

PRECISION CURRENT-SOURCE ARRANGEMENT.

The invention relates to a precision current-source arrangement for generating a plurality of currents whose values are proportioned accurately relative to each other, which arrangement

5 comprises

- a current-distribution circuit for generating a plurality of currents of substantially equal values, and
 - a switching circuit for switching the currents from the current-distribution circuit between outputs of the switching in
- 10 such manner that a cycle of permutations of said currents repeatedly occurs at the collective said outputs and each said current is switched to each said output during each cycle, resulting in the currents available on said outputs having average values which are proportioned accurately relative to each other and
- 15 exhibiting ripples which depend on the differences between the currents from the current-distribution circuit.

Such a precision current-source arrangement may be used in, for example, a digital-to-analog converter which requires a binary weighted series of currents whose values are proportioned

20 accurately relative to each other.

Two known such precision current-source arrangements, employing the dynamic permutation principle, are described in Patent Specifications 1479535 and 1526642. These arrangements employ a current-distribution circuit which supplies a plurality of

25 currents whose values are not exactly equal to each other due to the limited accuracy of the integration process. Each output current, of the switching circuit in consequence comprises a steady current component of the desired value and, superimposed on it, a ripple which depends on the differences between the currents from

30 the current-distribution circuit. The value of the steady current component on each output is equal to the average value of the currents from the current-distribution circuit. Averaged over each cycle time of the switching circuit the value of the ripple is zero. The ripple can be filtered out by arranging a filter

35 capacitor on each output of the switching circuit.

A disadvantage of the use of such filter capacitors is that because of their large values they cannot be integrated but have to be added to the integrated circuit as external components. This requires additional connection pins on the integrated circuit, which entails additional costs. For example, in the case of a 16-bit digital-to-analog converter employing such a precision current-source arrangement 16 additional connection pins are required.

It is an object of the invention to mitigate this disadvantage.

To this end a precision current-source arrangement of the type set forth in the opening paragraph is characterised in that the arrangement also comprises

- a detection circuit for, in synchronism with occurrences of at least all but one of the individual output currents of the current-distribution circuit on a said output of the switching circuit, detecting the deviation of the resulting value of the current at that output from the value of a reference current and generating an output signal representative of that deviation, and
- a control circuit arrangement responsive to the output of the detection circuit for controlling the currents constituting said at least all but one of the individual output currents of the current-distribution circuit in senses such as to reduce the deviations detected. (The said occurrences may be all at the same output of the switching circuit or, for example, a different output may be chosen in respect of each of the said individual output currents).

It has now been recognised that it is possible to detect the deviations of the various currents from the current-distribution circuit from each other by investigating the current carried by an output of the switching circuit and to correct the currents from the current-distribution circuit, in response to the deviations detected in such way that the ripples are almost eliminated. This may eliminate the need for additional filtering using filter capacitors. Furthermore, when several precision

current-source arrangements are connected in cascade, it can enable interaction therebetween, which can be a problem, to be substantially reduced. (When known precision current-source arrangements are cascaded the ripple in one stage can substantially affect the output currents of the next stage).

The precision current-source arrangement may be also characterised in that the detection circuit detects said deviation of the resulting value in synchronism with the occurrences of all but one of said individual output currents, and the reference current is constituted by the remaining one of the individual output currents of the current-distribution circuit. The values of the other currents can then be made effectively equal to the value of that current from the current-distribution circuit which is selected as the reference. The detection circuit need not then supply an output signal corresponding to the reference current, which means that a control circuit which would otherwise be required for this current may be dispensed with.

