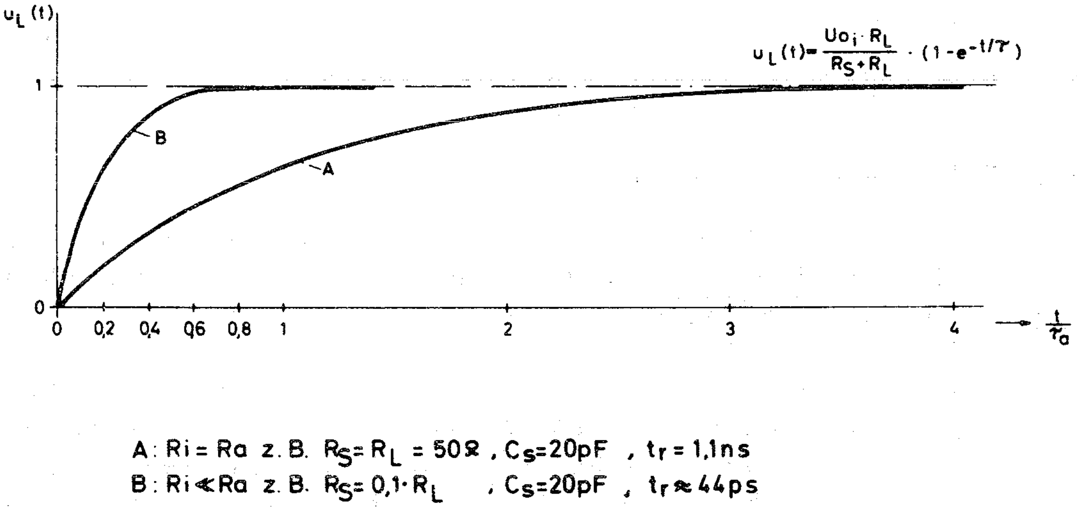

Fig. 4 Load Voltage as Function of Time

$$t_r = \tau \cdot \ln 9 = 2.2\,\tau$$

$$\text{with } \tau = (R_S \parallel R_L) \cdot C$$

This is surely a very simple example but it demonstrates that a 50 Ω terminated system can provide rise times in the order of one nanosecond.

9. Comments to 3.2.1. Input Impedance

The specification of broadband signals demands the implementation of a 50 Ω input (load impedance) with a tolerance specified with respect to different pulse rise times.

The question is why this effort? Since the input impedance must be 50 Ω special care must be taken whether this statement can be met in the considered range of rise times. Unfortunately there exists a technical limitation which is caused by properties of the connectors. The load is linked together with the other network via connectors. Mechanical size and costs restrict the use to a limited number of types. The properties of the connectors do not allow a narrow tolerance scheme for the full range of pulse rise times.

$$\text{SWR} \approx 1 + 2 \cdot \rho \qquad\qquad \rho \ll 1$$

$$\rho \approx 0.5 \cdot \frac{\Delta Z_L}{Z_W}$$

The LEMO type 00250 connectors show an SWR (standing wave ratio) in the order of 1.05 to 1.10 with 1 ns test pulses. The values for 250 ps test pulses are in the order of 1.1 to 1.2. The specification has been chosen according to practical rise times so that the technical values do not limit the use.

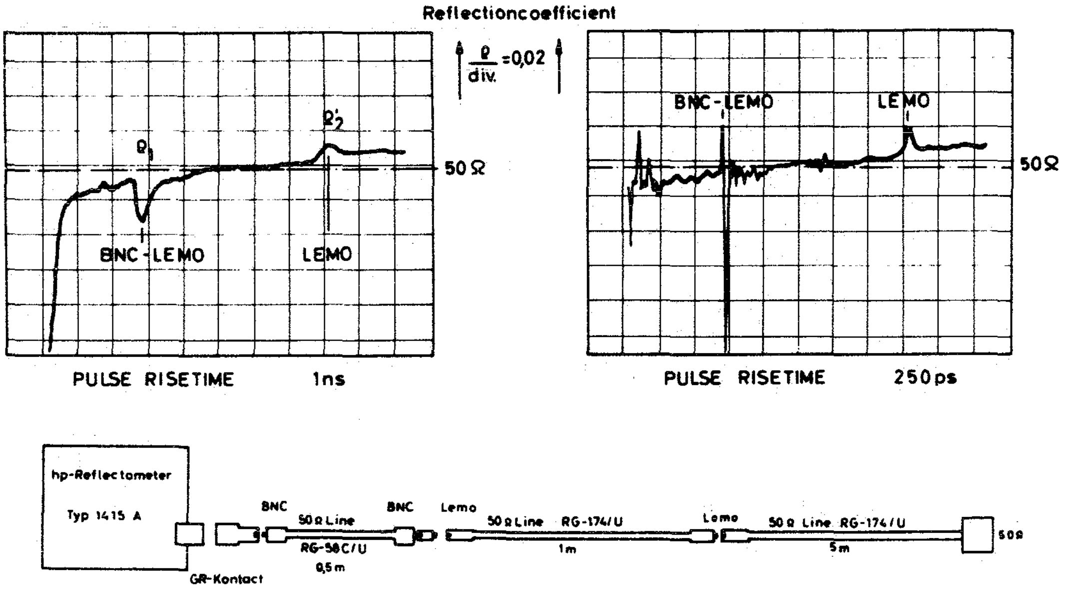

Fig. 5 Voltage Step Responses of Connectors

But any other connector type may be used if its properties as well as the mechanical conditions are compatible. The specification does not limit the use of the connectors with shorter rise times, which means that they may show in such a case higher SWR's.