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D E C I S I O N
of 18 January 1995

Case Number: T 0791/93 - 3.5.2

Application Number: 88202234.6

Publication Number: 0314218

IPC: H03F 1/08

Language of the proceedings: EN

Title of invention:
Amplifier arrangement and integrated amplifier circuit suitable for the amplifier arrangement, and display device including said amplifier arrangement

Applicant:
Philips Electronics N.V.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step - yes, after amendment"

Decisions cited:
-

Catchword:
-

Case Number: T 0791/93 - 3.5.2

D E C I S I O N
of the Technical Board of Appeal 3.5.2
of 18 January 1995

Appellant: Philips Electronics N.V.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office dated 17 May 1993 refusing European patent application No. 88 202 234.6 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: R. E. Persson
Members: W. J. L. Wheeler
A. G. Hagenbucher

Summary of Facts and Submissions

I. The Appellant contests the decision of the Examining Division to refuse European patent application No. 88 202 234.6. The reason given for the refusal was that the subject-matter of Claim 1, which had not been amended, did not involve an inventive step within the meaning of Article 56 EPC having regard of the following prior art documents:

D1: Kleines Handbuch technischer Regelvorgänge, Verlag Chemie, 5th edition 1972,

D2: Linear Databook, National Semiconductor Corporation, 1982 edition

and general knowledge in the art.

II. Oral proceedings were held on 18 January 1995. The Appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of Claim 1 as submitted at the hearing, Claims 2 to 21 as filed and Claim 24 as filed, renumbered 22; a description accordingly adapted; drawings as filed; and the title to be amended by deleting the words "and integrated amplifier circuit suitable for the amplifier arrangement".

The application now consists of the following documents:

Claims: 1 as filed in the oral proceedings of 18 January 1995;
2 to 21 and 24 (renumbered 22) as originally filed;

Description: pages 1 and 2 as filed with a letter dated 10 February 1992, received 12 February 1992;
pages 3 to 31 as originally filed with the deletion of lines 1 and 2 from page 3, as specified in the Statement of Grounds dated 2 August 1993, received on 6 August 1993, and with the deletion of page 8, line 33 to page 9, line 6 as specified in a letter dated 6 December 1994;

Drawings: Sheets 1/7 to 7/7 as originally filed.

III. Claim 1 now reads:

"1. An amplifier arrangement comprising
- a transadmittance circuit having an input coupled to an input of the amplifier arrangement and
- a transimpedance amplifier having an input coupled to an output of the transadmittance circuit and an output coupled to an output of the amplifier arrangement, the transfer function modulus of the transimpedance amplifier having a first-order decrease above a first frequency F1 and a second-order decrease above a second frequency F2, said transimpedance amplifier being negatively fed back by means of a negative current feedback circuit, characterized in that
- the negative current feedback circuit is constituted by a negative feedback impedance whose inverse of the transfer function modulus below the second frequency F2 is smaller than the transfer function modulus of the transimpedance amplifier, and which inverse of the transfer function modulus of the negative feedback impedance has a first-order decrease above a third frequency F3, so that the transfer function modulus of the negatively fed back transimpedance amplifier has a first-order decrease above a fourth frequency F4 which

is substantially equal to the third frequency F3, and a second-order decrease above a fifth frequency F5,

- the transfer function modulus of the transadmittance circuit has a first-order increase above a sixth frequency F6 which is substantially equal to the fourth frequency F4 so that the transfer function modulus of the amplifier arrangement has a first-order decrease above the fifth frequency F5, and

- the transimpedance amplifier has a low-ohmic negative current feedback input with an input impedance whose modulus, at least for frequencies below the fifth frequency F5, is so low-ohmic in comparison with the modulus of the negative feedback impedance, that the first-order decrease of the inverse of the transfer function modulus of the negative feedback impedance extends long enough to intercept the second-order decrease of the transfer function modulus of the transimpedance amplifier at the frequency F5 which is located above the second frequency F2."

Claims 2 to 22 are dependent on Claim 1.

