

31

The present invention relates to differential current amplifiers, that is to say to amplifiers able to receive a current I_1 at a first input terminal and a current I_2 at a second input terminal, to produce at the output a current proportional to $I_1 - I_2$.

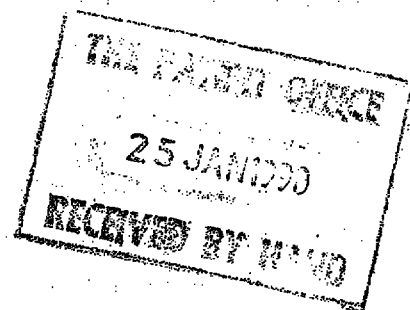
It is known how to make an amplifier of this kind, for example with the help of a scheme such as that of Figure 1 : the current I_1 is applied to a resistance R_1 and the current I_2 to a resistance R_2 of the same value as R_1 . The difference in the voltage drops $R_1 I_1$ and $R_2 I_2$ in these resistances is measured by a differential voltage amplifier AT. It is well known how to make voltage amplifiers having good ability to reject a common mode. The output voltage of the amplifier is proportional to $R_1 I_1 - R_2 I_2$.

If R_1 is exactly equal to R_2 there is no problem. However in practice it is difficult to make sufficiently exact resistances, particularly if the current amplifier must be made in the form of an integrated circuit. In the output signal a common mode component will appear as a result of the difference between the values of the resistances (a component proportional to the mean value of the currents and the difference $R_1 - R_2$).

The precision is thus directly connected to the matching of the resistances.

The present invention proposes a scheme for a current amplifier which avoids this fault whilst enabling a very exact differential measurement to be made equally well with direct currents and with alternating currents.

For this the invention proposes a differential current amplifier having two inputs each receiving a respective input current to produce at the output a signal proportional to the difference between the input currents, comprising two resistances connected to the same current supply source and having substantially the same value, connections between the



inputs of the current amplifier and the resistances and a means to produce in resistance R1 a voltage drop varying like the product $R1I1$ and in resistance R2 a voltage drop varying like $R2I2$, the resistances also each being connected to an input of a differential voltage amplifier, characterized in that means of commutation operated periodically with a cyclic relationship close to 0.5 are provided in order to :

1) reverse the connections between the inputs of the current amplifier and the resistances during half of each cycle of commutation so as to produce during this half of a cycle a voltage drop varying like $R1I2$ in the resistance R1 and a voltage drop varying like $R2I1$ in the resistance R2,

2) likewise reverse the connections between the resistances and the inputs of the amplifier during this half of a cycle.

By voltage drop varying "like $R1I1$ " (or $R1I2$ or $R2I2$ or $R2I1$) is meant in particular a drop in voltage $R1I1$ or $-R1I1$ but also $R1(I_0 + I1)$ where I_0 is constant, or also $R1(I_0 - I1)$ etc., the essential thing being that two voltage drops (for example $R1(I_0 - I1)$ and $R1(I_0 - I2)$) can easily be established, the difference between which, in this case $R1(I1 - I2)$, is related to a value proportional to $I1 - I2$.

Other characteristics and advantages of the invention will emerge from reading the following detailed description with reference to the attached drawings in which :

- Figure 1, already mentioned, shows the previous technique,
- Figure 2 shows a functional diagram of a current amplifier,
- Figure 3 shows by way of example only a differential voltage amplifier;
- Figure 4 shows a particular embodiment scheme enabling differential amplification of currents leaving the input terminals,

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25 JAN 1990
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- Figure 5 shows a particular embodiment scheme enabling differential amplification of currents entering or departing from the input terminals,

The differential current amplifier in Figure 2 comprises two input terminals E and F. The terminals E and F are connected to a differential voltage amplifier 10 having a high input impedance and having good rejection of common mode (as is well known for a differential voltage amplifier).

Two resistances R1 and R2 connected on one side to a common circuit supply source, which can be a mass M, are connected on the other side one (R1) to a first commutator K1 and the other (R2) to a second commutator K2. These commutators are operated periodically in phase with one another with a cyclic commutation relationship of about 0.5, that is to say that they are in a first state during a half period of the commutation frequency and in a second phase during the following half period.

The double commutator K1 enables resistance R1 to be connected either to terminal E or to terminal F.

