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[54] **ELECTRONIC ANALOG DIVISION MEANS**
19 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **235/196,** 235/179, 307/311, 307/229, 328/2, 328/161
[51] **Int. Cl.** **G06g 7/16**
[50] **Field of Search** 235/194, 195, 196, 179; 307/311, 229, 230; 328/2, 160, 161; 250/210

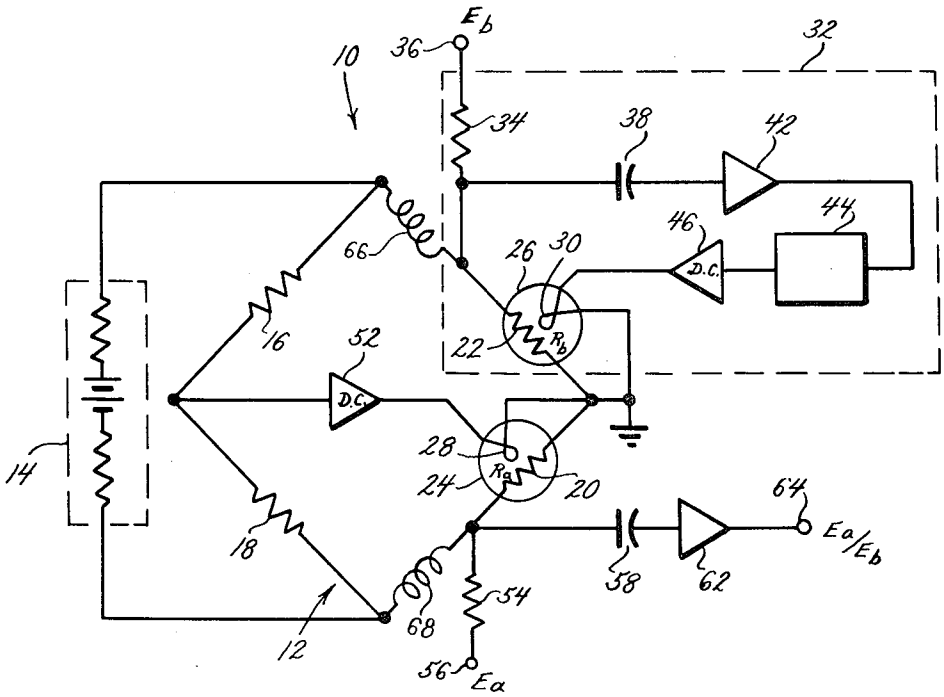
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ABSTRACT: Electronic circuit means for performing the division of one or more signals by another signal, said electronic circuit means including at least one bridge circuit including electrooptical devices therein which act as variable attenuators in the performance of one or more division operations, said circuit means also including direct-current feedback means to the electrooptical devices for control purposes.