IV. The Appellant argued essentially as follows:

The diagrams of the inverse of the transfer function modulus of the negative feedback impedance (1/K) shown in Figure 2B and 3C of the application implied that in the claimed amplifier arrangement the modulus of the impedance of the transimpedance amplifier's inverting input was "low-ohmic" with respect to the modulus of the feedback impedance, in the sense that the former was at least an order of magnitude smaller than the latter. D2 (pages 3-232 to 3-235) showed an amplifier arrangement according to the preamble of Claim 1. The impedance of the transimpedance amplifier's inverting input, however, was 2.5 kΩ and, therefore, could not be considered low-ohmic in comparison with a feedback resistance of 7.5 kΩ. Bode diagrams drawn for the transfer functions of the arrangement specified on page 3-235 of D2 showed that, with a feedback resistance to input resistance ratio of three, the first-order decrease of the inverse of the transfer function modulus of the negative feedback impedance would only extend for two octaves from 20 MHz to 80 MHz and therefore could not intercept the second-order decrease of the amplifier's open-loop transfer function shown on page 3-229 of D2, the second pole of which lay beyond 100 MHz. Thus, it was not possible to extend the bandwidth of the amplifier arrangement known from D2 beyond the second pole of the transimpedance amplifier. Since it was neither taught nor suggested in the prior art that the bandwidth of an amplifier arrangement comprising a transimpedance amplifier with negative current feedback could be increased by reducing the impedance of the amplifier's inverting input, it would not have been obvious to the skilled person starting from D2 to arrive at the claimed invention. Hence, the subject matter of Claim 1 involved an inventive step within the meaning of Article 56 EPC and a patent should be granted on the basis of such claim.

Reasons for the Decision

1. The appeal is admissible.

2.1 The present Claim 1 differs from Claim 1 as considered in the decision of the Examining Division essentially in that:

(a) the wording "which transfer function modulus has a first-order increase above a third frequency F3" (lines 13 and 14 of Claim 1 as filed) has been replaced by: "which inverse of the transfer function modulus of the negative feedback impedance has a first-order decrease above a third frequency F3";

(b) it is now further specified that the transimpedance amplifier has a "low-ohmic **negative** current **feedback** input" (emphasis added) (line 26 of Claim 1 as filed); and

(c) the wording "an input impedance whose modulus, at least for frequencies below the fifth frequency F5, is smaller than the modulus of the negative feedback impedance" (last three lines of Claim 1 as filed) has been replaced by "an input impedance whose modulus, at least for frequencies below the fifth frequency F5, is so low-ohmic in comparison with the modulus of the negative feedback impedance, that the first-order decrease of the inverse of the transfer function modulus of the negative feedback impedance extends long enough to intercept the second-order decrease of the transfer function modulus of the transimpedance amplifier at the frequency F5 which is located above the second frequency F2."

2.2 As to (a), the new wording has the same meaning as the original, but is easier to associate with Figures 2B and 3C of the drawings, which show 1/K, not K.

As to (b), the description and the circuit diagrams as filed clearly show that the negative current feedback input is low-ohmic (cf. the description as filed: page 6, lines 8 to 10 and 30 to 32; Figures 2A and page 13, lines 19 to 22 of the description as filed).

As to (c), it is specified in the description as filed (page 13, lines 19 to 22) that the transimpedance amplifier's low input impedance no longer makes it necessary for the negative current feedback circuit to have a high output impedance. Furthermore, Figures 2B and 3C relating to Bode diagrams of an amplifier arrangement according to the present invention show that the inverse of the transfer function modulus of the negative feedback impedance is long enough to intercept the second-order decrease of the transfer function modulus of the transimpedance amplifier at a frequency F5 located above a frequency F2 corresponding to the second pole of the transimpedance amplifier's open-loop transfer function. The Board agrees with the Appellant that the above amendment reflects a relationship between the transimpedance amplifier's inverting input impedance and its negative feedback impedance which can be directly derived from the description and the drawings.

2.3 Hence, the Board is satisfied that the features recited in Claim 1 were all disclosed in combination in the application documents as originally filed. The present form of the application does not infringe Article 123(2) EPC.

3. None of prior art documents on file discloses an amplifier arrangement comprising all the features recited in Claim 1. Thus, the subject-matter of the independent Claim 1 is novel within the meaning of Article 54 EPC.