The double commutator K2 enables resistance R2 to be connected either to terminal F or to terminal E.

When resistance R1 is connected to terminal E, resistance R2 is connected to terminal F and vice versa.

An input current I1 is introduced through terminal E and another input current I2 is introduced through terminal F.

The differential voltage amplifier has for example (for simplification) a gain of 1.

In this case, it produces at its output a voltage which is $R2I1 - R1I2$ during a first half period and $R2I1 - R1I2$ during the following half period.

THE PATENT OFFICE
25 JAN 1960
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24

To analyse the mean current $I_1 - I_2$, a low pass filter RC is placed at the output of the voltage amplifier which smoothes out the variations due to commutation. The mean voltage at the terminals of the capacitor is then $\frac{(R_1 + R_2)(I_1 - I_2)}{2}$.

Even if R_1 and R_2 are not equal there are no (to the first order) components of common mode due to the difference in values of the resistances.

It will however be arranged to make the values R_1 and R_2 as equal as possible to avoid a component of common mode which would be caused for example by a cyclic commutation relationship not equal to 0.5. Thus there is a purely differential amplification of the currents I_1 and I_2 , the components of common mode only existing at the second order.

If the currents I_1 and I_2 are alternating, a frequency of commutation of the commutators higher than the frequency of the signals I_1 and I_2 will be selected.

In certain very particular cases, it may be arranged that there is no smoothing out of the output voltage of the differential voltage amplifier by a filter RC.

For example, this may occur when the input currents I_1 and I_2 are alternating, if they have a common known frequency f and if commutation by the commutators K_1 and K_2 is effected exactly at the frequency f , with the aim, for example, of detecting a continuous component in the alternating signal $I_1 - I_2$: in this case the output voltage of the differential voltage amplifier may be converted into a current and this current applied to a condenser; then the voltage at the terminals of the condenser is sampled at the frequency f . The increase or decrease in this sampled voltage is a measure of the continuous component in the difference in the currents I_1 and I_2 .

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25 JAN 1999
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Figure 3 shows by way of example only a voltage amplification structure having good rejection of common mode, which may be used in the scheme of Figure 2. It comprises a differential output stage with two transistors Ta and Tb through which equal currents flow in the absence of an input signal and through which unequal currents flow in the presence of an input signal, the difference between the currents being proportional to the signal and being applied to a parallel network RC connected to the collector of one of the transistors. The voltage at the terminals of this network constitutes the output voltage of the amplifier and does not need to be filtered by another network RC. The inputs to this voltage amplifier are the bases of the transistors Ta and Tb, optionally each preceded by another differential stage with a high input impedance, one of the inputs of this other stage being looped to the emitter of transistor Ta (or Tb).

Figure 4 shows a concrete example of embodiment of the current amplifier.

In this example, instead of the input terminals E and F receiving the currents I1 and I2 (output currents in this case) being directly connected to the inputs to the voltage amplifier, they are connected to these inputs through the intermediation of two groups of commutators.

The first group comprises a commutator K1 and a commutator K2. The commutator K1 comprises a transistor T1 connected between terminal E and resistance R1, and a transistor T2 connected between terminal E and resistance R2. The commutator K2 comprises a transistor T4 connected between terminal F and resistance R1, and a transistor T3 connected between terminal F and resistance R2. The transistors T1 and T3 are made conductors during a half-alternation of the frequency of commutation of the commutators and blocked during the other half-alternation. The transistors T2 and T4 are made conductors and blocked in phase opposition to transistors T1 and T3.

The resistances R1 and R2 are also connected to a common current source.

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25 JAN 1990
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36

The second group of commutators comprises a commutator K3 and a commutator K4 operated at the same frequency of commutation. The commutator K3 enables connection of an input C of the differential voltage amplifier either to the junction point A of resistance R1 and transistors T1 and T4 during the half-alternation when T1 and T3 are conductors or to the junction point B of resistance R2 and transistors T2 and T3 during the half-alternation when T2 and T4 are conductors.

Commutator K4 enables connection of the other input D of the differential voltage amplifier either to the junction point A whilst T2 and T4 are conductors or to point B whilst T1 and T3 are conductors.

The mean difference of the voltage drops in R1 and R2 is the same as in Figure 2.