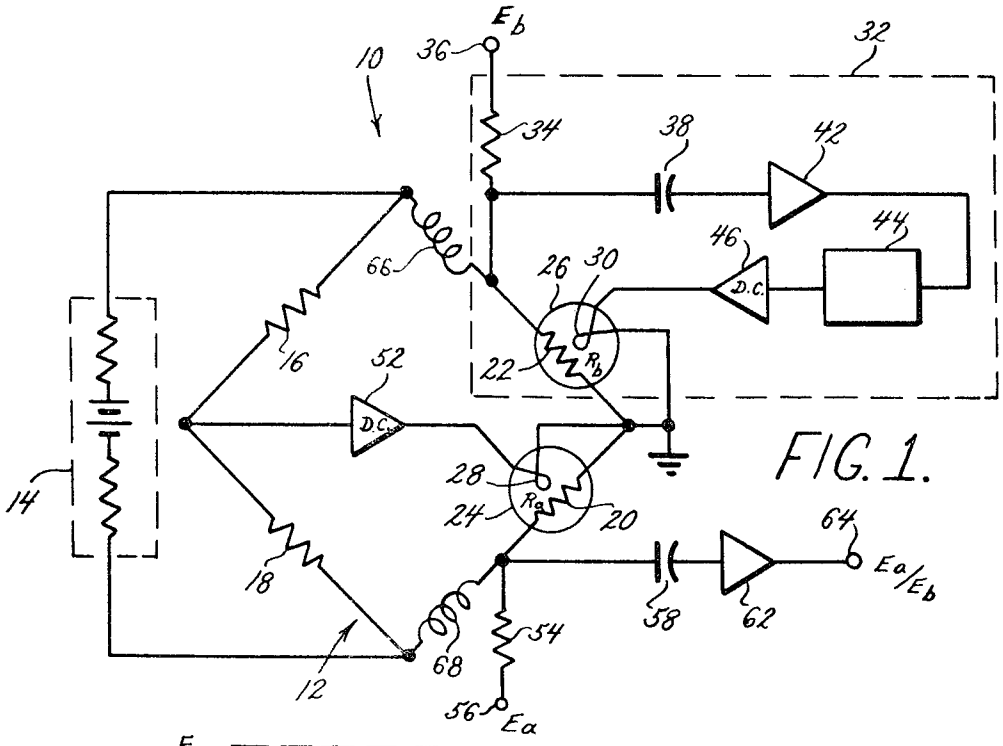

Eb
36
10
32
34
38
42
44
46
D.C.
66
26
30
22
Rb
16
52
D.C.
28
24
Rg
20
14
18
64
Ea/Eb
58
62
54
68
12
56
Ea

FIG. 1.

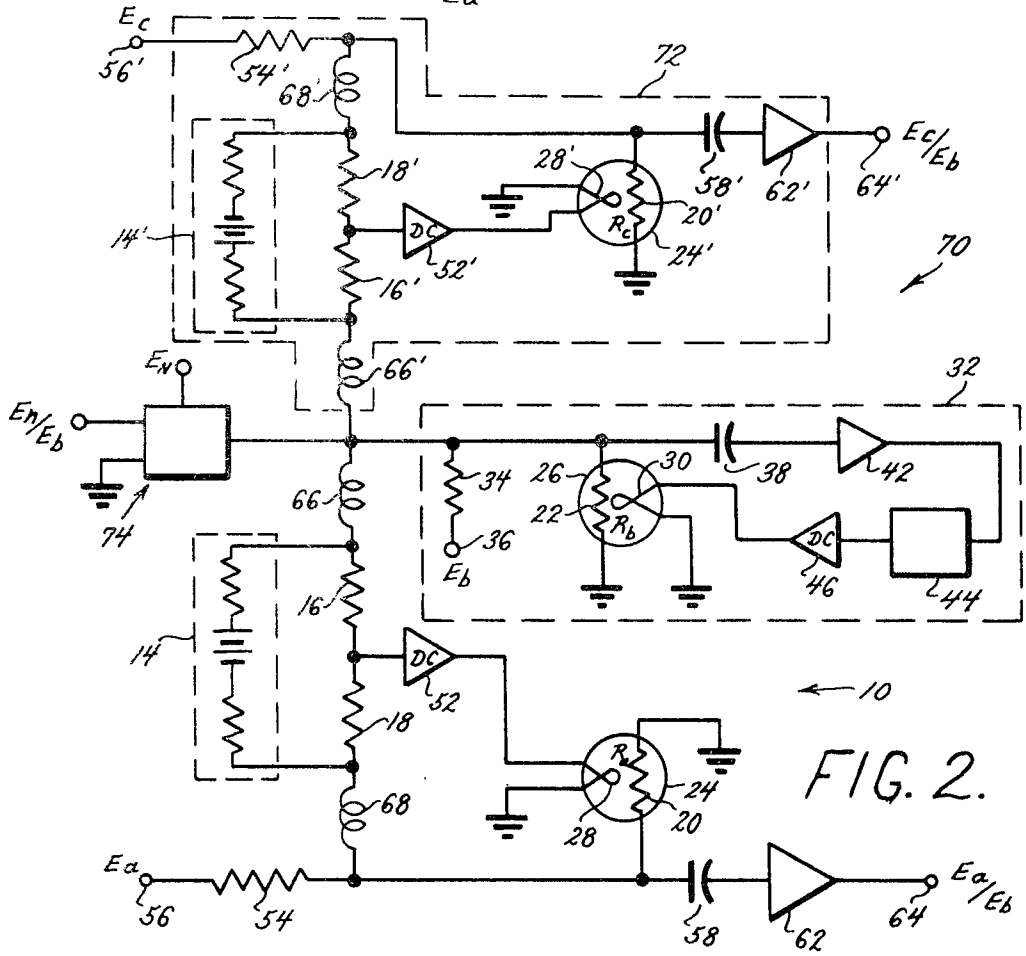

Ec
56'
54'
68'
72
Ec/Eb
64'
62'
58'
28'
20'
Rc
24'
18'
14'
DC
52'
16'
70
EN
66'
32
EN/Eb
74
34
26
30
38
42
22
Rb
36
Eb
DC
46
44
66
16
14
DC
52
10
18
Rw
24
28
20
68
Ea
56
54
58
62
64
Ea/Eb

FIG. 2.

