

Description

The invention relates to a filter arrangement comprising a first balanced amplifier having a non-inverting and an inverting input and having a non-inverting and an inverting output, a first and a second input terminal, a first and a second output terminal, a first and a second feedback circuit, each comprising a first capacitor, the first feedback circuit being arranged between the inverting output and the non-inverting input of the first amplifier, and the second feedback circuit being arranged between the non-inverting output and the inverting input of the first amplifier, a first and a second input circuit, each comprising the parallel arrangement of a first resistor and a second capacitor, the first input circuit being arranged between the first input terminal and the non-inverting input of the first amplifier and the second input circuit being arranged between the second input terminal and the inverting input of the first amplifier, a connection between the inverting output of the first amplifier and the second output terminal and a connection between the non-inverting output of the first amplifier and the first output terminal.

Such a filter arrangement is very suitable for realising active RC filters comprising balanced amplifiers.

Active RC filters comprising balanced amplifier are known from United States Patent Specification US 4,509,019. Said specification describes the basic principle of an active RC filter comprising a balanced amplifier. Moreover, said specification reveals some filter types based on said principle including a first-order low-pass filter (Fig. 3). There are several known methods of designing a filter having specific desired characteristics. A frequently employed method is that in which lower-order filter sections are cascaded. It is common practice to employ first-order and second-order sections for this purpose. Sections orders higher than four are hardly ever used because such sections are difficult to realise. A filter arrangement of a type as defined in the opening paragraph is known from the article "New Structures for MOSFET-C Filters", Proceedings of the IEEE, Vol. 75, No. 7, July 1987, page 957. This article describes how difficult it may be to translate known filter designs into versions comprising balanced amplifiers. Said article proposes three different second-order filter sections comprising balanced amplifiers. A disadvantage of these known filter circuits is that only second-order filters are mentioned and that neither of the filters is suitable for realising all the filter operations which are customary and possible for said order without thoroughly modifying the circuit configuration, i.e. without changing the interconnections between the filter elements and, sometimes, the positions of the inputs and outputs of the network. For this reason the systematic design of active RC filters comprising balanced amplifiers is a difficult task.

Therefore, it is the object of the invention to provide filter circuits by means of which first-order and higher-order active RC filters can be realised simply.

According to the invention a filter arrangement of a type defined in the opening paragraph is characterized in that the filter arrangement also comprises a third and a fourth input circuit, each comprising a third capacitor, the third input circuit being arranged between the first input terminal and the inverting input of the first amplifier, and the fourth input circuit being arranged between the second input terminal and the non-inverting input of the first amplifier.

This filter arrangement constitutes the elementary configuration which serves as a basis for realising first-order and higher-order filter arrangements, enabling active RC filters of a specific order for substantially every possible filter function to be realised by merely changing the values of resistors and capacitors.

A first embodiment of a filter arrangement in accordance with the invention is characterized in that the filter arrangement further comprises a first and a second coupling circuit, each comprising a second resistor, the first coupling circuit being arranged between the non-inverting input of the first amplifier and the inverting output of the first amplifier, and the second coupling circuit being arranged between the inverting input of the first amplifier and the non-inverting output of the first amplifier.

The addition of two network elements yielding a general first-order filter arrangement. Filter arrangements having special characteristics are obtained by an appropriate choice of the values of the filter elements.

A further embodiment is characterized in that the capacitance values of the third capacitors in the third and the fourth input circuit and the first capacitors in the first and the second feedback circuit are substantially equal, and in that the conductance values of the first resistors in the first and second input circuit and the second resistors in the first and second coupling circuit are substantially equal. This yields a first-order all-pass network.

IEEE Transactions on Circuits and Systems, CAS-34, No. 8, August 1987, "Analysis and compensation of high-frequency effects in integrated MOSFET-C continuous-time filters", pp. 862-875 discloses in its Figs. 1 and 4 a filter arrangement as set out in Claim 1 in which the second capacitor is not included. 1985 International Symposium on Circuits and Systems Proceedings, 5-17 June 1985 Kyoto, Vol. 3, "Considerations in the design of high frequency fully integrated continuous time filters", pp. 1439-1442, also shows in its Fig. 1 a filter arrangement as set out in Claim 1 without the second capacitor.

By extending the elementary configuration a second embodiment of a filter arrangement in accordance with the invention is obtained, which is characterized in that the filter arrangement further comprises a second balanced amplifier having a non-inverting and an inverting input and having a non-inverting and an inverting output, a fifth and a sixth input circuit, each comprising a fourth capacitor, the fifth input circuit being arranged
 5 between the first input terminal and the non-inverting input of the second amplifier, and the sixth input circuit being arranged between the second input terminal and the inverting input of the second amplifier, a seventh and an eighth input circuit, each comprising a third resistor, the seventh input circuit being arranged between the non-inverting output of the first amplifier and the non-inverting input of the second amplifier, and the eighth input circuit being arranged between the inverting output of the first amplifier and the inverting input of the
 10 second amplifier, a third and a fourth feedback circuit, each comprising a fifth capacitor, the third feedback circuit being arranged between the inverting output and the non-inverting input of the second amplifier, and the fourth feedback circuit being arranged between the non-inverting output and the inverting input of the second amplifier, a first and a second coupling circuit, each comprising a second resistor, the first coupling circuit being arranged between the non-inverting input of the first amplifier and a first node, and the second coupling
 15 circuit being arranged between the inverting input of the first amplifier and a second node, a third and a fourth coupling circuit, each comprising a fourth resistor, the third coupling circuit being arranged between the first node and the non-inverting input of the second amplifier, and the fourth coupling circuit being arranged between the second node and the inverting input of the second amplifier.

A modification thereof constitutes a general second-order filter arrangement which, in accordance with
 20 the invention is characterized in that the first node and the inverting output of the second amplifier and a fourth output terminal are interconnected, and in that the second node and the non-inverting output of the second amplifier and a third output terminal are interconnected. Special embodiments of the second-order filter arrangement are obtained by varying the values of the resistors and the capacitors.

An embodiment having the characteristics of an all-pass network is characterized in that the capacitance
 25 values of the second capacitors in the first and second input circuit are substantially equal zero, in that the conductance values of the first resistors in the first and the second input circuit and of the second resistor in the first and the second coupling circuit are substantially equal, in that the conductance values of the third resistors in the seventh and the eighth input circuit and of the fourth resistors in the third and the fourth coupling circuit are substantially equal, in that the capacitance values of the third capacitors in the third and the fourth
 30 input circuit and of the first capacitors in the first and the second feedback circuit are substantially equal, and in that the capacitance values of the fourth capacitors in the fifth and the sixth input circuit and of the fifth capacitors in the third and the fourth feedback circuit are substantially equal.

A further extension of the elementary configuration yields a third embodiment of a filter arrangement in accordance with the invention which is characterized in that the filter arrangement further comprises a third
 35 balanced amplifier having a non-inverting and an inverting input and having a non-inverting and an inverting output, a fifth and a sixth output terminal, a ninth and a tenth input circuit, each comprising a sixth capacitor, the ninth input circuit being arranged between the first input terminal and the non-inverting input of the third amplifier, and the tenth input circuit being arranged between the second input terminal and the inverting input of the third amplifier, an eleventh and a twelfth input circuit, each comprising a seventh capacitor, the eleventh
 40 input circuit being arranged between the first input terminal and the inverting input of the third amplifier, and the twelfth input circuit being arranged between the second input terminal and the non-inverting input of the third amplifier, a thirteenth and a fourteenth input circuit, each comprising a fifth resistor, the thirteenth input circuit being arranged between the inverting output of the second amplifier and the inverting input of the third amplifier, and the fourteenth input circuit being arranged between the non-inverting output of the second amplifier and the non-inverting input of the third amplifier, a fifth and a sixth coupling circuit, each comprising a
 45 sixth resistor, the fifth coupling circuit being arranged between the first node and the non-inverting input of the third amplifier, and the sixth coupling circuit being arranged between the second node and the inverting input of the third amplifier, a fifth and a sixth feedback circuit, each comprising an eighth capacitor, the fifth feedback circuit being arranged between the non-inverting input and the inverting output of the third amplifier, and the sixth feedback circuit being arranged between the inverting input and the non-inverting output of the
 50 third amplifier, and in that the inverting output of the third amplifier is connected to the sixth output terminal and the non-inverting output of the third amplifier is connected to the fifth output terminal.

A further embodiment constitutes a general third-order filter arrangement, characterized in that the first node is connected to the inverting output of the third amplifier and the second node is connected to the non-inverting output of the third amplifier.
 55

Special filter arrangements can be obtained by varying the values of the resistors and capacitors.

An all-pass network is obtained if the conductance values of the first resistors in the first and the second input circuit and of the second resistors in the first and the second coupling circuit are substantially equal, in

that the conductance values of the third resistors in the seventh and the eighth input circuit and of the fourth resistors in the third and the fourth coupling circuit are substantially equal, in that the conductance values of the fifth resistors in the thirteenth and the fourteenth input circuit and the sixth resistors in the fifth and of the sixth coupling circuit are substantially equal, in that the capacitance values of the second capacitors in the first and the second input circuit and of the sixth capacitors in the ninth and the tenth input circuit are substantially zero, in that the capacitance values of the third capacitors in the third and the fourth input circuit and of the first capacitors in the first and the second feedback circuit are substantially equal, in that the capacitance values of the fourth capacitors in the fifth and the sixth input circuit and of the fifth capacitors in the third and the fourth feedback circuit are substantially equal, and in that the capacitance values of the seventh capacitors in the eleventh and the twelfth input circuit and of the eighth capacitors in the fifth and in the sixth feedback circuit are substantially equal.

Yet another extension of the elementary configuration results in a fourth embodiment of a filter arrangement in accordance with the invention, which is characterized in that the filter arrangement further comprises a fourth balanced amplifier having a non-inverting input and an inverting input and having a non-inverting output and an inverting output, a seventh and an eighth output terminal, a fifteenth and a sixteenth input circuit, each comprising a ninth capacitor, the fifteenth input circuit being arranged between the first input terminal and the non-inverting input of the fourth amplifier and the sixteenth input circuit being arranged between the second input terminal and the inverting input of the fourth amplifier, a seventeenth and an eighteenth input circuit, each comprising a seventh resistor, the seventeenth input circuit being arranged between the non-inverting output of the third amplifier and the non-inverting input of the fourth amplifier, and the eighteenth input circuit being arranged between the inverting output of the third amplifier and the inverting input of the fourth amplifier, a seventh and an eighth feedback circuit, each comprising a tenth capacitor, the seventh feedback circuit being arranged between the non-inverting input and the inverting output of the fourth amplifier, and the eighth feedback circuit being arranged between the inverting input and the non-inverting output of the fourth amplifier, a ninth and a tenth feedback circuit, each comprising an eighth resistor, the ninth feedback circuit being arranged between the non-inverting input and the inverting output of the fourth amplifier, and the tenth feedback circuit being arranged between the inverting input and the non-inverting output of the fourth amplifier, and in that the inverting output of the fourth amplifier is connected to the eighth output terminal and the non-inverting output of the fourth amplifier is connected to the seventh output terminal.