If the said occurrences are all at the same output of the switching circuit the precision current-source arrangement may be also characterised in that the detection circuit comprises

- a first resistor, which is connected to the said output of the switching circuit and which converts the current on this output into a voltage,
- an amplifier circuit having an inverting first input to which is coupled the said output of the switching circuit by an isolating capacitor, a second input which carries a reference voltage, and an output which is coupled to the first input by a second resistor, and
- a distribution circuit having an input to which is coupled the output of the amplifier circuit and a plurality of outputs which are each coupled to a respective control circuit forming part of the control circuit arrangement, which distribution circuit, in synchronism with the occurrences of the individual output currents of the current-distribution circuit on the said output of the switching circuit couples the output of the amplifier circuit to

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corresponding ones of its own outputs. If this is the case the voltage across the first resistor can be applied to the first input via the isolating capacitor, the amplifier receiving negative feedback via the second resistor which will generally have a high resistance. The amplifier can then amplify the difference between said voltage and the reference voltage on the second input, which difference can be made proportional to the ripple component of the voltage across the first resistor. The isolating capacitor may have a capacitance which is substantially smaller than the values of the filter capacitors used in the known precision current-source arrangements, facilitating its integration. The distribution circuit can distribute the amplified voltage among the control circuits in such a way that the voltage derived from a specific current distribution circuit output current is applied to the control circuit for this current.

The second resistor may be by-passed by a switch which short-circuits the second resistor in synchronism with the occurrences of the said remaining one of the individual output currents of the current-distribution circuit on the said output of the switching circuit. As a result of this it can be arranged that no output signal appears on the amplifier output when the current selected as the reference appears on the said output of the switching circuit and, moreover, that the isolating capacitor is then charged until the voltage across it is equal to the difference between the voltage produced across the first resistor by the reference current and the reference voltage on the second input of the amplifier. During the other parts of each cycle of the switching circuit the amplifier circuit can then operate as a current-voltage converter, which converts the differences between the other currents and the reference current into voltages which are amplified and appear on the amplifier output.

If the second resistor has a very high resistance value it can be arranged that the amplifier functions as a comparator.

Embodiments of the invention will now be described in detail, by way of example, with reference to the accompanying drawings,

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in which

Figure 1 shows a first embodiment,

Figure 2 shows a second embodiment, and

Figure 3 shows a third embodiment.

5 Figure 1 schematically shows a first embodiment of the invention.

10 In Figure 1 a precision current-source arrangement comprises a current-distribution circuit 1 which supplies a plurality of substantially equal currents to a switching circuit 13. Circuit 13 switches these currents between outputs thereof in such manner that a cycle of permutations of these currents repeatedly occurs at the collective outputs and each current is switched to each output during each cycle. The nominally steady currents on these outputs exhibit a ripple as a result of the lack of exact equality of the
15 currents from the current-distribution circuit 1. A detection circuit 30 detects the ripple components produced on one of the outputs by all but one of the current from the current-distribution circuit 1 and applies them to corresponding control circuits which together constitute a control circuit arrangement 50. Each control
20 circuit produces a control current by means of which the relevant current is corrected in such a way that the ripple component is substantially eliminated.

In the present embodiment the current-distribution circuit 1 is in integrated circuit form and comprises parallel-connected
25 transistors 2,3,4 and 5, whose emitters are connected to a common connection point 10 via identical resistors 6,7,8 and 9. Point 10 carries a fixed voltage and in the present case is formed by the negative power-supply terminal. The commoned bases of the transistors 2,3,4 and 5 are driven by an amplifier 11 whose input
30 is coupled to the output of a current source 12. The amplifier 11 controls the voltage on the commoned bases in such a way that the sum of the currents on the outputs 20 and 21 of the permutation circuit 13 is equal to the current from the current source 12. The output currents i_1 , i_2 , i_3 and i_4 are not exactly equal to each
35 other as a result of the limited accuracy of the integration

process. In the present case they are each substantially equal to I_0 because at any given time two of them are formed by splitting the current $2I_0$ from the current source 12. The currents i_1 , i_2 , i_3 and i_4 are applied to the inputs 14, 15, 16 and 17 of the switching circuit 13. The switching circuit 13 is controlled by a circuit 22, for example a shift register, which in its turn is controlled by a clock generator 23. The operation of the switching circuit 13 is described comprehensively in the aforementioned Patent Specifications 1479535 and 1526642. The switching circuit 13 switches each of the currents i_1 , i_2 , i_3 and i_4 to each of its outputs 18, 19, 20 and 21 in such manner that a cycle of four permutations of these currents repeatedly occurs at the collective outputs and each current occurs at each output during each cycle. The cycle time is T say. Thus, the currents i_1 , i_2 , i_3 and i_4 appear consecutively (although not necessarily in the same order) on each of the outputs 18, 19, 20 and 21. The nominally steady current on each of the outputs 18, 19, 20 and 21 is equal to the average value I_0 of the currents i_1 , i_2 , i_3 , and i_4 . The output currents exhibit a ripple around this average value I_0 , the ripple being caused by the inexact equality of the currents i_1 , i_2 , i_3 , and i_4 . If the ripple is ignored, the currents appearing on the outputs 24, 25, and 26 of the precision current-source arrangement have values exactly equal to $2I_0$, I_0 and I_0 respectively. A resistor 27 having a resistance R_1 is arranged in the output line of output 25, which resistor converts the current in this output line into a voltage. The output 19 of the switching circuit 13 is coupled to the input 31 of the detection circuit 30. The input 31 is coupled via an isolating capacitor 35 having a capacitance c , to the inverting input 33 of an amplifier 32, whose non-inverting input 34 carries a fixed voltage, in the present case zero. The amplifier output 36 is fed back to the inverting input 33 via a resistor 37 having a resistance R_2 . The resistor 37 can be short-circuited by a switch 38 by means of a signal S_1 which is derived from the clock generator 23. Furthermore, the output 36 is coupled to the inverting input 41 of a comparator 40, whose

non-inverting input 42 is at a reference voltage, in the present case the same fixed voltage as the input 34 of the amplifier 32. The output 43 of the comparator 40 is coupled to the input 46 of a distribution circuit 45. This distribution circuit 45 for example
5 comprises a pair of cascaded flip-flops which is clocked by generator 23 and which controls a 1-to-4 demultiplexer of which only the three outputs 47, 48 and 49 are used.

The detection circuit 30 operates as follows. In the first quarter of each cycle of the switching circuit 13 a voltage V_1
10 corresponding to, for example, the current i_1 appears across the resistor 27. In synchronism with this the switch 38 is closed by means of the signal S_1 so that input 33 is at the same voltage as input 34, i.e. at a voltage of zero volts. The capacitor 35 is charged until the voltage V_1 corresponding to the current I_1
15 appears across this capacitor. The inputs 41 and 42 are also at a voltage of 0 V, so that the voltage on the output 43 of the comparator 40 is 0 V. This output voltage is applied to that output of the distribution circuit 45 which is not used connected to a control circuit.

20 In the second quarter of each cycle a voltage V_2 corresponding to, for example, i_2 appears across the resistor 27. In synchronism with this the switch 38 is opened. The resistance R_2 of the resistor 37 is so high that the time constant for charging the capacitor 35 is very large. The capacitor 35 is therefore not
25 charged to a voltage V_2 , but the voltage across the capacitor 35 remains equal to V_1 . The amplifier 32 with the feedback resistor 37 therefore functions as a current-voltage converter which converts the current difference $i_1 - i_2$ into an amplified output voltage which appears on the output 36. This output voltage is
30 applied to the input 41 of the comparator 40. Depending on whether the output voltage of the amplifier 32 is higher or lower than the voltage of 0V on the input 42 the voltage on the output 43 of the comparator 40 is high or low, which voltage is employed as a logic signal of the value "1" or "0". The distribution circuit 45
35 transfers this signal synchronously to the output 47 of the



detection circuit 30.

It is to be noted that the resistance R_2 of the resistor 37 may alternatively be sufficiently high that the amplifier 32 functions as a comparator, enabling the comparator 40 to be dispensed with if desired. In fact the resistance R_2 may be infinite.

In a similar way voltages which are proportional to the respective current differences i_1-i_3 and i_1-i_4 appear on the output 36 of the amplifier in the third and fourth quarters of each cycle, the voltage across the capacitor 35 remaining equal to V_1 . The comparator 40 converts the amplified voltages on the output 36 into logic signals, which are transferred to the outputs 48 and 49 respectively by the distribution circuit.

In this way logic signals appear on the outputs 47, 48 and 49 in synchronism with the second, third and fourth quarters respectively of each cycle of the switching circuit 13 each signal having a value which depends on whether the respective current i_2 , i_3 or i_4 is larger or smaller than the current i_1 from the current-distribution circuit 1, which current is selected as the reference. The distribution circuit 45 ensures, for example by including a suitably clocked D-type flip-flop in each output thereof, that the voltage on each output does not change until the corresponding quarter of the next cycle of the switching circuit 13 occurs.

The outputs 47, 48 and 49 of the detection circuit are connected to the inputs 51, 52 and 53 respectively of three identical control circuits which are included in the control circuit arrangement 50. The control circuits comprise counting circuits 54, 55 and 56 respectively, whose outputs 57, 58 and 59 respectively are coupled to the inputs of digital-to-analog converters 60, 61 and 62 respectively having outputs 63, 64 and 65 respectively.

The counter 54 is, for example, a six-bit counter with one sign bit which defines the direction of the current on the output 63 of the six-bit digital-to-analog converter 60. The

digital-to-analog converter 60 does not supply an output current if the count is zero. Depending on the value of the logic signal on the output 47 the counter 54 is incremented or decremented by one, once during each cycle of the switching circuit 13. This is done by means of a suitable clock signal (not shown) derived from generator 23. This count appears on the outputs 57 in the form of six logic signals which are converted into an analog output current by means of the six-bit digital-to-analog converter 60. This current is applied to the emitter of transistor 3 and this, depending on whether the voltage across the resistor 7 increases or decreases, results in a decrease or increase of the current i_2 . The phasing around the loop is arranged to be such that this results in a reduction in the difference between i_2 and i_1 . The currents i_3 and i_4 are corrected in a similar way by means of the output currents of the digital-to-analog converters 61 and 62.

During the next cycle the modified currents i_2 , i_3 , and i_4 are again compared with the reference current i_1 . When the currents i_2 , i_3 and i_4 change the average value of the currents i_1 , i_2 , i_3 and i_4 in general also changes. The sum of the currents on the outputs 20 and 21 of the switching circuit 13 should be equal to the current $2I_0$ from the current source 12, if the input current of amplifier 11 is disregarded. The amplifier 11 controls the common base voltage to meet this requirement, so that the average value of each of the currents i_1 , i_2 , i_3 and i_4 is equal to I_0 . In the above manner the currents i_2 , i_3 and i_4 are corrected until they are substantially equal to the current i_1 and at the same time i_1 is corrected until it is equal to I_0 . Currents substantially without ripple and which are proportional accurately as $2I_0:I_0:I_0$ thus appear on the outputs 24, 25 and 26 of the precision current-source arrangement.

In the precision current-source arrangement shown in Figure 2, identical parts bear the same reference numerals as in Figure 1. The arrangement of Figure 2 is constructed and operates in a similar manner to that of Figure 1, the only difference being in the control circuits forming the arrangement 50, which are now in

analog form. The control circuits now comprise integrators constituted by amplifiers 70, 71 and 72 respectively, whose inverting inputs are connected to the inputs 51, 52 and 53 respectively by the resistors 79, 80 and 81 respectively and which receive negative feedback via the capacitors 73, 74 and 75 respectively. Resistors 76, 77 and 78 are arranged in the output lines of the respective integrators. The outputs 63, 64 and 65 of the control circuits are again connected to the emitters of the transistors 3, 4 and 5.

The voltage on the output 47 is integrated by the integrator including the amplifier 70 after which the resistor 76 converts the integrated voltage into a current. By means of this current the collector current i_2 of the transistor 3 is corrected, so as to reduce the difference between it and the current i_1 . The currents i_3 and i_4 are corrected in a similar manner by the currents on the outputs 64 and 65 respectively. The amplifier 11 again controls the voltage on the commoned bases in such a way that the average value of the currents i_1 , i_2 , i_3 and i_4 remains equal to I_0 .

In the first and the second embodiments the commoned bases of the transistors 2,3,4 and 5 of the current-distribution circuit are maintained at a substantially fixed voltage by the amplifier 11. The current-distribution circuit 1 functions as a current mirror, the current I_0 flowing in the collector lines of the transistors 2,3,4 and 5.

Instead of maintaining the commoned bases at a fixed voltage by means of the current source 12 and the amplifier 11 this may be done by, for example, connecting the commoned bases to the base of a transistor arranged as a diode, which transistor has its emitter connected to the common point via a resistor of a value equal to that of the other resistors 6-9 and its collector connected to a high-impedance current source.

In the types of current-distribution circuit so far described the commoned bases are at a fixed voltage relative to the common connection point of the emitter resistors, which point is also at a fixed voltage and is connected to, for example, the negative

power-supply terminal. This enables the current carried by a transistor of the current-distribution circuit to be corrected by applying current to its emitter without the current carried by another transistor of the current-distribution circuit being influenced directly thereby. The sum of the currents carried by the transistors of the current-distribution circuit may increase or decrease in such a case.

In a current-distribution circuit in which the common connection point of the emitter resistors is connected to a current source, as in the case of cascaded precision current sources, control current cannot be applied to the emitters because the sum current should remain equal to the current from the current source. In such a case floating control must be applied.

A third embodiment of the invention, in the form of a precision current-source arrangement employing such floating control, will be described with reference to Figure 3. Identical parts bear the same reference numerals as in Figure 1.

The current-distribution circuit in the embodiment of Figure 3 again comprises parallel-connected transistors 2,3,4 and 5.

However, their emitters are now connected to a current source 80 via resistors 6,7,8 and 9. The current carried by current source 80 may be the output current of a preceding precision current-source arrangement, i.e. source 80 may be constituted by such an arrangement, for example an arrangement as described with reference to Figure 1 or Figure 2. The resistor 6 has a value $\frac{1}{3} R_1$ and the resistors 7, 8 and 9 have a value $\frac{1}{2} R_1$. By means of field-effect transistors 84, 85 and 86 resistors 81, 82 and 83 having the values R_1 , $\frac{1}{2} R_1$ and $2R_1$ respectively may be arranged in parallel with the resistor 7. Similarly, resistors 87, 88 and 89 may be arranged in parallel with the resistor 8 by means of transistors 90, 91 and 92, and resistors 93, 94 and 95 may be arranged in parallel with the resistor 9 by means of transistors 96, 97 and 98. The sum of the output currents i_1 , i_2 , i_3 and i_4 of the current-distribution circuit is equal to the current $4I_0$ from the current source 80. The switching circuit 13 again

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switches these currents between the outputs 18, 19, 20 and 21 in such manner that a cycle of permutations of said currents repeatedly occurs at the collective said outputs and each said current switched to each said output during each cycle. The
5 detection circuit 30 is of the same design as described with reference to Figure 1. In the consecutive quarters of the cycle logic signals appear on the outputs 47, 48 and 49, which signals have logic values which depend on whether the currents i_2 , i_3 and i_4 respectively are larger or smaller than the current i_1 and are
10 applied to the inputs 51, 52 and 53 respectively of counters 110, 111 and 112 respectively. Depending on the values of the logic signals on output 47, 48 and 49 the counts in counters 110, 111 and 112 respectively are incremented or decremented by one by means of suitable clock signals (not shown) derived from generator 23. In
15 order to enable control to be effected in either sense the counters are given initial count states which result (see below) in the resistors 81, 82 and 93 being connected in parallel with the resistors 7, 8 and 9 respectively. The value $1/3 R$ of resistor 6 is equal to the value of the parallel arrangement of the resistors 7 and 81, 8 and 87, and 9 and 93, the resistors of each pair having
20 the values $\frac{1}{2}R_1$ and R_1 respectively, so that in the initial situation the currents i_1 , i_2 , i_3 and i_4 are substantially equal to each other.

A specific count in the counter 110 results in three logic
25 signals on the counter outputs, which signals are applied to a buffer memory 125. Similarly, the logic signals corresponding to the counts in the counters 111 and 112 are applied to the buffer memories 126 and 127 respectively. After completion of the full switching cycle the values applied to the buffer memories 125, 126
30 and 127 are simultaneously stored therein utilizing a suitable clock signal (not shown) derived from generator 23, and thus appear at their outputs simultaneously. The buffer memory 125 produces three logic signals on the outputs 130, 131 and 132, which signals control the transistors 84, 85 and 86 in such a way that a specific
35 combination of the resistors 81, 82 and 83 is arranged in parallel

with the resistor 7. Similarly, a combination of the resistors 87, 88 and 89 is arranged in parallel with the resistor 8 by means of logic signals on the outputs 140, 141 and 142 of the buffer memory 126, and a combination of the resistors 93, 94 and 95 is connected in parallel with the resistor 9 by means of logic signals on the outputs 150, 151 and 152 of the buffer memory 127. This changes the ratios of the currents i_1 , i_2 , i_3 and i_4 in such a way as to make them more equal, the sum of the currents i_1 , i_2 , i_3 and i_4 remaining equal to $4I_0$. The buffer memories 125, 126 and 127 are needed because the ratios of the currents cannot be changed independently of each other since the sum current is constant. The output signals of the buffer memories are maintained until the memories are clocked again at the end of the next switching cycle. In the next cycle of the switching circuit the currents i_2 , i_3 and i_4 are again compared with i_1 . The currents i_2 , i_3 and i_4 are then corrected further and this continues until the currents i_1 , i_2 , i_3 and i_4 are made as equal to each other as possible. The currents carried by the outputs 24, 25 and 26 are then proportioned accurately as $2I_0:I_0:I_0$ without substantial ripple.

In each of the embodiments described the number of outputs of the switching circuit is equal to the number of inputs of the switching circuit. Moreover, the ratios between the output currents of the switching circuit are always substantially unity. However, this is not necessarily the case; the number of outputs of the switching circuit may differ from the number of inputs thereof, the number of currents flowing to an output at a given time may be different from one and the number of currents flowing to the various outputs at a given time may differ from each other.

For example, the current-distribution circuit may supply five substantially equal currents to five inputs of a switching circuit having two outputs. The currents are for example switched between the outputs in such a way that at any given time two currents appear on one output and three currents on the other output, (a cycle of permutations of said currents again repeatedly occurring at the collective outputs and each current again being switched to

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each output during each cycle). Because of the repeated appearance at and disappearance from each output of each current the deviations of the currents from the current distribution circuit from each other can again be determined and used to produce control signals by means of which the currents from the current-distribution circuit are made more equal to each other. The currents on the two outputs of the switching circuit will in this case be accurately in the ratio 2:3. In a similar way it is possible to obtain the accurate ratios 4:1, 3:2, 2:3 and 1:4.

Moreover, the individual currents from the current-distribution circuit may be switchable on and off. This enables all the ratios between 4:1 and 1:4 to be obtained in the case of a switching circuit having five inputs and two outputs. Again the repeated appearance at and disappearance from each output of each switched-on current enables the differences between the switched-on currents from the current-distribution circuit to be determined so as to enable these currents to be made more equal to each other.

It will be evident that within the scope of the invention a multitude of modifications to the embodiments described in the foregoing are possible, which are obvious to those skilled in the art. In particular, the deviations of the current at an output of the switching circuit may be determined with respect to a reference current other than one of those supplied by the current-distribution circuit to the switching circuit, in which case the deviation of the output current will have to be determined in synchronism with the occurrences of every one of the individual output currents of the current distribution circuit at the said output.



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CLAIMS:

1. A precision current-source arrangement for generating a plurality of currents whose values are proportioned accurately relative to each other, which arrangement comprises
- 5 - a current-distribution circuit for generating a plurality of currents of substantially equal values, and
- a switching circuit for switching the currents from the current-distribution circuit between outputs of the switching circuit in such manner that a cycle of permutations of said
- 10 currents repeatedly occurs at the collective said outputs and each said current is switched to each said output during each cycle, resulting in the currents available on said outputs having average values which are proportioned accurately relative to each other and exhibiting ripples which depend on the differences between the
- 15 currents from the current-distribution circuit, characterised in that the arrangement also comprises
- a detection circuit for, in synchronism with occurrences of at least all but one of the individual output currents of the current-distribution circuit on a said output of the switching
- 20 circuit, detecting the deviation of the resulting value of the current at that output from the value of a reference current and generating an output signal representative of that deviation, and
- a control circuit arrangement responsive to the output of the detection circuit for controlling the currents constituting said at
- 25 least all but one of the individual output currents of the current-distribution circuit in senses such as to reduce the deviations detected.