ELECTRONIC ANALOG DIVISION MEANS

Circuits for dividing one or more signals by another including division circuits utilizing electro-optical devices are well known but heretofore such circuits have had many disadvantages and shortcomings. Existing analog division circuits have been useful for applications involving narrow ranges of frequencies and amplitudes but because of internal phase shift and linearity problems, the existing division circuits have proved unsatisfactory when the inputs thereto vary widely in frequency and amplitude. In addition, those circuits which have used electro-optical devices, that is devices including light sources and photoconductors whose resistances vary in inverse proportion to the potentials applied to the light sources, have required that such devices be carefully matched both in light source and photoconductor characteristics. Unfortunately, commercially available electro-optical devices, even if initially matched in characteristics, have a tendency to change their characteristics with age and/or temperature. These variations in characteristics heretofore have caused analog division circuits which use electro-optical devices to require almost constant recalibration and/or replacement of the components therein. The present analog division circuit also uses electro-optical devices but in such a manner that the outputs thereof are relatively independent of changing characteristics in their light sources and photoconductors.

The present analog division means can be used in analog computation applications and in addition can be used in communication applications and instrumentation applications as well. In the fields of communication and control the possible uses include, among other things, use as an amplitude stabilizer, as an automatic gain control, and as other related devices. In the field of instrumentation the present circuits can be used in many applications including particularly uses as compressor amplifiers which are used to generate outputs which vary over relatively narrow ranges in response to receipt of input signals which may vary over relatively wide ranges.

The present analog division circuit includes one or more electrical bridges similar to the Wheatstone type. Each bridge has fixed resistors in two legs thereof for sensitivity control, and a photoconductor in each of the other two legs, which photoconductors act as variable attenuators. The photoconductors also have light sources associated therewith. The potential supplied to the light source of one of the photoconductors is varied by means of a direct-current feedback circuit in proportion to a divisor input signal which is the input signal applied to the circuit that is used to divide into other input signals which are hereinafter called dividend signals. This light variation causes the associated photoconductor to vary in resistance in inverse proportion to the divisor input. When the photoconductor varies it of course unbalances the bridge. Means are provided in the present circuit to sense the unbalances bridge condition and to vary the potential to the other light source in proportion to the amount of unbalance. The other light source when varied by the out-of-balance bridge condition changes the resistance of its associated photoconductor in a direction to rebalance the bridge circuit. Therefore, the resistances of both the photoconductors vary inversely with the divisor input signal. The other photoconductor is also part of a voltage divider network across which a dividend signal is applied. A quotient output signal therefore appears across this photoconductor because it is connected to attenuate the dividend signal in proportion to the divisor signal. A plurality of similar parallel bridges can be constructed all of which include the same first described photoconductor. This allows a divisor input to operate on and divide a plurality of dividend inputs as will be explained.

The present circuit is more stable in operation than the prior art devices whose stabilities in large measure depend on the questionable stabilities of the electro-optical devices employed therein as aforesaid. Also in the present circuit by providing direct current feedback between the two or more photoconductors, the errors due to ambient temperature

changes, changes in light source characteristics and differences in the responses of the photoconductors to light intensity are neutralized. The provision of direct current feedback is possible in the present circuit because the photoconductors are used as variable attenuators rather than as means to vary gain of amplifiers as has been common in the past.

When the present circuit includes a plurality of parallel bridge networks there is feedback between all the photoconductors so that there still is continuous compensation for changes in temperature and changes in element characteristics. The feedback between the plurality of photoconductors not only improves the circuit stability but it also widens the frequency response thereof. In fact, the frequency response of the present circuit is limited not by photoconductor characteristics as is the case with most prior art division circuits which employ photoconductors, but is limited only by stray capacitances and the operational limitations of the amplifiers employed therein. The use of direct-current feedback to vary the intensities of the light sources associated with the photoconductors also reduces phase shift errors, common in the prior art, to a minimum in the present circuit.

It is therefore a principal object of the present invention to provide improved analog division means.

Another object is to improve the stability characteristics of analog division circuits.

Another object is to provide an analog division circuit which can tolerate input signals which may vary over a wide range of frequencies and amplitudes.

Another object is to provide a solid-state division circuit which has no moving parts.

Another object is to provide an analog division circuit which can be quickly and easily expanded to provide additional input and output capability.

Another object is to provide an analog division circuit which is linear over a wide range of input signal amplitudes.

Another object is to provide an analog division circuit which is not subject to phase shift errors.

These and other objects and advantages of the present invention will become apparent after considering the following detailed specification which describes in detail several different embodiments of the subject analog division circuit in conjunction with the accompanying drawing, wherein:

FIG. **1** is a schematic circuit diagram showing the subject circuit for producing a quotient output signal from a dividend input signal and a divisor input signal; and,

FIG. **2** is a schematic circuit diagram showing the details of a division circuit similar to FIG. **1**, which circuit includes a plurality of parallel bridge networks capable of dividing a plurality of dividend input signals by a divisor input signal to produce two or more quotient output signals.

Referring to the drawings more particularly by reference numbers, the number **10** in FIG. **1** refers to a division circuit constructed according to the present invention. The division circuit **10** includes a direct current operated Wheatstone type bridge circuit **12** and a direct current power supply **14** connected thereacross. The DC output of the power supply **14** is divided by sensitivity controlling resistors **16** and **18** which are in two of the legs of the bridge circuit **12** and which are shown connected in series across the supply **14** and by photoconductors **20** and **22** which are in the other two legs of the bridge circuit **12** and which also are connected in series across the supply **14**. The photoconductors **20** and **22** are components of electro-optical devices **24** and **26**, respectively, which devices also include respective light sources **28** and **30**. The light sources **28** and **30** control the resistances R_a and R_b of the associated photoconductors **20** and **22**. As aforesaid, in devices such as the electro-optical devices **24** and **26**, the resistance of the photoconductor portion thereof varies inversely with the potential applied to the light source. In the present circuit **10** the potentials applied to the light sources are varied, as will be explained, so that the associated photoconductors act as variable attenuators.

The divisor input circuit **32** causes the resistance R_b of the photoconductor **22** to vary in inverse relationship to variations in a divisor input signal E_b. The inverse variation of R_b with E_b is at the heart of the present invention which through the bridge circuit **12** causes the resistance R_a of the photoconductor **20** to also vary inversely with E_b regardless of changes in characteristics of the electro-optical devices **24** and **26**, as will be explained.

A resistor **34** and the photoconductor **22** are connected in series between a divisor input terminal **36** and ground, and together the resistor **34** and the photoconductor **22** form a voltage divider network. The input signal E_b is applied across the said voltage divider network and the potential which is developed across the photoconductor **22** is connected through a direct-current blocking capacitor **38** to the input of an amplifier **42**. The amplifier **42** preferably includes field effect transistors or the like in the input circuitry thereof so that it has a high input impedance which prevents shunting of the divisor input signal E_b. The output of the high input impedance amplifier **42** is converted into a DC signal by a rectifier and filter circuit **44** which is connected to the output side of the amplifier **42**. This filtered DC signal is amplified by a high gain DC amplifier **46** and is applied across the light source **30** as a DC feedback signal to control the resistance R_b of the photoconductor **22**. The amplifiers **42** and **46** are connected so when the divisor input signal E_b is relatively small, the DC feedback signal is also relatively small, which in turn causes the light source **30** to shine at a relatively low intensity. Under these circumstances the resistance R_b of the photoconductor **22** will be relatively large. As the divisor input signal E_b increases in magnitude, the DC feedback signal from the amplifier **46** will also increase and in so doing will increase the voltage applied to the light source **30** thereby reducing the resistance R_b and keeping the potential across the photoconductor **22** which is designated E_1 relatively constant within the limits of the circuit **10**. The gain in the feedback circuit for the electro-optical device is selected to be high enough to assure that the resistance R_b of the photoconductor **22** is always the same for a given value of E_b no matter how the characteristics of the photoconductor **22** and the light source **30** may change. As already stated this is very important to the operation of the invention.

As can be seen in FIG. **1**, the potential E_1 across the photoconductor **22** by Ohm's Law can be expressed as:

$$E_1=E_bR_b/(R_{34}+R_b)$$

The divisor input circuit **32** usually is designed so the resistance of the resistor **34**, which is expressed as R_{34}, is always much larger than the resistance R_b of the photoconductor **22**. This being true the above function can be rewritten:

$$E_1\approx E_bR_b/R_{34}$$

The DC feedback signal to the light source **30** assures that E_1 remains substantially constant as aforesaid, and under these conditions R_b must vary inversely with E_b. Since E_1, the potential across the photoconductor **22**, is rectified and filtered before being amplified to produce the final DC feedback signal for the light source **30**, there is no phase shift associated therewith to affect the frequency bandwidth or the linearity of the circuit **10**.

Whenever R_b varies inversely with E_b, the bridge circuit **12** becomes unbalanced. The amount of the unbalance is detected by a high gain DC amplifier **52** which is connected at one side to the junction between the sensitivity resistors **16** and **18** and at its opposite side to one side of the light **28** in the electro-optical device **24**. The DC amplifier **52** amplifies the unbalanced condition of the bridge that it senses and feeds back into the bridge circuit **12** through it connection to the light source **28** of the electro-optical device **24** a signal proportional thereto. The amplifier **52** and light source **28** are also connected so that when the light source **28** increases or decreases its light intensity, it will cause the resistance R_a of the associated photoconductor **20** to vary in a proper direction to rebalance the bridge. This means, of course, that no matter how the characteristics of the photoconductor **20** and the light source **28** vary with temperature or age, the resistance R_a of the photoconductor **20** must always vary in proportion to the variations of R_b. In other words, a variable attenuator (photoconductor **20**) has been created using electro-optical devices, which attenuator is completely independent of variations in the characteristics of the electro-optical devices.

The photoconductor **20** is also connected in series with a fixed resistor **54**, and together they form a voltage divider network between the dividend input terminal **56**, to which the dividend input signal E_a is applied, and ground. The photoconductor **20** acts as a variable attenuator in the voltage divider network, and since the resistance R_a varies directly with R_b, and hence inversely with E_b, the photoconductor **20** attenuates $E_a$directly with E_b to produce a potential across the photoconductor **20** which is proportional to the quotient E_a/E_b. An output circuit, including in series a direct current blocking capacitor **58**, a high input impedance amplifier **62** and the quotient output terminal **64**, is connected to the junction between the photoconductor **20** and the resistor **54** to detect the potential E_a/E_b across the photoconductor **20**, and the amplify it to a usable level. The amplifier **62** also preferably has a high input impedance so that it will not load the voltage divider network made up of the resistor **54** and the photoconductor **20**. It should be obvious that by rearranging the components of the division circuit **10**, the quotient E_a/E_b can be made to appear at different locations therein. Also other functions appear in the circuit **10** such as the function $E_a(1-1/E_b)$ which appears across the resistor **54**. These other functions may be detected and amplified by suitably connected means such as the output circuit discussed above.

As shown in FIG. **1**, the circuit **10** also includes two inductors or chokes **66** and **68**. The inductor **66** is connected at one end to the junction between the resistor **34** and the photoconductor **22**, and at the other end to the junction between one side of the DC power supply **14** and the bridge sensitivity resistor **16**. The inductor **68** is connected at one of its ends to the junction between the resistor **54** and the photoconductor **20** and at its other end to the junction between the other side of the DC power supply **14** and the bridge sensitivity resistor **18**. The inductors **66** and **68** block the dividend and divisor input signals E_a and E_b and in so doing prevent them from passing through the DC portion of the bridge circuit **12** to undesirably interact with each other across the photoconductors **20** and **22**.

FIG. **2** shows a circuit **70** for obtaining the functions E_a/E_b, E_c/E_b, . . . E_n/E_b. The circuit **70** includes the circuit **10** with additional circuits **72** and **74** added thereto, each of which circuits **72** and **74** include a divisor input circuit similar to the divisor input circuit **32** including having a photoconductor such as the photoconductor **22** connected as part of their respective bridges. The remaining components of the circuits **72** and **74** are duplications of circuit **10** less the divisor input circuit **32**, and they operate in a like manner. This can be quickly verified by comparing the circuits component by component. For convenience, the components of circuit **72** have been numbered with numbers that correspond to the components in circuit **10** but with the numbers primed.

The circuits **72** and **74**, of which there can be any desired number, function like the circuit **10** to perform division operations and to produce quotient outputs E_a/E_b, E_c/E_b, . . . E_n/E_b, all of which are divided by the same divisor input signal E_b. With the circuit **70** as shown in FIG. **2**, not only are multiple quotient output signals produced but there is also feedback between the three or more photoconductors so that there is continuous compensation for changes in the photoconductor characteristics. This feedback improves the circuit stability and frequency response of the circuit **70**.

Thus there has been shown and described novel electronic analog division means which fulfill all of the objects and ad-

vantages sought therefor. Many changes, alterations, modifications, and other uses and applications of the subject division means will become apparent to those skilled in the art after considering this specification and the accompanying drawing. All such changes, alterations, modifications and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the claims which follow.

What is claimed is:

1. Means for dividing a first signal into a second signal including a balanced bridge circuit, said bridge circuit including at least two bridge legs each including a variable impedance element, first bridge input means to which the first signal is fed, said first bridge input means being connected in one of said bridge legs and including means to effect a change in the impedance of the one of said variable impedance elements in response to changes in the first signal to unbalance said bridge circuit, voltage divider means including the variable impedance elements in said two bridge legs, other means connected to said bridge circuit and to said variable impedance elements to respond to any unbalance in the bridge circuit due to changes in the first signal, said last-named means including means to rebalance the bridge by varying the impedance of the other of said variable impedance elements, and second bridge input means including means connected to apply a second signal across a portion of said voltage divider means including said variable impedance elements, an output signal being produced across a portion of said voltage divider means which varies in direct proportion to the second signal and inversely in proportion to the first signal.

2. The means defined in claim 1 wherein said first input means include control means and photoconductor means, said photoconductor means being connected in the said one leg of the bridge circuit, a portion of said first signal being applied across said photoconductor means, said control means including means to detect variations in the potential across said photoconductor means, and said control means including means to vary the conductance of the photoconductor means in response to detected potential variations in a direction to maintain the potential across the photoconductor means relatively constant.

3. The means defined in claim 1 wherein each of said variable impedance elements includes a photoconductor having a light source associated therewith, the intensity of the light from the light source associated with the said one variable impedance element varying with the magnitude of the first signal to control the conductance of said photoconductor, said means responsive to the unbalanced condition of the bridge circuit including a DC amplifier whose output is connected in a circuit with the light source associated with the photoconductor in the other variable impedance element to vary the potential applied thereto in a direction to maintain the bridge circuit in a balanced condition.

4. Means for dividing a first signal into a second signal including a multileg bridge circuit and first bridge input means to which the first signal is fed, first variable impedance means connected to said first input means in one leg of said bridge circuit, said first variable impedance means including means to vary the impedance thereof in inverse proportion to variations of said first signal, means included in the bridge circuit connected across said first variable impedance means for responding to variations in the impedance thereof to produce control outputs which vary in inverse relationship to said variations in the impedance of said first variable impedance means, second variable impedance means operatively connected to said impedance-responsive means and controlled by the control outputs thereof, the impedance of said second variable impedance means varying in direct proportion to the variations in impedance of said first variable impedance means, and second input means to which said second signal is fed connected to said second variable impedance means including means to apply a portion of said second signal across said second variable impedance means, the magnitude of the proportion of said second signal appearing across said second variable impedance means depending on the impedance thereof, the portion of the second signal appearing across said second variable impedance means being a function of the ratio of the first and second signals.

5. Electronic means for producing a division operation between two analog input signals represented as input signals E_a and E_b comprising a Wheatstone bridge circuit having two pairs of opposed bridge legs and two pairs of opposed bridge corners therebetween, means including a source of DC energy connected across one pair of opposed bridge corners and means including DC amplifier means connected across said other pair of opposed bridge corners, said DC amplifier means responding to imbalance in the condition of the bridge circuit, a first variable impedance device connected in one of the bridge legs, said variable impedance device including an impedance portion and an impedance control portion, a first bridge input circuit for applying to the bridge circuit the input signal E_b connected to the bridge circuit such that a portion of the input signal E_b is across the impedance portion of the first variable impedance device, means responsive to changes in the voltage across the first variable impedance device due to changes in the input signal E_b, said voltage responsive means being connected to the impedance control portion of the first variable impedance for varying the impedance of the impedance portion of the first variable impedance device in a direction to maintain the voltage thereacross relatively constant, changes in the impedance of said first variable impedance device producing an imbalance in the bridge circuit which is detected by the DC amplifier means, a second variable impedance device connected in another one of the legs of the bridge circuit, said second variable impedance device having an impedance portion and an impedance control portion, the impedance control portion of said second variable impedance device being operatively connected to the DC amplifier means whereby imbalance of the bridge sensed by the DC amplifier means operate to control the impedance of said second variable impedance device to change the impedance thereof in a direction to restore and maintain the bridge in a balanced condition, and second input means connected to the bridge circuit such that a portion of the input signal E_a is applied across the impedance portion of said second variable impedance device, the signal appearing across the impedance portion of said second variable impedance device being a function of the ratio of the input signals E_a and E_b.