This is a general fourth-order filter arrangement which enables filters having special characteristics to be obtained by varying the values of the resistors and the capacitors.

An all-pass network is obtained in that the conductance values of the first resistors in the first and the second input circuit and of the second resistors in the first and the second coupling circuit are substantially equal, in that the conductance values of the third resistors in the seventh and the eighth input circuit and of the fourth resistors in the third and the fourth coupling circuit are substantially equal, in that the conductance values of the fifth resistors in the thirteenth and the fourteenth input circuit and of the sixth resistors in the fifth and the sixth coupling circuit are substantially equal, in that the conductance values of the seventh resistors in the seventeenth and the eighteenth input circuit and of the eighth resistors in the ninth and the tenth feedback circuit are substantially equal, in that the capacitance values of the third capacitors in the third and the fourth input circuit and of the first capacitors in the first and the second feedback circuit are substantially equal, in that the capacitance values of the fourth capacitors in the fifth and the sixth input circuit and of the fifth capacitors in the third and the fourth feedback circuit are substantially equal, in that the capacitance values of the seventh capacitors in the eleventh and the twelfth input circuit and of the eighth capacitors in the fifth and the sixth feedback circuit are substantially equal, in that the capacitance values of the ninth capacitors in the fifteenth and the sixteenth input circuit and of the tenth capacitors in the seventh and the eighth feedback circuit are substantially equal, and in that the capacitance values of the second capacitors in the first and the second input circuit and of the sixth capacitors in the ninth and the tenth input circuit are substantially zero.

The invention will now be described in more detail, by way of example, with reference to the accompanying drawings, in which:

- Fig. 1 shows a diagram of a first-order elementary configuration in accordance with the invention,
- Fig. 2 shows a diagram of a general first-order filter arrangement in accordance with the invention,
- Fig. 3 shows a diagram of a first-order all-pass filter arrangement in accordance with the invention,
- Fig. 4 shows a diagram of a first-order high-pass filter arrangement,
- Fig. 5 shows a diagram of a second-order elementary configuration in accordance with the invention,
- Fig. 6 shows a diagram of a general second-order filter arrangement in accordance with the invention,
- Fig. 7 shows a diagram of a second-order low-pass filter arrangement,
- Fig. 8 shows a diagram of a second-order high-pass filter arrangement in,
- Fig. 9 shows a diagram of a second-order filter arrangement having a transmission zero point,

Fig. 10 shows a diagram of a second-order all-pass filter arrangement in accordance with the invention,
 Fig. 11 shows a diagram of a second-order band-pass filter arrangement,
 Fig. 12 shows a diagram of a third-order elementary configuration in accordance with the invention,
 Fig. 13 shows a diagram of a general third-order filter arrangement in accordance with the invention,
 Fig. 14 shows a diagram of a third-order low-pass filter arrangement,
 Fig. 15 shows a diagram of a third-order high-pass filter arrangement,
 Fig. 16 shows a diagram of a third-order filter arrangement having a transmission zero point,
 Fig. 17 shows a diagram of a third-order all-pass filter arrangement in accordance with the invention,
 Fig. 18 shows a diagram of a general fourth-order filter arrangement in accordance with the invention,
 Fig. 19 shows a diagram of a fourth-order low-pass filter arrangement,
 Fig. 20 shows a diagram of a fourth-order high-pass filter arrangement
 Fig. 21 shows a diagram of a fourth-order all-pass filter arrangement in accordance with the invention.

Hereinafter some examples of filter arrangements in accordance with the invention are described. Examples of first-order to fourth-order filter arrangements are given, in which an appropriate selection of the component values results in useful filters.

Fig. 1 shows diagrammatically the elementary configuration around which all the filter arrangements are built. It comprises a balanced amplifier A_1 having a non-inverting input 3 and an inverting input 4, an inverting output 5 and a non-inverting output 6. The filter arrangement has two input terminals 1 and 2 and two output terminals 7 and 8. The amplifier A_1 comprises a feedback capacitor C_1 between the inverting output 5 and the non-inverting input 6 and between the non-inverting output 6 and the inverting input 4. A parallel arrangement of a resistor R_1 and a capacitor C_2 is arranged between the input terminal 1 and the non-inverting input 3 and between the input terminal 2 and the inverting input 4. A capacitor C_3 is arranged between the input terminal 1 and the inverting input 4 and between the input terminal 2 and the non-inverting input 3. The inverting output 5 is connected to the output 8 and the non-inverting output 6 is connected to the output 7. This crosswise connection ensures that the output signals have the same polarities as the input signals applied to the filter arrangement. The circuit is fully symmetrical and is driven by two balanced input signals of opposite polarity. Fig. 2 shows the general first-order filter arrangement. It is obtained in that in the arrangement shown in Fig. 1 two resistors R_2 are added between the inverting output 5 and the non-inverting input 3 and between the non-inverting output 6 and the inverting input 4. The filter arrangement operates as follows. An input voltage $+V_1$ is applied to the input terminal 1 and an equal but opposite input voltage $-V_1$ is applied to the input terminal 2. An output voltage $+V_2$ is obtained on the output terminal 7 and an equal but opposite output voltage $-V_2$ is obtained on the output terminal 8.

The voltage transfer function can be computed by solving the nodal equation for the currents in the node N_1 . N_1 corresponds to the non-inverting input 3 of the amplifier A_1 , which amplifier is assumed not to draw any input current. In that case the following equation is valid:

$$G_1 \cdot V_1 + p \cdot (C_2 - C_3) \cdot V_1 = G_2 \cdot V_2 + p \cdot C_1 \cdot V_2 \quad (1)$$

$$\frac{V_2}{V_1} = \frac{G_1 + p \cdot (C_2 - C_3)}{G_2 + p \cdot C_1} \quad (2)$$

where G_1 is the conductance value of the resistor R_1 in conformity with $\frac{1}{R_1} = G_1$ and where p is the complex frequency $p = j\omega$. Formula (2) is the complex transfer function of the filter arrangement expressed as a polynomial of p . The highest power of p dictates the order of the filter network. The network shown in Fig. 2 is consequently of the first-order. Varying the values of the filter components yields filter arrangements having special characteristics. Some examples of such arrangements will be given hereinafter.

Fig. 3 shows a first-order all-pass filter arrangement. It is obtained by selecting $C_2=0$, $G_1=G_2=G$ and $C_3=C_1=C$ in the general first-order filter arrangement shown in Fig. 2. The voltage transfer function then becomes

$$\frac{V_2}{V_1} = \frac{G - pC}{G + pC} \quad (3)$$

Such a transfer function is characterized by a frequency-independent amplitude response.

Fig. 4 shows a second example. It is a first-order high-pass filter arrangement obtained by making $G_1=0$ and $C_3=0$ in the general first-order filter arrangement shown in Fig. 2. The transfer function is then

$$\frac{V_2}{V_1} = \frac{p \cdot C_2}{G_2 + pC_1} \quad (4)$$

Further it is to be noted that a first-order low-pass filter arrangement can be obtained by making $C_2=0$ and $C_3=0$ in the general filter arrangement shown in Fig. 2.

Extending the elementary configurations shown in Fig. 1 yields a filter arrangement which may be regarded

as the elementary configuration for second-order filter arrangements shown diagrammatically in Fig. 5. It is obtained by adding the following components to the arrangement shown in Fig. 1: a second balanced amplifier A_2 having a non-inverting input 11, an inverting input 12, an inverting output 13 and a non-inverting output 14; a resistor R_2 between the node 9 and the non-inverting input 3 of the first amplifier A_1 and between the node 10 and the inverting input of the amplifier A_1 ; a resistor R_4 between the non-inverting input 11 of the amplifier A_2 and the node 9, and between the inverting input 12 of the amplifier A_2 and the node 10; a resistor R_3 between the non-inverting output 6 of the amplifier A_1 and the non-inverting input 11 of the amplifier A_2 and between the inverting output 5 of A_1 and the inverting input 12 of the amplifier A_2 ; a capacitor C_4 between the input terminal 1 and the non-inverting input 11 of the amplifier A_2 and between the input terminal 2 and the inverting input 12 of the amplifier A_2 ; a capacitor C_5 between the non-inverting input 11 and the inverting output 13 of the amplifier A_2 and between the inverting input 12 and the non-inverting output 14 of the amplifier A_2 . A general second-order filter arrangement is shown in Fig. 6 and is obtained by providing in the arrangement shown in Fig. 5 a connection between the node 9 and the inverting output 13 of the amplifier A_2 and between the node 10 and the non-inverting output 14 of the amplifier A_2 . In addition, the inverting output 13 of the amplifier A_2 is connected to the output terminal 16 and the non-inverting output 14 of the amplifier A_2 is connected to the output terminal 15. This cross connection at the output of the arrangement ensures that the output signals have the same polarities as the input signals.

An input voltage $+V_1$ is applied to the input terminal 1 and an input voltage $-V_1$ is applied to the input terminal 2. A voltage $-V_2$ is obtained on the inverting output 5 of the amplifier A_1 and a voltage $+V_2$ is obtained on the non-inverting output 6 of the amplifier A_2 . A voltage $+V_3$ is obtained on the output terminal 15 of the filter arrangement and a voltage $-V_3$ appears on the output terminal 16. The plus and minus signs preceding the signal voltages indicate that the signal voltages are of equal amplitude but opposite polarity. In order to calculate the voltage transfer function it is assumed that the balanced amplifiers A_1 and A_2 draw no input current. Moreover, a second node N_2 is introduced, which corresponds to the non-inverting input 11 of the amplifier A_2 .

The node N_1 complies with:

$$G_1 \cdot V_1 + p \cdot (C_2 - C_3) \cdot V_1 = G_2 \cdot V_3 + p \cdot C_1 \cdot V_2 \quad (5)$$

and the node N_2 complies with:

$$G_3 \cdot V_2 + p \cdot C_4 \cdot V_1 = G_4 \cdot V_3 + p \cdot C_5 \cdot V_3 \quad (6)$$

V_2 can be eliminated from the set of equations by multiplying the terms of equation (5) by G_3 and those of equation (6) by $p \cdot C_1$ and subsequently adding (5) and (6) to one another, which operations may be represented by the following diagrammatic notation

$$\begin{array}{rcl} (5) & *G_3 & \\ (6) & *p \cdot C_1 & (7) \\ \hline & + & \end{array}$$

From the result the voltage transfer function can be computed:

$$\frac{V_3}{V_1} = \frac{G_1 \cdot G_3 + p \cdot (C_2 - C_3) \cdot G_3 + p \cdot p \cdot C_1 \cdot C_4}{G_2 \cdot G_3 + p \cdot C_1 \cdot G_4 + p \cdot p \cdot C_1 \cdot C_5} \quad (8)$$

This is a second-order transfer function. By an appropriate choice of the values of the filter components special second-order filter arrangements are obtained, of which a number of examples will be described hereinafter. A second-order low-pass filter arrangement is obtained by selecting $C_2=C_3=C_4=0$ in (8). The voltage transfer function then becomes:

$$\frac{V_3}{V_1} = \frac{G_1 \cdot G_3}{G_2 \cdot G_3 + p \cdot C_1 \cdot G_4 + p \cdot p \cdot C_1 \cdot C_5} \quad (9)$$

The diagram of the low-pass filter is shown in Fig. 7.