4.1 The Examining Division appears to have regarded D1 as the closest prior art document. D1 is a technical handbook covering various linear applications of an operational amplifier and, in particular, an arrangement comprising an operational amplifier with negative feedback and a transadmittance input circuit. However, as acknowledged in the contested decision, this amplifier is not a transimpedance amplifier as specified in the preamble of Claim 1 of the present application (cf. D1, page 713, lines 3 and 4). Furthermore, it is not correct to argue, as the Examining Division did, on the basis of a combination of features taken from two alternative mutually exclusive circuit arrangements.

4.2 Document D2 discloses, inter alia, an amplifier arrangement (page 3-235) comprising all the features recited in the preamble of Claim 1. Though the open-loop gain diagram of the transimpedance amplifier used in the disclosed arrangement (D2, page 3-229) shows only one pole at a frequency close to 100 kHz and a first-order decrease up to 100 MHz, it is not in dispute that such an transimpedance amplifier must have at least a second pole at a frequency above 100 MHz, so that its transfer function modulus has a second-order decrease above a second frequency F2 > 100 MHz. In the opinion of the Board, D2 represents the closest prior art available.

4.3 Starting from D2, the problem addressed in the present application can be defined as to provide an amplifier arrangement having a larger bandwidth than the known amplifier arrangements.

4.4 According to the present application, the above problem is solved by ensuring that the transimpedance amplifier's closed-loop transfer function has a second pole at a frequency above the second pole of its open-loop transfer function and by setting the zero of the transadmittance circuit at a frequency corresponding to the first pole of the amplifier's closed-loop transfer function. This is achieved when the conditions specified in Claim 1 are satisfied.

4.5 According to the Appellant, the gist of the invention consists in selecting a transimpedance amplifier with a negative current feedback input impedance whose modulus is so low-ohmic with respect to the modulus of the negative feedback impedance K that the 20 dB/decade slope of 1/K can be made to intercept the 40 dB/decade slope of the transimpedance amplifier's open-loop transfer function at a frequency F5 located beyond a frequency F2 corresponding to the transimpedance amplifier's second pole. The resulting transimpedance amplifier's closed-loop transfer function has a second-order decrease at the frequency F5 > F2.

4.6 The Appellant has convinced the Board that, in the arrangement known from D2, the relatively high impedance (2.5 kΩ; page 3-227) of the transimpedance amplifier's inverting input in comparison with the impedance of the feedback circuit (≤7.5 kΩ) makes it impossible to arrive at transfer functions satisfying the above conditions and, thus, to solve the above problem. Indeed, the voltage gain curve of the arrangement shown on page 3-235 is shown on page 3-236 to have a first-order decrease starting at a frequency of about 20 MHz, which is much lower than the frequency at which the second pole of the uncompensated transimpedance amplifier is located (> 100 MHz). Even by appropriately modifying the parameters of the transadmittance and feedback circuits, the bandwidth of the amplifier arrangement cannot be extended beyond the second pole of the transimpedance amplifier.

4.7 It is commonly known in the field that a low input impedance in an amplifier is a desirable feature, for instance to reduce the influence of parasitic capacitances. However, none of the prior art documents shows or even hints at the possibility of increasing the bandwidth of a closed-loop transimpedance amplifier by reducing the impedance of the amplifier's inverting input. Only with the benefit of hindsight would the skilled person realize that a transimpedance amplifier with a low-ohmic input impedance as specified in Claim 1 would allow the bandwidth of the amplifier arrangement known from D2 to be extended beyond the second pole of the transimpedance amplifier's open-loop transfer function.

4.8 For the above reasons, the Board finds that it would not be obvious to the skilled person starting from the teaching of D2 and the general knowledge in the field to arrive at an amplifier arrangement falling within the terms of Claim 1. Thus, the subject-matter of Claim 1 involves an inventive step within the meaning of Article 56 EPC.

5. In the opinion of the Board, Claim 1 is clear and meets the requirements of the EPC.

6. The Board has not examined the dependent claims (other than to check that they are dependent) or the description (apart from reading it to obtain an understanding of the invention). Rather than do this itself, the Board makes use of its powers under Article 111(1) EPC to remit the case to the department of first instance for further examination. For avoidance of doubt, it is pointed out that according to Article 111 (2) EPC the department of first instance is bound by the present decision only to the extent that it has been decided that the subject-matter as covered by Claim 1 filed in the oral proceedings meets the requirements of the EPC.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance for further prosecution on the basis of the Appellant's request (see paragraph II above).

The Registrar: The Chairman:

M. Kiehl E. Persson