6. The electronic means defined in claim 5 including a plurality of similar bridge circuits all of which have one leg in common, said common leg including the impedance portion of said first variable impedance device, each of said bridge circuits having another leg that includes an impedance portion of a second variable impedance device, each of said second variable impedance devices being capable of being connected to a different input signal.

7. A circuit for generating an output signal which can be expressed as a function of E_a/E_b where E_a and E_b are analog input signals fed to the circuit, said circuit including power supply means, a balanced bridge circuit having first and second impedance legs connected in series across said power supply means, and third and fourth impedance legs connected in series across said power supply, said third leg including first variable impedance means, and said fourth leg including second variable impedance means, first input means connected to said first variable impedance means including means for applying a portion of the input signal E_b thereacross, said first input means including first control means responsive to variations in the input signal E_b and including means for varying the impedance of said first variable impedance means in an inverse relationship to the variations of the input signal E_b so as to maintain the level of the input signal E_b applied to the first variable impedance means relatively constant, said variations in the impedance of said first variable impedance means causing an unbalanced impedance condition of said bridge circuit, second control means operatively connected to said

second variable impedance means to control the impedance thereof, said second control means including means responsive to unbalanced conditions that occur in said bridge circuit, said second control means including means for varying the impedance of said second variable impedance means due to imbalances in the bridge circuit in a direction to restore and maintain the bridge in a balanced condition, second bridge input means connected to the second variable impedance means including means for applying a portion of the input signal E_a thereacross, and output means connected across said second variable impedance means, an output signal being produced in the output means as a result of the bridge being maintained in a balanced condition, which output signal is a function of the ratio E_a/E_b of the input signals.

8. The circuit defined in claim 7 wherein said first and second variable impedance means are photoconductor devices each including an associated light source and light-responsive means, the impedance of said first and second variable impedance devices varying in an inverse relationship with the intensity of light produced by the associated light sources.

9. The circuit defined in claim 7 wherein said means responsive to unbalanced conditions that occur in said bridge circuit include direct-current amplifier means.

10. The circuit defined in claim 7 including means to prevent the input signals E_a and E_b from affecting said first and second bridge legs.

11. The circuit defined in claim 7 including means to prevent the input signals E_a and E_b from affecting the power supply.

12. The circuit defined in claim 7 wherein said first input means include an input terminal to which the input signal E_b is applied and an impedance member connected between said input terminal and said first variable impedance means.

13. The circuit defined in claim 7 wherein said first control means produces a direct-current output signal which varies with the variations in signal level detected across the first impedance means.

14. Means for generating signals which are functions of the ratios E_a/E_b and E_c/E_b of input signals E_a, E_b, and E_c including first and second balanced bridge circuits both of which have at least one bridge leg in common, divisor input means associated with the common bridge leg to which the input signal E_b is fed, said divisor input means including means in said common leg to unbalance said first and second bridge circuits in response to variations of the input signal E_b by producing changes in the impedance of the means in said common leg in an inverse relationship to changes of the input signal E_b, first variable impedance means connected in another leg of said first bridge circuit, second variable impedance means connected in another leg of said second bridge circuit, means connected to respond to unbalanced conditions produced in said first bridge circuit as a result of changes in the impedance of the common bridge leg, said last-named means including means to restore said first bridge circuit to a balanced condition by varying the impedance of said first variable impedance means, means connected to respond to unbalanced conditions produced in said second bridge circuit as a result of changes in the impedance of the common bridge leg, said last-named means including means to restore said second bridge circuit to a balanced condition by varying the impedance of said second variable impedance means, a first impedance member connected in series with said first variable impedance means, a second impedance member connected in series with said second variable impedance means, means for applying the input signal E_a across the series combination of said first impedance member and said first variable impedance means, means for applying said input signal E_c across the series combination of said second impedance member and said second variable impedance means, a first output signal which is a function of the ratio E_a/E_b of the input signals E_a and E_b being present across said first variable impedance means and a second output signal which is a function of the ratio E_c/E_b of the input signals E_c and E_b being present across said second variable impedance means.