A second-order high-pass filter arrangement is obtained by selecting $G_1 = 0$ and $C_3 = 0$ in (8). The voltage transfer function then becomes:

$$\frac{V_3}{V_1} = \frac{p \cdot C_2 \cdot G_3 + p \cdot p \cdot C_1 \cdot C_4}{G_2 \cdot G_3 + p \cdot C_1 \cdot G_4 + p \cdot p \cdot C_1 \cdot C_5} \quad (10)$$

and the diagram of the high-pass filter is shown in Fig. 8.

A second-order filter arrangement with which the frequency can be rejected, also referred to as a band-rejection filter or notch filter, is obtained by selecting $C_2=C_3=0$ in (8). The voltage transfer function is then:

$$\frac{V_3}{V_1} = \frac{G_1 \cdot G_3 + p \cdot p \cdot C_1 \cdot C_4}{G_2 \cdot G_3 + p \cdot C_1 \cdot G_4 + p \cdot p \cdot C_1 \cdot C_5} \quad (11)$$

and the diagram is given in Fig. 9. A further example relates to a filter arrangement which behaves as a second-order all-pass filter. By selecting $G_2=G_1$, $G_4=G_3$, $C_2=0$, $C_1=C_3$ and $C_5=C_4$ in (8), the voltage transfer function becomes:

$$\frac{V_3}{V_1} = \frac{G_1 * G_3 - p * C_3 * G_3 + p * p * C_3 * C_4}{G_2 * G_3 + p * C_3 * G_3 + p * p * C_3 * C_4} \quad (12)$$

The diagram of the all-pass filter is shown in Fig. 10.

The last example of a special second-order filter arrangement is a second-order band-pass arrangement shown in Fig. 11. It is obtained by selecting by $G_1=0$ and $C_3=C_4=0$ in (8). The voltage transfer function then becomes:

$$\frac{V_3}{V_1} = \frac{p * C_2 * G_3}{G_2 * G_3 + p * C_1 * G_4 + p * p * C_1 * C_5} \quad (13)$$

The elementary configuration for second-order filter arrangement of Fig. 5 can be extended to obtain a third-order elementary configuration whose diagram is shown in Fig. 12. It is obtained by adding the following components to the arrangement of Fig. 5: a balanced amplifier A_3 having a non-inverting input 17 and an inverting input 18 and having an inverting output 19 and a non-inverting output 20; a capacitor C_6 between the input terminal 1 and the non-inverting input 17 and between the input terminal 2 and the inverting input 18; a capacitor C_7 between the input terminal 1 and the inverting input 18 and between the input terminal 2 and the non-inverting input 17; a resistor R_5 between the inverting output 13 and the inverting input 18 and between the non-inverting output 14 and the non-inverting input 17; a capacitor C_8 between the non-inverting input 17 and the inverting output 19 and between the inverting input 18 and the non-inverting output 20; a resistor R_6 between the node 9 and the non-inverting input 17 and between the node 10 and the inverting input 18. Further, the inverting output 19 is connected to the output terminal 22 and the non-inverting output 22 is connected to the output terminal 21. A general third-order filter arrangement is shown in Fig. 13 and is formed by arranging a connection between the node 9 and the inverting output 19 and between the node 10 and the non-inverting input 20 in the arrangement shown in Fig. 12. An input voltage $+V_1$ is applied to the input terminal 2 and an input voltage $-V_1$ is applied to the input terminal 1. The output voltage on the inverting output 5 of the amplifier A_1 is $-V_2$, that on the non-inverting output 6 of the amplifier A_1 is $+V_2$, that on the inverting output 13 of the amplifier A_2 is $-V_3$, that on the non-inverting output 14 of the amplifier A_2 is $+V_3$, that on the output terminal 21 is $+V_4$, and that on the output terminal 22 is $-V_4$. Moreover, a third node N_3 is shown which node corresponds to the non-inverting input 17 of the amplifier A_3 .

The node N_1 complies with:

$$G_1 * V_1 + p * (C_2 - C_3) * V_1 = G_2 * V_4 + p * C_1 * V_2 \quad (14)$$

The node N_2 complies with:

$$G_3 * V_2 + p * C_4 * V_1 = G_4 * V_4 + p * C_5 * V_3 \quad (15)$$

and the node N_3 complies with:

$$G_5 * V_3 + p * (C_6 - C_7) * V_1 = G_6 * V_4 + p * C_8 * V_4 \quad (16)$$

In these three equations V_2 and V_3 can be eliminated as follows:

$$\begin{aligned} (14) \quad & *G_3 * G_5 \\ (15) \quad & *p * C_1 * G_5 \\ (16) \quad & *p * C_1 * p * C_4 \end{aligned} \quad (17)$$

which yields the following voltage transfer function:

$$\frac{V_4}{V_1} = \frac{G_1 * G_3 * G_5 + p * (C_2 - C_3) * G_3 * G_5 + p * p * C_1 * C_4 * G_5 + p * p * p * C_1 * C_5 * (C_6 - C_7)}{G_2 * G_3 * G_5 + p * C_1 * G_4 * G_5 + p * p * C_1 * C_5 * G_6 + p * p * p * C_1 * C_5 * C_8} \quad (18)$$

Filters having special characteristics can be obtained by an appropriate choice of the values of the filter elements in the general third-order filter arrangement of Fig. 13.

A first example is a third-order low-pass filter, of which the diagram is shown in Fig. 14. This is achieved by selecting $C_2=C_3=C_6=C_7=0$ in (18). The transfer function then becomes:

$$\frac{V_4}{V_1} = \frac{G_1 * G_3 * G_5}{G_2 * G_3 * G_5 + p * C_1 * G_4 * G_5 + p * p * C_1 * C_5 * G_6 + p * p * p * C_1 * C_5 * C_8} \quad (19)$$

A second example is a third-order high-pass filter arrangement, shown in Fig. 15, which is obtained by

selecting $G_1=0$ and $C_3=C_7=0$ in (18). The transfer function is then:

$$\frac{V_4}{V_1} = \frac{p \cdot C_2 \cdot G_3 \cdot G_5 + p \cdot p \cdot C_1 \cdot C_4 \cdot G_5 + p \cdot p \cdot p \cdot C_1 \cdot C_5 \cdot C_6}{G_2 \cdot G_3 \cdot G_5 + p \cdot C_1 \cdot G_4 \cdot G_5 + p \cdot p \cdot C_1 \cdot C_5 \cdot G_6 + p \cdot p \cdot p \cdot C_1 \cdot C_5 \cdot C_8} \quad (20)$$

A third example is a third-order band-rejection filter, whose diagram is shown in Fig. 16. By selecting $G_5=G_1$, $C_3=C_7=0$ and $C_2 \cdot C_4 = C_5 \cdot C_6$ in (18) the voltage transfer function becomes:

$$\frac{(G_1 \cdot G_3 + p \cdot p \cdot C_1 \cdot C_4) \cdot (G_1 + p \cdot C_2/G_1)}{G_2 \cdot G_3 \cdot G_1 + p \cdot C_1 \cdot G_4 \cdot G_1 + p \cdot p \cdot C_1 \cdot C_5 \cdot G_6 + p \cdot p \cdot p \cdot C_1 \cdot C_5 \cdot C_8} \quad (21)$$

The numerator of (21) now includes a term equal to the numerator of the voltage transfer function (11) of a second-order band-rejection filter.

Fig. 17 shows a fourth example. It is a third-order all-pass filter arrangement obtained by selecting $G_2=G_1$, $G_4=G_3$, $G_6=G_5$, $C_2=C_6=0$, $C_3=C_1$, $C_5=C_4$ and $C_8=C_7$ in formula (18). The voltage transfer function is then:

$$\frac{V_4}{V_1} = \frac{G_1 \cdot G_3 \cdot G_5 - p \cdot C_1 \cdot G_3 \cdot G_5 + p \cdot p \cdot C_1 \cdot C_4 \cdot G_5 - p \cdot p \cdot p \cdot C_1 \cdot C_4 \cdot C_7}{G_1 \cdot G_3 \cdot G_5 + p \cdot C_1 \cdot G_3 \cdot G_5 + p \cdot p \cdot C_1 \cdot C_4 \cdot G_5 + p \cdot p \cdot p \cdot C_1 \cdot C_4 \cdot C_7} \quad (22)$$

The third-order elementary configuration of Fig. 12 can be extended to obtain a general fourth-order arrangement, whose diagram is shown in Fig. 18, by adding the following components to the arrangement shown in Fig. 12: a balanced amplifier A_4 having a non-inverting input 23 and an inverting input 24 and having an inverting output 25 and a non-inverting output 26; a capacitor C_9 between the first input terminal 1 and the non-inverting input 23 and between the input terminal 2 and the inverting input 24, a resistor R_7 between the inverting output 19 and the inverting input 24 and between the non-inverting output 20 and the non-inverting input 23; the parallel arrangement of a resistor R_8 and a capacitor C_{10} between the non-inverting input 23 and the inverting output 25 and between the inverting input 24 and the non-inverting output 26. Moreover, a connection is arranged between a first output terminal 27 and the non-inverting output 26 and between the second output terminal 28 and the inverting output 25.

It is to be noted that the arrangement shown in Fig. 18 is not identical to a fourth-order elementary configuration corresponding to the third-order elementary configuration of Fig. 12, the second-order elementary configuration of Fig. 5 and the first-order elementary configuration of Fig. 1, but is a general fourth-order filter arrangement corresponding to the general third-order filter arrangement shown in Fig. 13, the general second-order filter arrangement of Fig. 16, and the general first-order filter arrangement of Fig. 2. Extension to fifth-order and higher-order elementary configurations and fifth-order and higher-order general filter arrangement derived therefrom is readily possible by proceeding with the extensions in a manner as specified in the foregoing.