2. A precision current-source arrangement as claimed in Claim 1, characterised in that the detection circuit detects said
- 30 deviation of the resulting value in synchronism with the occurrences of all but one of said individual output currents, and the reference current is constituted by the remaining one of the individual output currents of the current-distribution circuit.

3. A precision current-source arrangement as claimed in Claim 1 or 2, wherein the said occurrences are all of the same output of
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the switching circuit, characterised in that the detection circuit comprises

- a first resistor, which is connected to the said output of the switching circuit and which converts the current on this output into a voltage,
- an amplifier circuit having an inverting first input to which is coupled the said output of the switching circuit by an isolating capacitor, a second input which carries a reference voltage, and an output which is coupled to the first input by a second resistor,
and a distribution circuit having an input to which is coupled the output of the amplifier circuit and a plurality of outputs which are each coupled to a respective control circuit forming part of the control circuit arrangement, which distribution circuit, in synchronism with the occurrences of the individual output currents of the current-distribution circuit on the said output of the switching circuit, couples the output of the amplifier circuit to corresponding ones of its own outputs.

4. A precision current-source arrangement as claimed in Claim 3, characterised in that the amplifier circuit is coupled to the distribution circuit by means of a comparator for converting the output signal of the amplifier circuit into a digital output signal, which comparator has a first input to which is coupled the output of the amplifier circuit, a second input to which is coupled a reference-voltage source, and an output which is coupled to the input of the distribution circuit.

5. A precision current-source arrangement as claimed in Claim 3 or 4 when appended to Claim 2, characterised in that the second resistor is by-passed by a switch which short-circuits the second resistor in synchronism with the occurrences of the said remaining one of the individual output currents of the current-distribution circuit on the said output of the switching circuit.

6. A precision current source arrangement as claimed in Claim 5, characterised in that the second resistor has such a high value that the amplifier circuit operates as a comparator when the switch is open.



7. A precision current-source arrangement as claimed in Claim 4, or in Claim 5 or Claim 6 when appended to Claim 4, characterised in that each control circuit comprises a counting circuit the count in which is incremented or decremented once for each complete said cycle of permutations and in dependence upon the logic signal on the relevant output of the distribution circuit.

8. A precision current-source arrangement as claimed in Claim 7, characterised in that each control circuit further comprises a digital-to-analog converter which converts the count in the counting circuit into an analog output current by means of which the relevant output current of the current-distribution circuit is controlled.

9. A precision current source arrangement as claimed in Claim 3, characterised in that each control circuit comprises an integrator which integrates the signal on the relevant output of the distribution circuit, the relevant output current of the current distribution circuit being controlled by means of the output signal of the integrator.

10. A precision current-source arrangement as claimed in Claim 8 or 9, wherein the current-distribution circuit comprises a plurality of transistors whose bases are connected together and whose emitters are connected to a common point of fixed voltage via equal-value resistors, characterised in that the output of each control circuit is coupled to the emitter of a respective said transistor.

11. A precision current-source arrangement as claimed in Claim 7, wherein the current-distribution circuit comprises a plurality of transistors whose bases are connected together and whose emitters are connected to a common point via equal-value resistors, to which common point a constant current is applied, characterised in that the counts in the counting circuits are stored in a buffer memory and upon termination of each complete said cycle of permutations simultaneously operate switches by means of which resistors are connected in parallel with the emitter resistor of a respective said transistor.



12. A precision current-source arrangement as claimed in Claim 11, characterised in that the switches are constituted by field-effect transistors.

13. A precision current-source arrangement as claimed in Claim 11 or 12, characterised in that the constant current is an output current of another precision current-source arrangement as claimed in Claim 1.

14. A precision current-source arrangement substantially as described herein with reference to Figure 1, Figure 2 or Figure 3 of the drawings.

