United States Patent [19]

Kramer

[11] **3,753,131**

[45] **Aug. 14, 1973**

[54] **CURRENT SOURCE FOR SUPPLYING A CURRENT HAVING AN EXPONENTIAL WAVE FORM**

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[73] Assignee: **U.S. Philips Corporation**, New York, N.Y.

[22] Filed: **Dec. 30, 1971**

[21] Appl. No.: **214,286**

[30] **Foreign Application Priority Data**

Jan. 8, 1971 Netherlands 7100277

[52] **U.S. Cl.** **328/145**, 330/69

[51] **Int. Cl.** **G06g 7/24**

[58] **Field of Search** ..... 328/1, 142, 143, 328/144, 145, 167; 330/69, 104, 1 R

[56] **References Cited**

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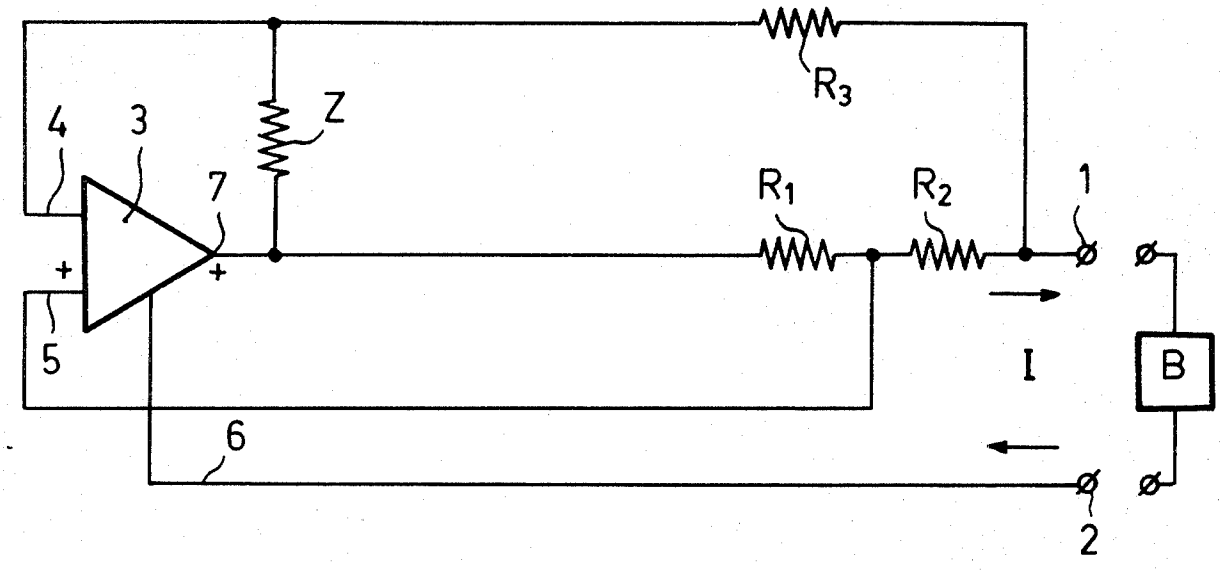
Primary Examiner—John W. Huckert
Assistant Examiner—R. E. Hart
Attorney—Frank R. Trifari

[57] **ABSTRACT**

By using an operational amplifier, a few resistors and a reactance a current source is obtained which supplies a current having an exponential waveform. The current source may be used in analogue computers for operations with logarithms, in apparatus for testing semiconductors and in measuring instruments provided with a logarithmic display.