An input voltage $+V_1$ is applied to the input terminal 1 and an input voltage $-V_1$ is applied to an input terminal 2. The output voltage on the inverting output 5 of the amplifier A_1 is $-V_2$, that on the non-inverting output 6 of the amplifier A_1 is $+V_2$, that on the inverting output 13 of the amplifier A_2 is $-V_3$, that on the non-inverting output 14 of the amplifier A_2 is $+V_3$, that on the inverting output 19 of the amplifier A_3 is $-V_4$, that on the non-inverting output 20 of the amplifier A_3 is $+V_4$, that on the output terminal 27 is $+V_5$, and that on the output terminal 28 is $-V_5$. Moreover, a fourth node N_4 is shown, which node corresponds to the non-inverting input 23 of the amplifier A_4 . The voltage transfer function is computed by calculating the currents in the four nodes $N_1 \dots N_4$. It is assumed that the amplifiers $A_1 \dots A_4$ draw no input current. The node N_1 complies with:

$$G_1 \cdot V_1 + p \cdot (C_2 - C_3) \cdot V_1 = G_2 \cdot V_5 + p \cdot C_1 \cdot V_2 \quad (23)$$

N_2 complies with:

$$G_3 \cdot V_2 + p \cdot C_4 \cdot V_1 = G_4 \cdot V_5 + p \cdot C_5 \cdot V_3 \quad (24)$$

N_3 complies with:

$$G_5 \cdot V_3 + p \cdot (C_6 - C_7) \cdot V_1 = G_6 \cdot V_5 + p \cdot C_8 \cdot V_4 \quad (25)$$

and N_4 complies with:

$$G_7 \cdot V_4 + p \cdot C_9 \cdot V_1 = G_8 \cdot V_5 + p \cdot C_{10} \cdot V_5 \quad (26)$$

In this set of equations V_2 , V_3 and V_4 can be eliminated by:

$$\begin{aligned} (23) \quad & *G_3 * G_5 * G_7 \\ (24) \quad & *p * C_1 * G_5 * G_7 \\ (25) \quad & *p * C_1 * p * C_5 * G_7 \\ (26) \quad & *p * C_1 * p * C_5 * p * C_8 \end{aligned} \quad (27)$$

This yields the following voltage transfer function:

$$\frac{V5}{V1} = \frac{G1 \cdot G3 \cdot G5 \cdot G7 + p \cdot (C2 - C3) \cdot G3 \cdot G5 \cdot G7 + p \cdot p \cdot C1 \cdot C4 \cdot G5 \cdot G7 + p \cdot p \cdot p \cdot C1 \cdot C5 \cdot (C6 - C7) \cdot G7 + p \cdot p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C8 \cdot C9}{G2 \cdot G3 \cdot G5 \cdot G7 + p \cdot C1 \cdot G4 \cdot G5 \cdot G7 + p \cdot p \cdot C1 \cdot C5 \cdot G6 \cdot G7 + p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C8 \cdot G8 + p \cdot p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C8 \cdot C10} \quad (28)$$

By selecting suitable values for the filter components in (28) special arrangements can be derived from the general fourth-order filter arrangement of Fig. 18, of which a number of examples will be given hereinafter.

A fourth-order low-pass filter arrangement is obtained by selecting $C_2 = C_3 = C_4 = C_6 = C_7 = C_9 = 0$ in (28). The voltage transfer function is then:

$$\frac{V5}{V1} = \frac{G1 \cdot G3 \cdot G5 \cdot G7}{G2 \cdot G3 \cdot G5 \cdot G7 + p \cdot C1 \cdot G4 \cdot G5 \cdot G7 + p \cdot p \cdot C1 \cdot C5 \cdot G6 \cdot G7 + p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C8 \cdot G8 + p \cdot p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C8 \cdot C10} \quad (29)$$

The diagram is shown in Fig. 19.

Fig. 20 shows a fourth-order high-pass filter arrangement obtained by selecting $G_1 = 0$ and $C_3 = C_7 = 0$ in (28). The voltage transfer function is then:

$$\frac{V5}{V1} = \frac{p \cdot C2 \cdot G3 \cdot G5 \cdot G7 + p \cdot p \cdot C1 \cdot C4 \cdot G5 \cdot G7 + p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C6 \cdot G7 + p \cdot p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C8 \cdot C9}{G2 \cdot G3 \cdot G5 \cdot G7 + p \cdot C1 \cdot G4 \cdot G5 \cdot G7 + p \cdot p \cdot C1 \cdot C5 \cdot G6 \cdot G7 + p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C8 \cdot G8 + p \cdot p \cdot p \cdot p \cdot C1 \cdot C5 \cdot C8 \cdot C10} \quad (30)$$

Fig. 21 shows a fourth-order all-pass filter arrangement. It is obtained by the following selection of components in formula (28): $G_2 = G_1$, $G_4 = G_3$, $G_6 = G_5$ and $G_8 = G_7$;

$C_2 = C_6 = 0$; $C_3 = C_1$, $C_5 = C_4$, $C_8 = C_7$ and $C_{10} = C_9$.

The voltage transfer function may then be written as follows:

$$\frac{V5}{V1} = \frac{G1 \cdot G3 \cdot G5 \cdot G7 - p \cdot C1 \cdot G3 \cdot G5 \cdot G7 + p \cdot p \cdot C1 \cdot C4 \cdot G5 \cdot G7 - p \cdot p \cdot p \cdot C1 \cdot C4 \cdot C7 \cdot G7 + p \cdot p \cdot p \cdot p \cdot C1 \cdot C4 \cdot C7 \cdot C9}{G1 \cdot G3 \cdot G5 \cdot G7 + p \cdot C1 \cdot G3 \cdot G5 \cdot G7 + p \cdot p \cdot C1 \cdot C4 \cdot G5 \cdot G7 + p \cdot p \cdot p \cdot C1 \cdot C4 \cdot C7 \cdot G7 + p \cdot p \cdot p \cdot p \cdot C1 \cdot C4 \cdot C7 \cdot C9} \quad (31)$$

The invention is not limited to the embodiments shown herein. The general and special first-order and higher-order filter arrangements shown herein may be arranged in series, as required, in order to create other filter arrangements having different characteristics. For this reason some filter arrangements are provided with cross connections at their output sides in order to preclude changes in polarity when these filter arrangements are connected in series.

As will be apparent from the description, the invention is by no means limited to a specific integration process technology, such as for example MOS technology.

As already stated in the foregoing, the invention is not limited to fourth-order filter arrangements. Proceeding from the method as proposed by the invention those skilled in the art will be able to design any desired higher-order filter arrangement.



Claims

1. A filter arrangement comprising a first balanced amplifier (A_1) having a non-inverting (3) and an inverting input (4) and having a non-inverting output (6) and an inverting output (5), a first (1) and a second (2) input terminal, a first (7) and a second (8) output terminal, a first and a second feedback circuit, each comprising a first capacitor (C_1), the first feedback circuit being arranged between the inverting output (5) and the non-inverting input (3) of the first amplifier (A_1), and the second feedback circuit being arranged between the non-inverting output (6) and the inverting input (4) of the first amplifier (A_1), a first and a second input circuit, each comprising the parallel arrangement of a first resistor (R_1) and a second capacitor (C_2), the first input circuit being arranged between the first input terminal (1) and the non-inverting input (3) of the first amplifier (A_1) and the second input circuit being arranged between the second input terminal (2) and the inverting input (4) of the first amplifier (A_1), a connection between the inverting output (5) of the first amplifier (A_1) and the second output terminal (8) and a connection between the non-inverting output (6) of the first amplifier (A_1) and the first output terminal (7), characterized in that the filter arrangement also comprises a third and a fourth input circuit, each comprising a third capacitor (C_3), the third input circuit being arranged between the first input terminal (1) and the inverting input (4) of the first amplifier (A_1), and the fourth input circuit being arranged between the second input terminal (2) and the non-inverting input (3) of the first amplifier (A_1).
2. A filter arrangement as claimed in Claim 1, characterized in that the filter arrangement further comprises a first and a second coupling circuit, each comprising a second resistor (R_2), the first coupling circuit being arranged between the non-inverting input (3) of the first amplifier (A_1) and the inverting output (5) of the first amplifier (A_1), and the second coupling circuit being arranged between the inverting input (4) of the first amplifier (A_1) and the non-inverting output (6) of the first amplifier (A_1).
3. A filter arrangement as claimed in Claim 2, characterized in that the capacitance values of the second capacitors (C_2) in the first and the second input circuit are substantially zero, in that the capacitance values of the third capacitors (C_3) in the third and the fourth input circuit and the first capacitors (C_1) in the first and the second feedback circuit are substantially equal, and in that the conductance values of the first resistors (R_1) in the first and second input circuit and the second resistors (R_2) in the first and the second coupling circuits are substantially equal.
4. A filter arrangement as claimed in Claim 1, characterized in that the filter arrangement further comprises a second balanced amplifier (A_2) having a non-inverting input (11) and an inverting input (12) and having a non-inverting output (14) and an inverting output (13), a fifth and a sixth input circuit, each comprising a fourth capacitor (C_4), the fifth input circuit being arranged between the first input terminal (1) and the non-inverting input (11) of the second amplifier (A_2) and the sixth input circuit being arranged between the second input terminal (2) and the inverting input (12) of the second amplifier (A_2), a seventh and an eighth input circuit, each comprising a third resistor (R_3), the seventh input circuit being arranged between the non-inverting output (6) of the first amplifier (A_1) and the non-inverting input (11) of the second amplifier (A_2), and the eighth input circuit being arranged between the inverting output (5) of the first amplifier (A_1) and the inverting input (12) of the second amplifier (A_2), a third and a fourth feedback circuit, each comprising a fifth capacitor (C_5), the third feedback circuit being arranged between the inverting output (13) and the non-inverting input (11) of the second amplifier (A_2) and the fourth feedback circuit being arranged between the non-inverting output (14) and the inverting input (12) of the second amplifier (A_2), a first and second coupling circuit, each comprising a second resistor (R_2), the first coupling circuit being arranged between the non-inverting input (3) of the first amplifier (A_1) and a first node (9), and the second coupling circuit being arranged between the inverting input (4) of the first amplifier (A_1) and a second node (10), a third and a fourth coupling circuit, each comprising a fourth resistor (R_4), the third coupling circuit being arranged between the first node (9) and the non-inverting input (11) of the second amplifier (A_2), and the fourth coupling circuit being arranged between the second node (10) and the inverting input (12) of the second amplifier (A_2).
5. A filter arrangement as claimed in Claim 4, characterized in that the first node (9) and the inverting output (13) of the second amplifier and a fourth output terminal (16) are interconnected, and in that the second node (10) and the non-inverting output (14) of the second amplifier (A_2) and a third output terminal (15) are interconnected.