In another embodiment shown in Figure 5, the scheme of Figure 4 is integrally retained and the following elements are added to it : terminal E is connected to a transistor T5 and to a transistor T8. Transistor T5 is connected between terminal E and a source of current I_{p1} ; transistor T8 is connected between terminal E and a source of current I_{p2} . Terminal F is connected to a transistor T6 and to a transistor T7. Transistor T6 is connected between terminal F and the source of current I_{p1} ; transistor T7 is connected between terminal F and the source of current I_{p2} .

Transistors T5 and T7 are made conductors and blocked in phase with transistors T1 and T3 ; transistors T6 and T8 in phase with transistors T2 and T4.

Under these conditions, a current $I_{p1} - I_1$ flows through resistance R1 during one half-alternation and a current $I_{p1} - I_2$ during the following half-alternation.

Reciprocally, at first a current $I_{p2} - I_2$ flows through resistance R2 (first half-alternation) then the current $I_{p2} - I_1$.

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25 JAN 1990
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The difference in voltage drops in R1 and R2 is thus first $R2(I_{p2} - I_2) - R1(I_{p1} - I_1)$ then $R2(I_{p2} - I_1) - R1(I_{p1} - I_2)$, but the latter value is inverted at the voltage amplifier terminals during the second half-alternation (by the commutators K3 and K4).

On average, the voltage difference at the input terminals of the voltage amplifier is thus equal to :

$$1/2(R2(I_{p2} - I_2) - R1(I_{p1} - I_1) + R1(I_{p1} - I_2) - R2(I_{p2} - I_1)) \text{ or } 1/2(R1 + R2)(I_1 - I_2).$$

Here again, the error in the equality of resistances R1 and R2 is not involved at the first order. The same applies to error in the equality of currents I_{p1} and I_{p2} , but preferably they are selected to be equal.

Here again, rejection of common mode is only limited by the performances of the voltage amplifier if the resistances R1 and R2, the currents I_{p1} and I_{p2} , and the half-alternations in the commutation cycle are as well paired as possible.

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CLAIMS

1. A differential current amplifier having two inputs (E, F) each receiving a respective input current (I_1 and I_2) to produce at the output a signal proportional to the difference between the input currents, comprising two resistances (R_1 and R_2) connected to the same current supply source (M) and having substantially the same value, connections between the inputs of the current amplifier and the resistances, and commutation means to produce in resistance R_1 a voltage drop varying like the product $R_1 I_1$ and in resistance R_2 a voltage drop varying like $R_2 I_2$, the resistances also each being connected to an input of a differential voltage amplifier (10), characterized in that the said means of commutation (K_1 , K_2 , K_3 , K_4) are operated periodically with a cyclic relationship close to 0.5 in order to :

1) reverse the connections between the inputs of the current amplifier and the resistances during half of each cycle of commutation so as to produce during this half of a cycle a voltage drop varying like $R_1 I_2$ in the resistance R_1 and a voltage drop varying like $R_2 I_1$ in the resistance R_2 ,

2) likewise reverse the connections between the resistances and the inputs of the differential voltage amplifier during this half of a cycle.

2. A differential amplifier according to Claim 1, characterized in that the input currents I_1 and I_2 are directly applied to the resistance R_1 and the resistance R_2 respectively during a first half of a cycle and applied to the resistance R_2 and the resistance R_1 respectively during a second half of the cycle.

3. A differential amplifier according to Claim 2, characterized in that each resistance has a current flowing through it which is the difference between a fixed current (I_{p1} , I_{p2}) and one of the input currents (I_1 , I_2).

4. A differential amplifier according to any one of Claims 1 to 3, characterized in that the first resistance (R_1) is connected to a first

29

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25 JAN 1990
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40

transistor (T1) and to a second transistor (T4) connected respectively to the first input (E) and to the second input (F) of the current amplifier, the second resistance (R2) is connected to a third transistor (T2) and to a fourth transistor (T3) connected respectively to the second and the first input of the current amplifier, the resistances also being connected through a double commutator to the inputs of the voltage amplifier, the transistors and the commutator being switched periodically with an alternation in phase having a cyclic relationship close to 0.5, the first and fourth transistors being made conductors during a first half of the periodic cycle and blocked during the other half and conversely the second and third transistors being blocked during the first half and conducting during the second, the double commutator reversing the connections between the resistances and the amplifier inputs at each half-alternation.

41

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25 JAN 1990
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