3 Claims, 3 Drawing Figures



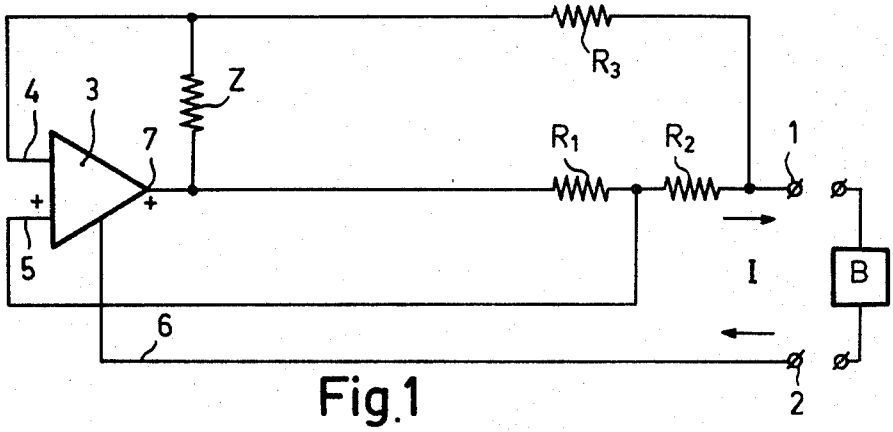


Fig.1

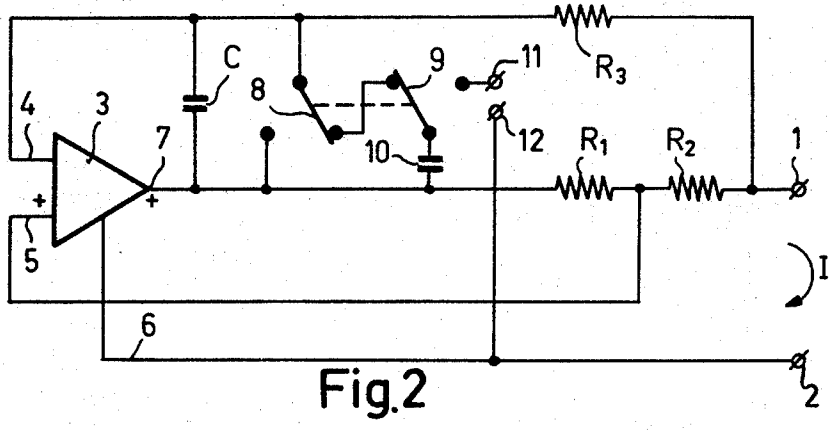


Fig.2

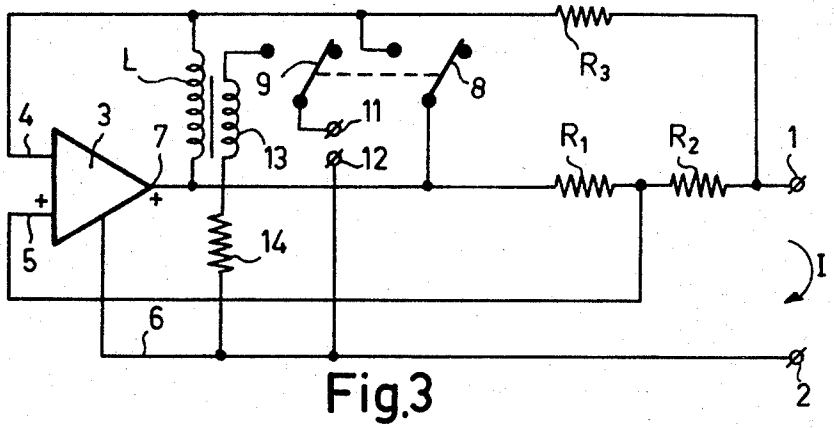


Fig.3

CURRENT SOURCE FOR SUPPLYING A CURRENT HAVING AN EXPONENTIAL WAVE FORM

The invention relates to a current source for producing a current having an exponential wave form, which circuit comprises a first and a second terminal for connection to a load, a reactance, resistors and a differential amplifier provided with a first and a second input terminal, an output terminal and a common lead.

Current sources are known. They generally are in the form of a two-terminal device between which a load may be connected so that the load passes a current which within certain limits is independent of the value of the load. Usually the current source comprises a high-tension voltage supply having a large internal resistance, so that in the case of comparatively small loads the current is determined by the voltage and the high internal resistance.

For some purpose it may be necessary for the current delivered by a current source to satisfy certain conditions, for example to have a certain time dependence or to be dependent on a given parameter. In this case a function generator may be used which produces the required function and delivers it output quantity, usually a voltage, to a final stage which is connected as a current source.

It is known to produce exponential or logarithmic time functions by means of charging or discharging capacitors, generally in conjunction with a fixed voltage and a series resistor. Inductors may also be used in conjunction with voltage supply source and series resistors.

It is an object of the invention to provide a very simple circuit which has a current supply output at which a current is supplied which veries exponentially with time, without using succeeding function generators and current source cirucits.

For this purpose a current source for supplying a current having an exponential waveform of the type described at the beginning of the specification is characterized in that the output terminal is connected through a first resistor to the first input terminal and through the reactance to the second input terminal, the first load connection terminal being connected through a second resistor to the first input terminal and through a third resistor to the second input terminal, the common lead being connected to the second load connection terminal.