6. A filter arrangement as claimed in Claim 5, characterized in that the capacitance values of the second capacitors (C_2) in the first and the second input circuit are substantially zero, in that the conductance values of the first resistors (R_1) in the first and second input circuit and of the second resistors (R_2) in the first and the second coupling circuit are substantially equal, in that the conductance values of the third resistors (R_3) in the seventh and the eighth input circuit and of the fourth resistors (R_4) in the third and the fourth coupling circuit are substantially equal, in that the capacitance value of the third capacitors (C_3) in the third and the fourth input circuit and of the first capacitors (C_1) in the first and the second feedback circuit are substantially equal, and in that the capacitance values of the fourth capacitors (C_4) in the fifth and the sixth input circuit and of the fifth capacitors (C_5) in the third and the fourth feedback circuit are substantially equal.
7. A filter arrangement as claimed in Claim 4, characterized in that the filter arrangement further comprises a third balanced amplifier (A_3) having a non-inverting (17) and an inverting (18) input and having a non-inverting (20) and an inverting (19) output, a fifth (21) and a sixth (22) output terminal, a ninth and a tenth input circuit, each comprising a sixth capacitor (C_6), the ninth input circuit being arranged between the first input terminal (1) and the non-inverting input (17) of the third amplifier (A_3), and the tenth input circuit being arranged between the second input terminal (2) and the inverting input (18) of the third amplifier (A_3), an eleventh and a twelfth input circuit, each comprising a seventh capacitor (C_7), the eleventh input circuit being arranged between the first input terminal (1) and the inverting input (18) of the third amplifier (A_3), and the twelfth input circuit being arranged between the second input terminal (2) and the non-inverting input (17) of the third amplifier (A_3), a thirteenth and a fourteenth input circuit, each comprising a fifth resistor (R_5), the thirteenth input circuit being arranged between the inverting output (13) of the second amplifier (A_2) and the inverting input (18) of the third amplifier (A_3), and the fourteenth input circuit being arranged between the non-inverting output (14) of the second amplifier (A_2) and the non-inverting input (17) of the third amplifier (A_3), a fifth and a sixth coupling circuit, each comprising a sixth resistor (R_6), the fifth coupling circuit being arranged between the first node (9) and the non-inverting input (17) of the third amplifier (A_3), and the sixth coupling circuit being arranged between the second node (10) and the inverting input (18) of the third amplifier (A_3), a fifth and a sixth feedback circuit, each comprising an eighth capacitor (C_8), the fifth feedback circuit being arranged between the non-inverting input (17) and the inverting output (19) of the third amplifier (A_3), and the sixth feedback circuit being arranged between the inverting input (18) and the non-inverting output (20) of the third amplifier (A_3), and in that the inverting output (19) of the third amplifier (A_3) is connected to the sixth output terminal (22) and the non-inverting output (20) of the third amplifier (A_3) is connected to the fifth output terminal (21).
8. A filter arrangement as claimed in Claim 7, characterized in that the first node (9) is connected to the inverting output (19) of the third amplifier (A_3) and the second node (10) is connected to the non-inverting output (20) of the third amplifier (A_3).
9. A filter arrangement as claimed in Claim 8, characterized in that the conductance values of the first resistors (R_1) in the first and the second input circuit and of the second resistors (R_2) in the first and the second coupling circuit are substantially equal, in that the conductance values of the third resistors (R_3) in the seventh and the eighth input circuit and of the fourth resistors (R_4) in the third and the fourth coupling circuit are substantially equal, in that the conductance values of the fifth resistors (R_5) in the thirteenth and the fourteenth input circuit and the sixth resistors (R_6) in the fifth and of the sixth coupling circuit are substantially equal, in that the capacitance values of the second capacitors (C_2) in the first and the second input circuit and of the sixth capacitors (C_6) in the ninth and the tenth input circuit are substantially zero, in that the capacitance values of the third capacitors (C_3) in the third and the fourth input circuit and of the first capacitors (C_1) in the first and the second feedback circuit are substantially equal, in that the capacitance values of the fourth capacitors (C_4) in the fifth and the sixth input circuit and of the fifth capacitors (C_5) in the third and the fourth feedback circuit are substantially equal, and in that the capacitance values of the seventh capacitors (C_7) in the eleventh and the twelfth input circuit and of the eighth capacitors (C_8) in the fifth and in the sixth feedback circuit are substantially equal.
10. A filter arrangement as claimed in Claim 7, characterized in that the filter arrangement further comprises a fourth balanced amplifier (A_4) having a non-inverting input (23) and an inverting input (24) and having a non-inverting output (26) and an inverting output (25), a seventh (27) and an eighth (28) output terminal, a fifteenth and a sixteenth input circuit, each comprising a ninth capacitor (C_9), the fifteenth input circuit being arranged between the first input terminal (1) and the non-inverting input (23) of the fourth amplifier



(A₄) and the sixteenth input circuit being arranged between the second input terminal (2) and the inverting input (24) of the fourth amplifier (A₄), a seventeenth and an eighteenth input circuit, each comprising a seventh resistor (R₇), the seventeenth input circuit being arranged between the non-inverting output (20) of the third amplifier (A₃) and the non-inverting input (23) of the fourth amplifier (A₄), and the eighteenth input circuit being arranged between the inverting output (19) of the third amplifier (A₃) and the inverting input (24) of the fourth amplifier (A₄), a seventh and an eighth feedback circuit, each comprising a tenth capacitor (C₁₀), the seventh feedback circuit being arranged between the non-inverting input (23) and the inverting output (25) of the fourth amplifier (A₄), and the eighth feedback circuit being arranged between the inverting input (24) and the non-inverting output (26) of the fourth amplifier (A₄), a ninth and a tenth feedback circuit, each comprising an eighth resistor (R₈), the ninth feedback circuit being arranged between the non-inverting input (23) and the inverting output (25) of the fourth amplifier (A₄), and the tenth feedback circuit being arranged between the inverting input (24) and the non-inverting output (26) of the fourth amplifier (A₄), and in that the inverting output (25) of the fourth amplifier (A₄) is connected to the eighth output terminal (28) and the non-inverting output (26) of the fourth amplifier (A₄) is connected to the seventh output terminal (27).

11. A filter arrangement as claimed in Claim 10, characterized in that the conductance values of the first resistors (R₁) in the first and the second input circuit and of the second resistors (R₂) in the first and the second coupling circuit are substantially equal, in that the conductance values of the third resistors (R₃) in the seventh and the eighth input circuit and the fourth resistors (R₄) in the third and the fourth coupling circuit are substantially equal, in that the conductance values of the fifth resistors (R₅) in the thirteenth and the fourteenth input circuit and of the sixth resistors (R₆) in the fifth and the sixth coupling circuit are substantially equal, in that the conductance values of the seventh resistors (R₇) in the seventeenth and the eighteenth input circuit and of the eighth resistors (R₈) in the ninth and the tenth feedback circuit are substantially equal, in that the capacitance values of the third capacitors (C₃) in the third and the fourth input circuit and of the first capacitors (C₁) in the first and the second feedback circuit are substantially equal, in that the capacitance values of the fourth capacitors (C₄) in the fifth and the sixth input circuit and of the fifth capacitors (C₅) in the third and the fourth feedback circuit are substantially equal, in that the capacitance values of the seventh capacitors (C₇) in the eleventh and the twelfth input circuit and of the eighth capacitors (C₈) in the fifth and the sixth feedback circuit are substantially equal, in that the capacitance values of the ninth capacitors (C₉) in the fifteenth and the sixteenth input circuit and of the tenth capacitors (C₁₀) in the seventh and the eighth feedback circuit are substantially equal, and in that the capacitance values of the second capacitors (C₂) in the first and the second input circuit and of the sixth capacitors (C₆) in the ninth and the tenth input circuit are substantially zero.

Patentsprüche

1. Filterschaltung, die folgendes enthält: einen ersten Gegentakt-Verstärker (A₁) mit einem nicht-invertierenden Eingang (3) und einem invertierenden Eingang (4) und mit einem nicht-invertierenden Ausgang (6) und einem invertierenden Ausgang (5); einen ersten (1) und einen zweiten (2) Eingangsanschluß; einen ersten (7) und einen zweiten (8) Ausgangsanschluß; einen ersten und einen zweiten Rückkopplungskreis, von denen jeder einen ersten Kondensator (C₁) enthält, wobei der erste Rückkopplungskreis zwischen dem invertierenden Ausgang (5) und dem nicht-invertierenden Eingang (3) des ersten Verstärkers (A₁) angeordnet ist, und wobei der zweite Rückkopplungskreis zwischen dem nicht-invertierenden Ausgang (6) und dem invertierenden Eingang (4) des ersten Verstärkers (A₁) angeordnet ist; eine erste und eine zweite Eingangsschaltung, von denen jede eine Parallelschaltung bestehend aus einem ersten Widerstand (R₁) und einem zweiten Kondensator (C₂) beinhaltet, wobei die erste Eingangsschaltung zwischen dem ersten Eingangsanschluß (1) und dem nicht-invertierenden Eingang (3) des ersten Verstärkers (A₁) angeordnet ist, und wobei die zweite Eingangsschaltung zwischen dem zweiten Eingangsanschluß (2) und dem invertierenden Eingang (4) des ersten Verstärkers (A₁) angeordnet ist; eine Verbindung zwischen dem invertierenden Ausgang (5) des ersten Verstärkers (A₁) und dem zweiten Ausgangsanschluß (8) und eine Verbindung zwischen dem nicht-invertierenden Ausgang (6) des ersten Verstärkers (A₁) und dem ersten Ausgangsanschluß (7), dadurch gekennzeichnet, daß die Filterschaltung auch eine dritte und eine vierte Eingangsschaltung umfaßt, von denen jede einen dritten Kondensator (C₃) enthält, wobei die dritte Eingangsschaltung zwischen dem ersten Eingangsanschluß (1) und dem invertierenden Eingang (4) des ersten Verstärkers (A₁) angeordnet ist, und wobei die vierte Eingangsschaltung zwischen dem zweiten Eingangsanschluß (2) und dem nicht-invertierenden Eingang (3) des ersten Verstärkers (A₁) an-



geordnet ist.

2. Filterschaltung nach Anspruch 1, dadurch gekennzeichnet, daß die Filterschaltung außerdem eine erste und eine zweite Koppelschaltung enthält, von denen jede einen zweiten Widerstand (R_2) enthält, wobei die erste Koppelschaltung zwischen dem nicht-Invertierenden Eingang (3) des ersten Verstärkers (A_1) und dem invertierenden Ausgang (5) des ersten Verstärkers (A_1) angeordnet ist, und wobei die zweite Koppelschaltung zwischen dem invertierenden Eingang (4) des ersten Verstärkers (A_1) und dem nicht-Invertierenden Ausgang (6) des ersten Verstärkers (A_1) angeordnet ist.
3. Filterschaltung nach Anspruch 2, dadurch gekennzeichnet, daß die Kapazitätswerte der zweiten Kondensatoren (C_2) in der ersten und in der zweiten Eingangsschaltung im wesentlichen gleich Null sind; daß die Kapazitätswerte der dritten Kondensatoren (C_3) in der dritten und in der vierten Eingangsschaltung und diejenigen der ersten Kondensatoren (C_1) in dem ersten und in dem zweiten Rückkopplungskreis im wesentlichen gleich sind; und daß die Konduktanzwerte der ersten Widerstände (R_1) in der ersten und in der zweiten Eingangsschaltung und diejenigen der zweiten Widerstände (R_2) in der ersten und in der zweiten Koppelschaltung im wesentlichen gleich sind.
4. Filterschaltung nach Anspruch 1, dadurch gekennzeichnet, daß die Filterschaltung außerdem folgendes enthält: einen zweiten Gegentakt-Verstärker (A_2) mit einem nicht-Invertierenden Eingang (11) und einem invertierenden Eingang (12) und mit einem nicht-Invertierenden Ausgang (14) und einem invertierenden Ausgang (13); eine fünfte und eine sechste Eingangsschaltung, von denen jede einen vierten Kondensator (C_4) enthält, wobei die fünfte Eingangsschaltung zwischen dem ersten Eingangsanschluß (1) und dem nicht-Invertierenden Eingang (11) des zweiten Verstärkers (A_2) angeordnet ist, und wobei die sechste Eingangsschaltung zwischen dem zweiten Eingangsanschluß (2) und dem invertierenden Eingang (12) des zweiten Verstärkers (A_2) angeordnet ist; eine siebte und eine achte Eingangsschaltung, von denen jede einen dritten Widerstand (R_3) enthält, wobei die siebte Eingangsschaltung zwischen dem nicht-Invertierenden Ausgang (6) des ersten Verstärkers (A_1) und dem nicht-Invertierenden Eingang (11) des zweiten Verstärkers (A_2) angeordnet ist, und wobei die achte Eingangsschaltung zwischen dem invertierenden Ausgang (5) des ersten Verstärkers (A_1) und dem invertierenden Eingang (12) des zweiten Verstärkers (A_2) angeordnet ist; einen dritten und einen vierten Rückkopplungskreis, von denen jeder einen fünften Kondensator (C_5) enthält, wobei der dritte Rückkopplungskreis zwischen dem invertierenden Ausgang (13) und dem nicht-Invertierenden Eingang (11) des zweiten Verstärkers (A_2) angeordnet ist, und wobei der vierte Rückkopplungskreis zwischen dem nicht-Invertierenden Ausgang (14) und dem invertierenden Eingang (12) des zweiten Verstärkers (A_2) angeordnet ist; eine erste und eine zweite Koppelschaltung, von denen jede einen zweiten Widerstand (R_2) enthält, wobei die erste Koppelschaltung zwischen dem nicht-Invertierenden Eingang (3) des ersten Verstärkers (A_1) und einem ersten Knotenpunkt (9) angeordnet ist, und wobei die zweite Koppelschaltung zwischen dem invertierenden Eingang (4) des ersten Verstärkers (A_1) und einem zweiten Knotenpunkt (10) angeordnet ist; eine dritte und eine vierte Koppelschaltung, von denen jede einen vierten Widerstand (R_4) enthält, wobei die dritte Koppelschaltung zwischen dem ersten Knotenpunkt (9) und dem nicht-Invertierenden Eingang (11) des zweiten Verstärkers (A_2) angeordnet ist, und wobei die vierte Koppelschaltung zwischen dem zweiten Knotenpunkt (10) und dem invertierenden Eingang (12) des zweiten Verstärkers (A_2) angeordnet ist.
5. Filterschaltung nach Anspruch 4, dadurch gekennzeichnet, daß der erste Knotenpunkt (9) und der invertierende Ausgang (13) des zweiten Verstärkers (A_2) und ein vierter Ausgangsanschluß (16) miteinander verbunden sind, und daß der zweite Knotenpunkt (10) und der nicht-Invertierende Ausgang (14) des zweiten Verstärkers (A_2) und ein dritter Ausgangsanschluß (15) miteinander verbunden sind.
6. Filterschaltung nach Anspruch 5, dadurch gekennzeichnet, daß die Kapazitätswerte der zweiten Kondensatoren (C_2) in der ersten und in der zweiten Eingangsschaltung im wesentlichen gleich Null sind; daß die Konduktanzwerte der ersten Widerstände (R_1) in der ersten und in der zweiten Eingangsschaltung und diejenigen der zweiten Widerstände (R_2) in der ersten und in der zweiten Koppelschaltung im wesentlichen gleich sind; daß die Konduktanzwerte der dritten Widerstände (R_3) in der siebten und in der achten Eingangsschaltung und diejenigen der vierten Widerstände (R_4) in der dritten und in der vierten Koppelschaltung im wesentlichen gleich sind; daß die Kapazitätswerte der dritten Kondensatoren (C_3) in der dritten und in der vierten Eingangsschaltung und diejenigen der ersten Kondensatoren (C_1) in dem ersten und in dem zweiten Rückkopplungskreis im wesentlichen gleich sind; und daß die Kapazitätswerte der vierten Kondensatoren (C_4) in der fünften und in der sechsten Eingangsschaltung und diejenigen der



fünftens Kondensatoren (C_5) in dem dritten und in dem vierten Rückkopplungskreis im wesentlichen gleich sind.

- 5 7. Filterschaltung nach Anspruch 4, dadurch gekennzeichnet, daß die Filterschaltung außerdem folgendes enthält: einen dritten Gegentakt-Verstärker (A_3) mit einem nicht-Invertierenden Eingang (17) und einem Invertierenden Eingang (18) und mit einem nicht-Invertierenden Ausgang (20) und einem Invertierenden Ausgang (19); einen fünften (21) und einen sechsten (22) Ausgangsanschluß; eine neunte und eine zehnte Eingangsschaltung, von denen jede einen sechsten Kondensator (C_6) enthält, wobei die neunte Eingangsschaltung zwischen dem ersten Eingangsanschluß (1) und dem nicht-Invertierenden Eingang (17) des dritten Verstärkers (A_3) angeordnet ist, und wobei die zehnte Eingangsschaltung zwischen dem zweiten Eingangsanschluß (2) und dem Invertierenden Eingang (18) des dritten Verstärkers (A_3) angeordnet ist; eine elfte und eine zwölfte Eingangsschaltung, von denen jede einen siebten Kondensator (C_7) enthält, wobei die elfte Eingangsschaltung zwischen dem ersten Eingangsanschluß (1) und dem Invertierenden Eingang (18) des dritten Verstärkers (A_3) angeordnet ist, und wobei die zwölfte Eingangsschaltung zwischen dem zweiten Eingangsanschluß (2) und dem nicht-Invertierenden Eingang (17) des dritten Verstärkers (A_3) angeordnet ist; eine dreizehnte und eine vierzehnte Eingangsschaltung, von denen jede einen fünften Widerstand (R_5) enthält, wobei die dreizehnte Eingangsschaltung zwischen dem Invertierenden Ausgang (13) des zweiten Verstärkers (A_2) und dem Invertierenden Eingang (18) des dritten Verstärkers (A_3) angeordnet ist, und wobei die vierzehnte Eingangsschaltung zwischen dem nicht-Invertierenden Ausgang (14) des zweiten Verstärkers (A_2) und dem nicht-Invertierenden Eingang (17) des dritten Verstärkers (A_3) angeordnet ist; eine fünfte und eine sechste Koppelschaltung, von denen jede einen sechsten Widerstand (R_6) enthält, wobei die fünfte Koppelschaltung zwischen dem ersten Knotenpunkt (9) und dem nicht-Invertierenden Eingang (17) des dritten Verstärkers (A_3) angeordnet ist, und wobei die sechste Koppelschaltung zwischen dem zweiten Knotenpunkt (10) und dem Invertierenden Eingang (18) des dritten Verstärkers (A_3) angeordnet ist; einen fünften und einen sechsten Rückkopplungskreis, von denen jeder einen achten Kondensator (C_8) enthält, wobei der fünfte Rückkopplungskreis zwischen dem nicht-Invertierenden Eingang (17) und dem Invertierenden Ausgang (19) des dritten Verstärkers (A_3) angeordnet ist, und wobei der sechste Rückkopplungskreis zwischen dem Invertierenden Eingang (18) und dem nicht-Invertierenden Ausgang (20) des dritten Verstärkers (A_3) angeordnet ist; und daß der Invertierende Ausgang (19) des dritten Verstärkers (A_3) mit dem sechsten Ausgangsanschluß (22) verbunden ist und daß der nicht-Invertierende Ausgang (20) des dritten Verstärkers (A_3) mit dem fünften Ausgangsanschluß (21) verbunden ist.
- 35 8. Filterschaltung nach Anspruch 7, dadurch gekennzeichnet, daß der erste Knotenpunkt (9) mit dem Invertierenden Ausgang (19) des dritten Verstärkers (A_3) verbunden ist, und daß der zweite Knotenpunkt (10) mit dem nicht-Invertierenden Ausgang (20) des dritten Verstärkers (A_3) verbunden ist.
- 40 9. Filterschaltung nach Anspruch 8, dadurch gekennzeichnet, daß die Konduktanzwerte der ersten Widerstände (R_1) in der ersten und in der zweiten Eingangsschaltung und diejenigen der zweiten Widerstände (R_2) in der ersten und in der zweiten Koppelschaltung im wesentlichen gleich sind; daß die Konduktanzwerte der dritten Widerstände (R_3) in der siebten und in der achten Eingangsschaltung und diejenigen der vierten Widerstände (R_4) in der dritten und in der vierten Koppelschaltung im wesentlichen gleich sind; daß die Konduktanzwerte der fünften Widerstände (R_5) in der dreizehnten und in der vierzehnten Eingangsschaltung und diejenigen der sechsten Widerstände (R_6) in der fünften und in der sechsten Koppelschaltung im wesentlichen gleich sind; daß die Kapazitätswerte der zweiten Kondensatoren (C_2) in der ersten und in der zweiten Eingangsschaltung und diejenigen der sechsten Kondensatoren (C_6) in der neunten und in der zehnten Eingangsschaltung im wesentlichen gleich Null sind; daß die Kapazitätswerte der dritten Kondensatoren (C_3) in der dritten und in der vierten Eingangsschaltung und diejenigen der ersten Kondensatoren (C_1) in dem ersten und in dem zweiten Rückkopplungskreis im wesentlichen gleich sind; daß die Kapazitätswerte der vierten Kondensatoren (C_4) in der fünften und in der sechsten Eingangsschaltung und diejenigen der fünften Kondensatoren (C_5) in dem dritten und in dem vierten Rückkopplungskreis im wesentlichen gleich sind; und daß die Kapazitätswerte der siebten Kondensatoren (C_7) in der elften und in der zwölften Eingangsschaltung und diejenigen der achten Kondensatoren (C_8) in dem fünften und in dem sechsten Rückkopplungskreis im wesentlichen gleich sind.
- 55 10. Filterschaltung nach Anspruch 7, dadurch gekennzeichnet, daß die Filterschaltung desweiteren folgendes enthält: einen vierten Gegentakt-Verstärker (A_4) mit einem nicht-Invertierenden Eingang (23) und einem Invertierenden Eingang (24) und mit einem nicht-Invertierenden Ausgang (26) und einem Invertie-



renden Ausgang (25); einen siebten (27) und einen achten (28) Ausgangsanschluß; eine fünfzehnte und eine sechzehnte Eingangsschaltung, von denen jede einen neunten Kondensator (C_9) enthält, wobei die fünfzehnte Eingangsschaltung zwischen dem ersten Eingangsanschluß (1) und dem nicht-invertierenden Eingang (23) des vierten Verstärkers (A_4) angeordnet ist, und wobei die sechzehnte Eingangsschaltung zwischen dem zweiten Eingangsanschluß (2) und dem invertierenden Eingang (24) des vierten Verstärkers (A_4) angeordnet ist; eine siebzehnte und eine achtzehnte Eingangsschaltung, von denen jede einen siebten Widerstand (R_7) enthält, wobei die siebzehnte Eingangsschaltung zwischen dem nicht-invertierenden Ausgang (20) des dritten Verstärkers (A_3) und dem nicht-invertierenden Eingang (23) des vierten Verstärkers (A_4) angeordnet ist, und wobei die achtzehnte Eingangsschaltung zwischen dem invertierenden Ausgang (19) des dritten Verstärkers (A_3) und dem invertierenden Eingang (24) des vierten Verstärkers (A_4) angeordnet ist; einen siebten und einen achten Rückkopplungskreis, von denen jeder einen zehnten Kondensator (C_{10}) enthält, wobei der siebte Rückkopplungskreis zwischen dem nicht-invertierenden Eingang (23) und dem invertierenden Ausgang (25) des vierten Verstärkers (A_4) angeordnet ist, und wobei der achte Rückkopplungskreis zwischen dem invertierenden Eingang (24) und dem nicht-invertierenden Ausgang (26) des vierten Verstärkers (A_4) angeordnet ist; einen neunten und einen zehnten Rückkopplungskreis, von denen jeder einen achten Widerstand (R_8) enthält, wobei der neunte Rückkopplungskreis zwischen dem nicht-invertierenden Eingang (23) und dem invertierenden Ausgang (25) des vierten Verstärkers (A_4) angeordnet ist, und wobei der zehnte Rückkopplungskreis zwischen dem invertierenden Eingang (24) und dem nicht-invertierenden Ausgang (26) des vierten Verstärkers (A_4) angeordnet ist; und daß der invertierende Ausgang (25) des vierten Verstärkers (A_4) mit dem achten Ausgangsanschluß (28) verbunden ist, und daß der nicht-invertierende Ausgang (26) des vierten Verstärkers (A_4) mit dem siebten Ausgangsanschluß (27) verbunden ist.

11. Filterschaltung nach Anspruch 10, dadurch gekennzeichnet, daß die Konduktanzwerte der ersten Widerstände (R_1) in der ersten und in der zweiten Eingangsschaltung und diejenigen der zweiten Widerstände (R_2) in der ersten und in der zweiten Koppelschaltung im wesentlichen gleich sind; daß die Konduktanzwerte der dritten Widerstände (R_3) in der siebten und in der achten Eingangsschaltung und diejenigen der vierten Widerstände (R_4) in der dritten und in der vierten Koppelschaltung im wesentlichen gleich sind; daß die Konduktanzwerte der fünften Widerstände (R_5) in der dreizehnten und in der vierzehnten Eingangsschaltung und diejenigen der sechsten Widerstände (R_6) in der fünften und in der sechsten Koppelschaltung im wesentlichen gleich sind; daß die Konduktanzwerte der siebten Widerstände (R_7) in der siebzehnten und in der achtzehnten Eingangsschaltung und diejenigen der achten Widerstände (R_8) in dem neunten und in dem zehnten Rückkopplungskreis im wesentlichen gleich sind; daß die Kapazitätswerte der dritten Kondensatoren (C_3) in der dritten und in der vierten Eingangsschaltung und diejenigen der ersten Kondensatoren (C_1) in dem ersten und in dem zweiten Rückkopplungskreis im wesentlichen gleich sind; daß die Kapazitätswerte der vierten Kondensatoren (C_4) in der fünften und in der sechsten Eingangsschaltung und diejenigen der fünften Kondensatoren (C_5) in dem dritten und in dem vierten Rückkopplungskreis im wesentlichen gleich sind; daß die Kapazitätswerte der siebten Kondensatoren (C_7) in der elften und in der zwölften Eingangsschaltung und diejenigen der achten Kondensatoren (C_8) in dem fünften und in dem sechsten Rückkopplungskreis im wesentlichen gleich sind; daß die Kapazitätswerte der neunten Kondensatoren (C_9) in der fünfzehnten und in der sechzehnten Eingangsschaltung und diejenigen der zehnten Kondensatoren (C_{10}) in dem siebten und in dem achten Rückkopplungskreis im wesentlichen gleich sind; und daß die Kapazitätswerte der zweiten Kondensatoren (C_2) in der ersten und in der zweiten Eingangsschaltung und diejenigen der sechsten Kondensatoren (C_6) in der neunten und in der zehnten Eingangsschaltung im wesentlichen gleich Null sind.

Revendications

1. Circuit de filtrage muni d'un premier amplificateur équilibré (A_1) présentant une entrée non inverseuse (3) et une entrée inverseuse (4) et une sortie non inverseuse (6) et une sortie inverseuse (5), une première borne d'entrée (1) et une deuxième borne d'entrée (2), une première borne de sortie (7) et une deuxième borne de sortie (8), un premier circuit de réaction et un deuxième circuit de réaction, chacun comprenant un premier condensateur (C_1), le premier circuit de réaction étant disposé entre la sortie inverseuse (5) et l'entrée non inverseuse (3) du premier amplificateur (A_1) et le deuxième circuit de réaction étant disposé entre la sortie non inverseuse (6) et l'entrée inverseuse (4) du premier amplificateur (A_1), un premier circuit d'entrée et un deuxième circuit d'entrée, comprenant chacun la disposition parallèle d'une première résistance (R_1) et d'un deuxième condensateur (C_2), le premier circuit d'entrée étant disposé entre la pre-



- mière borne d'entrée (1) et l'entrée non inverseuse (3) du premier amplificateur (A_1) et le deuxième circuit d'entrée étant disposé entre la deuxième borne d'entrée (2) et l'entrée inverseuse (4) du premier amplificateur (A_1), une connexion entre la sortie inverseuse (5) du premier amplificateur (A_1) et la deuxième borne de sortie (8) et une connexion entre la sortie non inverseuse (6) du premier amplificateur (A_1) et la deuxième borne de sortie (7), caractérisé en ce que la disposition de filtrage comprend également un troisième circuit d'entrée et un quatrième circuit d'entrée comprenant chacun un troisième condensateur (C_3), le troisième circuit d'entrée étant disposé entre la première borne d'entrée (1) et l'entrée inverseuse (4) du premier amplificateur (A_1) et le quatrième circuit d'entrée étant disposé entre la deuxième borne d'entrée (2) et l'entrée non inverseuse (3) du premier amplificateur (A_1).
2. Circuit de filtrage selon la revendication 1, caractérisé en ce que le circuit de filtrage comprend en outre un premier circuit de couplage et un deuxième circuit de couplage, comprenant chacun une deuxième résistance (R_2), le premier circuit de couplage étant disposé entre l'entrée non inverseuse (3) du premier amplificateur (A_1) et la sortie inverseuse (5) du premier amplificateur (A_1), et le deuxième circuit de couplage étant disposé entre l'entrée inverseuse (4) du premier amplificateur (A_1) et la sortie non inverseuse (6) du premier amplificateur (A_1).
 3. Circuit de filtrage selon la revendication 2, caractérisé en ce que les valeurs de capacité des deuxièmes condensateurs (C_2) dans le premier circuit d'entrée et le deuxième circuit d'entrée sont pratiquement égales à zéro, en ce que les valeurs de capacité des troisièmes condensateurs (C_3) dans le troisième circuit d'entrée et le quatrième circuit d'entrée et les premiers condensateurs (C_1) dans le premier circuit de réaction et le deuxième circuit de réaction sont pratiquement égales, et en ce que les valeurs de conductance des premières résistances (R_1) dans le premier circuit d'entrée et le deuxième circuit d'entrée et les deuxièmes résistances (R_2) dans le premier circuit de couplage et le deuxième circuit de couplage sont pratiquement égales.
 4. Circuit de filtrage selon la revendication 1, caractérisé en ce que le circuit de filtrage comprend en outre un deuxième amplificateur équilibré (A_2) présentant une entrée non inverseuse (11) et une entrée inverseuse (12) et une sortie non inverseuse (14) et une sortie inverseuse (13), un cinquième circuit d'entrée et un sixième circuit d'entrée, comprenant chacun un quatrième condensateur (C_4), le cinquième circuit d'entrée étant disposé entre la première borne d'entrée (1) et l'entrée non inverseuse (11) du deuxième amplificateur (A_2) et le sixième circuit d'entrée étant disposé entre la deuxième borne d'entrée (2) et l'entrée inverseuse (12) du deuxième amplificateur (A_2), un septième circuit d'entrée et un huitième circuit d'entrée, comprenant chacun une troisième résistance (R_3), le septième circuit d'entrée étant disposé entre la sortie non inverseuse (6) du premier amplificateur (A_1) et l'entrée non inverseuse (11) du deuxième amplificateur (A_2) et le huitième circuit d'entrée étant disposé entre la sortie inverseuse (5) du premier amplificateur (A_1) et l'entrée inverseuse (12) du deuxième amplificateur (A_2) un troisième circuit de réaction et un quatrième circuit de réaction, comprenant chacun un cinquième condensateur (C_5), le troisième circuit de réaction étant disposé entre la sortie inverseuse (13) et l'entrée non inverseuse (11) du deuxième amplificateur (A_2) et le quatrième circuit de réaction étant disposé entre la sortie non inverseuse (14) et l'entrée inverseuse (12) du deuxième amplificateur (A_2), un premier circuit de couplage et un deuxième circuit de couplage, comprenant chacun une deuxième résistance (R_2), le premier circuit de couplage étant disposé entre l'entrée non inverseuse (3) du premier amplificateur (A_1) et un premier noeud (9) et le deuxième circuit de couplage étant disposé entre l'entrée inverseuse (4) du premier circuit amplificateur (A_1) et un deuxième noeud (10), un troisième circuit de couplage et un quatrième circuit de couplage, comprenant chacun une quatrième résistance (R_4), le troisième circuit de couplage étant disposé entre le premier noeud (9) et l'entrée non inverseuse (11) du deuxième amplificateur (A_2) et le quatrième circuit de couplage étant disposé entre le deuxième noeud (10) et l'entrée inverseuse (12) du deuxième amplificateur (A_2).
 5. Circuit de filtrage selon la revendication 4, caractérisé en ce que le premier noeud (9) et la sortie inverseuse (13) du deuxième amplificateur et une quatrième borne de sortie (16) sont interconnectés et en ce que le deuxième noeud (10) et la sortie non inverseuse (14) du deuxième amplificateur (A_2) et une troisième borne de sortie (15) sont interconnectés.
 6. Circuit de filtrage selon la revendication 5, caractérisé en ce que les valeurs de capacité des deuxièmes condensateurs (C_2) dans le premier circuit d'entrée et le deuxième circuit d'entrée sont pratiquement égales à zéro, en ce que les valeurs de conductance des premières résistances (R_1) dans le premier circuit



d'entrée et le deuxième circuit d'entrée et des deuxièmes résistances (R_2) dans le premier circuit de couplage et le deuxième circuit de couplage sont pratiquement égales, en ce que les valeurs de conductance des troisièmes résistances (R_3) dans le septième circuit d'entrée et le huitième circuit d'entrée et des quatrièmes résistances (R_4) dans le troisième circuit de couplage et le quatrième circuit de couplage sont pratiquement égales, en ce que les valeurs de capacité des troisièmes condensateurs (C_3) dans le troisième circuit d'entrée et le quatrième circuit d'entrée et des premiers condensateurs (C_1) dans le premier circuit de réaction et le deuxième circuit de réaction sont pratiquement égales, et en ce que les valeurs de capacité des quatrièmes condensateurs (C_4) dans le cinquième circuit d'entrée et le sixième circuit d'entrée et des cinquièmes condensateurs (C_5) dans le troisième circuit de réaction et le quatrième circuit de réaction sont pratiquement égales.

7. Circuit de filtrage selon la revendication 4, caractérisé en ce que le circuit de filtrage comprend en outre un troisième amplificateur équilibré (A_3) présentant une entrée non inverseuse (17) et une entrée inverseuse (18) et une sortie non inverseuse (20) et une sortie inverseuse (19), une cinquième borne de sortie (21) et une sixième borne de sortie (22), un neuvième circuit d'entrée et un dixième circuit d'entrée, comprenant chacun un sixième condensateur (C_6), le neuvième circuit d'entrée étant disposé entre la première borne d'entrée (1) et l'entrée non inverseuse (17) du troisième amplificateur (A_3) et le dixième circuit d'entrée étant disposé entre la deuxième borne d'entrée (2) et l'entrée inverseuse (18) du troisième amplificateur (A_3), un onzième circuit d'entrée et un douzième circuit d'entrée, comprenant chacun un septième condensateur (C_7), le onzième circuit d'entrée étant disposé entre la première borne d'entrée (1) et l'entrée inverseuse (18) du troisième amplificateur (A_3) et le douzième circuit d'entrée étant disposé entre la deuxième borne d'entrée (2) et l'entrée non inverseuse (17) du troisième amplificateur (A_3), un treizième circuit d'entrée et un quatorzième circuit d'entrée, comprenant chacun une cinquième résistance (R_5), le treizième circuit d'entrée étant disposé entre la sortie inverseuse (13) du deuxième amplificateur (A_2) et l'entrée inverseuse (18) du troisième amplificateur (A_3) et le quatrième circuit d'entrée étant disposé entre la sortie non inverseuse (14) du deuxième amplificateur (A_2) et l'entrée non inverseuse (17) du troisième amplificateur (A_3), un cinquième circuit de couplage et un sixième circuit de couplage, comprenant chacun une sixième résistance (R_6), le cinquième circuit de couplage étant disposé entre le premier noeud (9) et l'entrée non inverseuse (17) du troisième amplificateur (A_3) et le sixième circuit de couplage étant disposé entre le deuxième noeud (10) et l'entrée inverseuse (18) du troisième amplificateur (A_3), un cinquième circuit de réaction et un sixième circuit de réaction, comprenant chacun un huitième condensateur (C_8), le cinquième circuit de réaction étant disposé entre l'entrée non inverseuse (17) et la sortie inverseuse (19) du troisième amplificateur (A_3) et le sixième circuit de réaction étant disposé entre l'entrée inverseuse (18) et la sortie non inverseuse (20) du troisième amplificateur (A_3) et en ce que la sortie inverseuse (19) du troisième amplificateur (A_3) est connectée à la sixième borne de sortie (22) et la sortie non inverseuse (19) du troisième amplificateur (A_3) est connectée à la cinquième borne de sortie (21).

8. Circuit de filtrage selon la revendication 7, caractérisé en ce que le premier noeud (9) est connecté à la sortie inverseuse (19) du troisième amplificateur (A_3) et le deuxième noeud (10) est connecté à la sortie non inverseuse (20) du troisième amplificateur (A_3).

9. Circuit de filtrage selon la revendication 8, caractérisé en ce que les valeurs de conductance des premières résistances (R_1) dans le premier circuit d'entrée et le deuxième circuit d'entrée et des deuxièmes résistances (R_2) dans le premier circuit de couplage et le deuxième circuit de couplage sont pratiquement égales, en ce que les valeurs de conductance des troisièmes résistances (R_3) dans le septième circuit d'entrée et le huitième circuit d'entrée et des quatrièmes résistances (R_4) dans le troisième circuit de couplage et le quatrième circuit de couplage sont pratiquement égales, en ce que les valeurs de conductance des cinquièmes résistances (R_5) dans le treizième circuit d'entrée et le quatorzième circuit d'entrée et les sixièmes résistances (R_6) dans le cinquième circuit de couplage et le sixième circuit de couplage sont pratiquement égales, en ce que les valeurs de capacité des deuxièmes condensateurs (C_2) dans le premier circuit d'entrée et le deuxième circuit d'entrée et des sixièmes condensateurs (C_6) dans le neuvième circuit d'entrée et le dixième circuit d'entrée sont pratiquement égales à zéro, en ce que les valeurs de capacité des troisièmes condensateurs (C_3) dans le troisième circuit d'entrée et le quatrième circuit d'entrée et des premiers condensateurs (C_1) dans le premier circuit de réaction et le deuxième circuit de réaction sont pratiquement égales, en ce que les valeurs de capacité des quatrièmes condensateurs (C_4) dans le cinquième circuit d'entrée et le sixième circuit d'entrée et des cinquièmes condensateurs (C_5) dans le troisième circuit de réaction et le quatrième circuit de réaction sont pratiquement égales, et en ce que les valeurs



de capacité des septièmes condensateurs (C_7) dans le onzième circuit d'entrée et le douzième circuit d'entrée et des huitièmes condensateurs (C_8) dans le cinquième circuit de réaction et le sixième circuit de réaction sont pratiquement égales.

- 5 10. Circuit de filtrage selon la revendication 7, caractérisé en ce que le circuit de filtrage comprend en outre un quatrième amplificateur équilibré (A_4) présentant une entrée non inverseuse (23) et une entrée inverseuse (24) et une sortie non inverseuse (26) et une sortie inverseuse (25), une septième borne de sortie (27) et une huitième borne de sortie (28), un quinzième circuit d'entrée et un seizième circuit d'entrée, comprenant chacun un neuvième condensateur (C_9), le quinzième circuit d'entrée étant disposé entre la première borne d'entrée (1) et l'entrée non inverseuse (23) du quatrième amplificateur (A_4) et le seizième circuit d'entrée étant disposé entre la deuxième borne d'entrée (2) et l'entrée inverseuse (24) du quatrième amplificateur (A_4), un dix-septième circuit d'entrée et un dix-huitième circuit d'entrée, comprenant chacun une septième résistance (R_7), le dix-septième circuit d'entrée étant disposé entre la sortie non inverseuse (20) du troisième amplificateur (A_3) et l'entrée non inverseuse (23) du quatrième amplificateur (A_4) et le dix-huitième circuit d'entrée étant disposé entre la sortie inverseuse (19) du troisième amplificateur (A_3) et l'entrée inverseuse (24) du quatrième amplificateur (A_4), un septième circuit de réaction et un huitième circuit de réaction, comprenant chacun un dixième condensateur (C_{10}), le septième circuit de réaction étant disposé entre l'entrée non inverseuse (23) et la sortie inverseuse (25) du quatrième amplificateur (A_4), et le huitième circuit de réaction étant disposé entre l'entrée inverseuse (24) et la sortie non inverseuse (26) du quatrième amplificateur (A_4), un neuvième circuit de réaction et un dixième circuit de réaction, comprenant chacun une huitième résistance (R_8), le neuvième circuit de réaction étant disposé entre l'entrée non inverseuse (23) et la sortie inverseuse (25) du quatrième amplificateur (A_4), et le dixième circuit de réaction étant disposé entre l'entrée inverseuse (24) et la sortie non inverseuse (26) du quatrième amplificateur (A_4) et en ce que la sortie inverseuse (25) du quatrième amplificateur (A_4) est connectée à la huitième borne de sortie (28) et la sortie non inverseuse (26) du quatrième amplificateur (A_4) est connectée à la septième borne de sortie (27).
11. Circuit de filtrage selon la revendication 10, caractérisé en ce que les valeurs de conductance des premières résistances (R_1) dans le premier circuit d'entrée et le deuxième circuit d'entrée et des deuxième résistances (R_2) dans le premier circuit de couplage et le deuxième circuit de couplage sont pratiquement égales, en ce que les valeurs de conductance des troisièmes résistances (R_3) dans le septième circuit d'entrée et le huitième circuit d'entrée et des quatrième résistances (R_4) dans le troisième circuit de couplage et le quatrième circuit de couplage sont pratiquement égales, en ce que les valeurs de conductance des cinquièmes résistances (R_5) dans le treizième circuit d'entrée et le quatorzième circuit d'entrée et des sixièmes résistances (R_6) dans le cinquième circuit de couplage et le sixième circuit de couplage sont pratiquement égales, en ce que les valeurs de conductance des septièmes résistances (R_7) dans le dix-septième circuit d'entrée et le dix-huitième circuit d'entrée et des huitièmes résistances (R_8) dans le neuvième circuit de réaction et le dixième circuit de réaction sont pratiquement égales, en ce que les valeurs de capacité des troisièmes condensateurs (C_3) dans le troisième circuit d'entrée et le quatrième circuit d'entrée et des premiers condensateurs (C_1) dans le premier circuit de réaction sont pratiquement égales, en ce que les valeurs de capacité des quatrième condensateurs (C_4) dans le cinquième circuit d'entrée et le sixième circuit d'entrée et des cinquième condensateurs (C_5) dans le troisième circuit de réaction et le quatrième circuit de réaction sont pratiquement égales, en ce que les valeurs de capacité des septièmes condensateurs (C_7) dans le onzième circuit d'entrée et le douzième circuit d'entrée et des huitième condensateurs (C_8) dans le cinquième circuit de réaction et le sixième circuit de réaction sont pratiquement égales, en ce que les valeurs de capacité des neuvième condensateurs (C_9) dans le quinzième circuit d'entrée et le seizième circuit d'entrée et des dixième condensateurs (C_{10}) dans le septième circuit de réaction et le huitième circuit de réaction sont pratiquement égales, en ce que les valeurs de capacité des deuxième condensateurs (C_2) dans le premier circuit d'entrée et le deuxième circuit d'entrée et des sixièmes condensateurs (C_6) dans le neuvième circuit d'entrée et le dixième circuit d'entrée sont pratiquement égales à zéro.