15. Means for dividing a plurality of dividend input signals by a divisor input signal to produce a plurality of quotient output signals representing the ratio of each dividend input signal by the divisor input signal including a plurality of balanced bridge circuits all of which have one bridge leg in common, divisor input means connected in said common leg, means to vary the impedance of said common leg to unbalance the impedance characteristics of all of said plurality of bridge circuits simultaneously, said impedance varying means including means responsive to variations of the divisor input signal, a plurality of variable impedances each being connected respectively into another leg of each of said plurality of bridge circuits, means connected to each of said bridge circuits to respond to any unbalance of the associated bridge circuit, said last-named means including means for varying the impedances of said associated variable impedances to restore a balanced condition to each of said bridge circuits, a voltage divider circuit associated with each of said bridge circuits and formed in part by the associated variable impedance of said circuit dividend input means associated with each bridge circuit including means for applying an associated dividend input signal across each of the associated voltage divider circuits, a quotient output signal being produced across a portion of each respective voltage divider circuit, said quotient output signals in each of said bridge circuits being directly proportional to the associated dividend input signal and inversely proportional to the divisor input signal.

16. The means defined in claim 15 wherein said divisor input means include variable conductance means connected in said common bridge leg and control means associated with said variable conductance means, a portion of said divisor input signal being across said variable conductance means, said control means responding to variations in the portion of the divisor input signal across said variable conductance means and including means for varying the conductance of said variable conductance in a direction and in proportion to variations of the divisor input signal so as to maintain the potential across the variable conductance relatively constant.

17. Means for dividing a first signal into a second signal including a balanced bridge circuit, said bridge circuit including at least two bridge legs, first bridge input means to which the first signal is fed, said first bridge input means being connected in one of said bridge legs to unbalance said bridge circuit in response to changes in the first signal, voltage divider means including variable impedance means being connected in another of said legs of said bridge circuit, means connected to said bridge circuit and to said variable impedance means responsive to any unbalance in the bridge circuit due to changes in the first signal, said last-named means including means to rebalance the bridge by varying the impedance of said variable impedance means, said first input means including control means and photoconductor means, said photoconductor means being connected in said one leg of the bridge circuit, a portion of said first signal being applied across said photoconductor means, said control means including means to vary the conductance of the photoconductor means in response to the detected variations in a direction to maintain the potential across the photoconductor means relatively constant, said first signal including an AC component, and said control means including means connected to said photoconductor means to detect AC signals appearing thereacross and to generate therefrom variable DC signals, and a light source associated with said photoconductor means to which the variable DC signals are applied, the intensity of the light produced by said light source controlling the conductance of the photoconductor means, and second bridge input means connected to apply the second signal across said voltage divider means including said variable impedance means, an output signal being produced across a portion of said voltage divider means which is directly proportional to the second signal and inversely proportional to the first signal.

18. A circuit for generating an output signal which can be expressed as a function of E_a/E_b where E_a and E_b are analog input signals fed to the circuit, said circuit including power

supply means, a balanced bridge circuit having first and second impedance legs connected in series across said power supply means, and third and fourth impedance legs connected in series across said power supply, said third leg including first variable impedance means, and said fourth leg including second variable impedance means, first input means connected to said first variable impedance means including means for applying the input signal E_b thereto, said first input means including first control means responsive to variations in the input signal E_b and including means for varying the impedance of said first variable impedance means in inverse relationship to the variations of the input signal E_b so as to maintain the level of the input signal E_b applied to the first variable impedance means relatively constant, said variations in the impedance of said first variable impedance means causing an unbalanced condition of said bridge circuit, second control means operatively connected to said second variable impedance means to control the impedance thereof, said second control means including means responsive to unbalanced conditions that occur in said bridge circuit, said second control means including means for varying the impedance of said second variable impedance means in a direction to restore and maintain the bridge in a balanced condition, second bridge input means connected to the second variable impedance means including means for applying the input signal E_a thereto, and output means connected across said second variable impedance means, an output signal being produced in the output means as a result of the bridge being maintained in a balanced condition which is a function of the ratio E_a/E_b of the input signals, said first control means producing a direct current output signal which varies with the variations in signal level detected across the first impedance means, said first control means also including a charge storage device and an amplifier having relatively high input impedance characteristics

19. The circuit defined in claim 18 wherein the same means that produce a direct current signal include means connected to said high input impedance amplifier to rectify and filter outputs therefrom, a direct current amplifier connected to amplify the rectified and filtered outputs, and a light source connected to the output of the direct current amplifier, the intensity of the light produced by said light source varying with the output of the direct current amplifier and controlling the impedance of said first variable impedance means.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,624,378 Dated November 30, 1971

Inventor(s) Lloyd E. Brunkhorst

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

Column 1, line 55, "balances" should be "balanced".
Column 3, line 71, "it" should be "its".
Column 4, line 24, "the" (third occurrence) should be "to".
Column 8, line 56, after "to" insert "detect variations in the potential across said photoconductor means, said control means including means to".

Signed and sealed this 30th day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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