The differential amplifier may be of the operational amplifier type, providing large amplification and a high input impedance.

Depending upon the voltage drive of the amplifier and the initial condition, the current source circuit according to the invention enables an exponential waveform extending over several decades to be obtained with a satisfactory degree of accuracy. If a capacitor is used as the reactance, the initial condition may simply be set by imparting an initial charge to the capacitor via switches. In the formula $I = Ae^{Bt}$, where I is the current of the circuit and e is the base of the natural logarithm, the constant A is determined by the said initial charge and by the values of the capacitor and the resistors, whilst B is inversely proportional to a time constant fixed by these values. The capacitor may be replaced by an inductor to which an initial current is supplied to fix the initial condition.

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

FIG. 1 is a circuit diagram of the current source according to the invention,

FIG. 2 is a circuit diagram of a current source using a capacitor and a starting circuit, and

FIG. 3 is a circuit diagram of an embodiment using an inductor and an associated starting cirucit.

Referring now to FIG. 1, the current source shown has terminals 1 and 2 load B is to be connected. A differential amplifier 3 having input terminals 4 and 5 and a common lead 6 is fed from supply sources, not shown. An output terminal 7 supplies current which through a reactance Z and a resistor R_3 and through the series combination of resistors R_1 and R_2 is available to the load B at the terminal 1. The current returns via the terminal 2 and the lead 6. The reactance Z is connected to the input terminal 4 and to the output terminal 7 of the amplifier, wilst the resistor R_3 is connected between the input terminal 4 and the terminal 1. The input terminal 5 is connected to the junction point of the resistors R_1 and R_2.

In FIG. 2 elements corresponding to those of the circuit of FIG. 1 are designated by like reference numerals. The reactance here is a capacitor C which is shunted by a switch 8, which in the operative position short-circuits the capacitor and hence sets the current source circuit to the rest condition in which the terminals 1 and 2 carry no current.

The switch 8 is coupled to a switch 9 capable of switching a capacitor 10. In the rest position of the two switches, which position is shown in the Figure, the capacitor 10 is connected in parallel with the capacitor C. In the operative positions of the two switches, which are mechanically coupled to one another, the capacitor 10 is charged from a direct-voltage supply source connected to terminals 11 and 12. The value of the capacitor 10 is very small compared with that of the capacitor C, so that when determining the time constant of the circuit the latter capacitor only need be taken into account and on the other hand when the switches 8 and 9 are in their rest positions the charge distribution between the two capacitors is such that when the circuit is started only a small voltage is set up across the capacitor C, for example a voltage of the order of microvolts or at most millivolts, whilst at the same time the direct-voltage supply source voltage across the terminals 11 and 12 may be, say, 12 volts.

A calculation of the current I shows that, neglecting the influence of the amplification factor and the input resistance of the amplifier which are assumed to be very large, the exponential function is:

$$I = U_{oc}\,(R_2 = R_3/R_1R_3)\; e\; (R_2/R_1R_3C)\; t \qquad (1)$$

where I is the current, U_{oc} the initial voltage across the capacitor C at starting, R_1, R_2, R_3 and C are the values of the elements designated by these references, and t is time, the time constant in the e power being given by

$$(R_1R_3/R_2) \cdot C \qquad (2)$$

The initial voltage U_{oc} may alternatively be directly applied to the capacitor C via change-over switches by a separate supply source.

In the circuit shown in FIG. 3 the reactance is a coil L having an inductance L. In this case the current satisfies the relationship:

$$I = i_{o1} (R_2 + R_3/R_2) \text{ e } (R_1R_3/R_2L) t \quad (3)$$

where i_{oL} is the initial current through the coil which is necessary when starting the circuit. The time constant is given by:

$$L/(R_1R_3/R_2) \quad (4)$$

By means of a switch **8** the coil is short-circuited and the circuit is brought to the starting condition in which the current I is zero. In this condition the current i_{oL} is produced in the magnetic circuit in the coil by a current in a separate winding **13** which is supplied via a switch **9** and a resistor **14** by a source connected to the terminals **11** and **12**. Since the switches **8** and **9** are mechanically coupled to one another, at the starting of the circuit the short-circuit of the coil L is removed and a current i_{oL} is produced in the coil L.

The zero point of the current I at the instant t=0 may be shifted by supplying an additional current from a separate current supply to the terminals **1** and **2**. Thus, there may be supplied to a load a current having the nature I =const. $(1 - e^{Bt})$.

The current supply circuit according to the invention may be used to advantage in analogue computer circuits, an apparatus for testing semiconductors, where an e-power function is frequently met with, and in measuring instruments in which a logarithmic display of measurements is desired.

What is claimed is:

1. Current source for producing a current having an exponential waveform, which circuit comprises a first and a second terminal for connection to a load, a reactance, resistors and a differential amplifier provided with a first and a second input terminal, an output terminal and a common lead, characterized in that the output terminal is connected through a first resistor to the first input terminal and through the reactance to the second input terminal, the first load connection terminal being connected through a second resistor to the first input terminal and through a third resistor to the second input terminal, whilst the common lead is connected to the second load connection terminal.

2. Current source as claimed in claim **1**, characterized in that the reactance is a capacitor the capacitance value of which together with the first, second and third resistors determines the time constant of the exponential waveform and which by means of switches may be short-circuited to return the current source to the starting position and also may be provided with an initial charge by means of which, when the current is started, and by means of the values of the capacitor and the resistor the proportionality constant of the current may be fixed.

3. Current source as claimed in claim **1**, characterized in that the reactance is an inductor the value of which together with the first, second and third **9** resistors determines the time constant of the exponential waveform and which by means of switches may be short-circuited to return the current source to the starting position and also may be provided with an initial current i_0 so that, when the current is started, by this initial current and by the values of the inductor and the resistors the proportionality constant of the circuit current may be fixed.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,753,131 Dated August 14, 1973

Inventor(s) PIETER KRAMER

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

connecting the amplifier output terminal through a first resistor to the first input terminal and through the reactance to the second input terminal, means connecting the first load connection terminal through a second resistor to the first input terminal and through a third resistor to the second input terminal, and means connecting the common lead to the second load connection terminal.

2. A current source as claimed in claim 1, characterized in that the reactance comprises a capacitor having a capacitance value which, together with the first, second and third resistors determines the time constant of the exponential waveform, and switching means by means of which the capacitor may be short-circuited to return the current source to a starting position and by which the capacitor also may be provided with an initial charge so that, when the current is started, and by means of the values of the capacitor and the resistors the proportionality constant of the current may be fixed.

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It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

col. 1, line 5, cancel ", which";

line 6, cancel "circuit" and insert -- and more particularly to a current source which --;

line 7, before "resistors" insert -- some --;

line 19, change "purpose" to -- purposes --;

line 21, after "example" insert a comma (,);

line 24, change "it" to -- its --;

line 32, change "source" to -- sources --;

line 35, change "veries" to -- varies --;

line 64, cancel "whilst" and insert -- while --;

col. 2, line 11, after "2" insert -- to which a --;

line 13, cancel "fed" and insert -- energized --;

line 20, cancel ", wilst" and insert -- and --;

line 41, cancel the comma (,);

after "that" insert a comma (,);

line 42, before "the" insert a comma (,);

line 43, cancel "and on" and insert -- . On --;

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It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

col. 2, line 44, after "positions" insert a comma (,);

line 47, before "a" insert a comma (,);

line 48, cancel ", whilst at" and insert -- . At --;

line 55, cancel "e (R_2/R_1R_3C) t" and insert -- $e^{(R_2/R_1R_3C)\ t}$ --;

col. 3, line 4, cancel "$I = i_{o1}$" and insert -- $I = i_{oL}$ --;

cancel "e (R_1R_3/R_2L) t" and insert -- $e^{(R_1R_3/R_2L)\ t}$ --;

line 30, cancel "an" and insert -- in --;

IN THE CLAIMS

Claims 1-3 should read as follows:

1. A current source for producing a current having an exponential waveform comprising, a first and a second terminal for connection to a load, a reactance, a plurality of resistors, a differential amplifier provided with a first and a second input terminal, an output terminal and a common lead, means

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Patent No. 3,753,131 Dated August 14, 1973

Inventor(s) PIETER KRAMER

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

3. A current source as claimed in claim 1, characterized in that the reactance comprises an inductor having an inductance value which, together with the first, second and third resistors determines the time constant of the exponential waveform, and switching means for short-circuiting the inductor to return the current source to a starting position and also for providing the inductor with an initial current i_o so that, when the current is started, the initial current and the values of the inductor and the resistors fix the proportionality constant of the current.

Signed and sealed this 1st day of October 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents