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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to electronic amplifiers

We, GEORGE A. PHILBRICK RESEARCHES INC., a Corporation organised and existing under the laws of the Commonwealth of Massachusetts, United States of America, of Allied Drive at Route 128, Dedham, Massachusetts, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to an electronic amplifier, in particular, to one commonly known as an operational amplifier.

The usefulness of an operational amplifier is well-known to those skilled in the art; typical applications include analog computation, instrumentation, and so forth. An operational amplifier is a high gain device able to operate with extremely low input signal voltages and currents to give a relatively high level voltage output accurately related to the input over a frequency range from D.C. to many kilocycles per second.

One of the most difficult problems in building a high gain amplifier with D.C. response and with high input impedance is to minimize "drift," that is, unwanted change in output voltage when the input voltage remains fixed. Drift is caused by the change in the operating characteristics of the elements of the amplifier circuit. These changes can be due to long term ageing or to variations in gain, resistance, capacitance, etc. of circuit components as a function of temperature.

To minimize drift, workers in the art have developed amplifiers which operate by modulating an alternating carrier voltage in accordance with a very low level D.C. voltage. The modulated carrier is then A.C. amplified and demodulated, that is, rectified, to give a high level D.C. output accurately proportional to the input.

One of the most effective of the modulating-type of amplifiers is that using a ring of four variable-capacity silicon diodes connected in a four terminal bridge arrangement. An A.C. modulating voltage is applied to one diagonal pair of terminals of the bridge and an A.C. output signal is obtained at the other pair of terminals. When the diodes are exactly matched in capacity, and assuming that the modulating signal is not great enough to cause any of the diodes to conduct in the forward direction, the output voltage will be exactly zero. By applying a very low level bias, in the form of an input signal, to the diodes, their capacities can be changed and the bridge unbalanced. This results in an A.C. voltage being produced across the output terminals of the bridge, the A.C. voltage being substantially exactly proportional to the input signal voltage over a wide range of operation.

Now, in order to achieve great accuracy in this type of amplifier, it is necessary to match as closely as possible to each other the four diodes with respect to their electrical characteristics, namely absolute capacity (by which is meant the measured capacity value) at a given temperature, change in capacity versus temperature, back resistance, and forward current versus voltage. Even assuming that the diodes of the bridge are of the same type and produced in the same lot, it is difficult if not impossible to select four that are precisely the same in all of these characteristics. For example, in any one batch of diodes having the same nominal capacity, i.e. the rated value of capacity at zero D.C. bias; the absolute value, i.e. the measured value of capacity, is often slightly different between one diode and another. Moreover, precise matching requires expensive testing.

[Price 4s. 6d.]

From one aspect, the present invention consists in an electronic amplifier arrangement including a modulating network comprising a single pair of matched variable-capacity semiconductors and a single capacitor having a value substantially twice the nominal capacity of one of said semiconductors, an electrode of one semiconductor being connected at a junction point to an opposite polarity electrode of the other semiconductor, first impedance means connected across said semiconductors, second impedance means, and said capacitor and said second impedance means being connected in series between said first impedance means and said junction point.

The present invention also consists in an electronic amplifier arrangement wherein an input carrier wave is modulated by a relatively low level input signal to give an output carrier wave having a modulated component proportional to the input signal but of a relatively much higher level, said arrangement including a modulating network comprising an input winding across which the input carrier wave is applied, a single pair of matched variable-capacity semiconductors connected together at a junction point and connected in series and with opposite polarity across said input winding, an output winding across which said output carrier wave is obtained, a single capacitor having a value substantially twice the nominal capacity of one of said semiconductors, said capacitor and said output winding being connected in series between said junction point and a point on said input winding, and means to apply said low level input signal to said semiconductors to vary their capacity.

Preferably the input winding is the secondary winding of a first transformer having a primary winding to which said carrier wave is applied, and the output winding is the primary winding of a second transformer having a secondary winding from which said modulated output carrier wave is obtained, said secondary winding of said first transformer being centre-tapped, and presenting a balanced impedance across itself, and said capacitor being connected to the centre tap on said secondary winding.

The present invention, by eliminating two of the four diodes previously required, considerably simplifies manufacturing procedures and at the same time reduces the cost of components. But also, because matching of one diode to only one other diode is now all that is needed, rather than the matching of one diode to three others, much greater accuracy and improved performance in circuit operation can be obtained.

In one specific embodiment of the invention, a single pair of variable-capacity silicon diodes is arranged in an unsymmetrical network. A carrier voltage is applied to the diodes from the low impedance side of a step-down first transformer, which in turn is connected to the output of a high frequency oscillator. A modulated output voltage is obtained from the network through a second transformer, the output from which is A.C. amplified and demodulated to obtain a high level D.C. voltage output proportional to the input signal voltage. This signal voltage is applied to the network at respective centre taps on the appropriate windings of the input and output transformers.

The arrangement of this circuit makes possible extremely high impedance isolation of the input signal terminals from the remainder of the circuit, moreover unwanted feedthrough or stray pickup from the oscillator is minimized. The circuit has improved common mode noise cancellation, higher signal to noise ratio, and much better stability than previously known circuits. For example, in comparison with one of the best, four diode circuits of the prior art, the circuit of the present invention has, in its practical embodiment, at least ten times greater signal sensitivity (for a given degree of accuracy), and at least five times better temperature stability, in spite of the fact that the present circuit is less expensive to manufacture.

In order that the invention may be more readily understood, reference will now be made to the accompanying drawing which shows an electrical circuit embodying the invention.

The amplifier circuit 10 shown in the drawing comprises a diode and transformer arrangement, generally indicated at 12, a carrier voltage oscillator 14, and an A.C. amplifier-demodulator 16. The latter produces a direct output voltage at a pair of terminals 17. Oscillator 14 and the amplifier-demodulator 16 can be like ones known in the art and will not be described in greater detail.

The diode and transformer arrangement 12 has a pair of input signal terminals 18, one of which connects to a transformer secondary winding 20, and the other to a transformer primary winding 22. Winding 20 is the low impedance secondary of a transformer 24, and winding 22 is the primary of a transformer 26. These transformers, which will be described shortly, provide very high impedance isolation of the signal terminals from circuit ground.

Connected to the upper end of winding 20 is a first diode 30 and connected to the lower end, is a second diode 32. These two diodes are of the variable-capacity silicon type, carefully matched as explained above. They are poled as shown, with the cathode of diode 30 being connected to the anode of diode 32. This common point is connected to the lower end of winding 22, the upper end of which is connected by a capacitor 34 to the center tap of winding 20. The capacity of capacitor 34 is twice the nominal capacity (as hereinbefore defined) of diode 30 or diode 32. These elements form an unsymmetrical bridge-like network (although not a true "bridge"), which is balanced at the carrier frequency for zero input signal at terminals 18 and which, by shifting the absolute value of capacity (as hereinbefore defined) of diodes 30 and 32 by means of the input signal, becomes unbalanced in proportion to the amplitude of the input signal. The use of a single capacitor here eliminates the difficulty of using additional diodes or an additional capacitor. Capacitor 34 is selected from a type having great temperature stability.

Transformer 24 has a primary winding 36, the centre tap of which is grounded; the turns ratio of primary to secondary is, for example, eight to one. This transformer has a small toroidal ferrite core with winding 20 comprising one turn of a bifilar winding on one side of the core, and winding 36 comprising N turns on the opposite side of the core. Thus the windings have low capacity between them, and winding 20 presents a very low, balanced impedance across itself.

Primary winding 36 is connected to a secondary winding 40 of a transformer 42 which has a primary winding 44. The latter is connected to the balanced output of oscillator 14. Transformer 42 is substantially identical to transformer 24 and is physically isolated from it by the lead connections between secondary 40 and primary 36. Thus stray pickup from the oscillator is minimized.

Transformer 26 has a secondary winding 46, the centre tap of which is connected via a small inductor 48 to ground. Winding 46 is shunted by a small trimmer capacitor 50; the upper end of the winding is connected via a coupling capacitor 52 to amplifier-demodulator 16. Transformer 26 is similar to transformer 24 except that a one-to-one turns ratio is used.

In order to cancel out residual and unbalanced stray errors in the output signal on secondary winding 46 of transformer 26, there is connected between this winding and the primary 36 of transformer 24 an adjustable balancing network generally indicated at 60. This includes a potentiometer 62 connected in parallel across primary 36 and having an adjustable centre tap 64 connected to the centre tap of secondary 46. Network 60 also includes four small capacitors 66, 67, 68 and 69, of equal size and which are connected in series with each other and across primary 36. Connected in shunt across capacitors 67 and 68 is an adjustable trimmer capacitor 70 having a grounded centre tap 72. The junction of capacitors 67 and 68 is connected via a lead 74 to the lower side of secondary winding 46.

In a circuit substantially identical to the one described herein which has been built and successfully operated, oscillator 14 operated at 5 mc. and gave an output of roughly 7 volts. Demodulator 16 was a synchronous rectifier preceded by an A.C. amplifier and followed by a high level D.C. amplifier. An input signal of 0.2 millivolt applied to terminals 18 produced an output voltage of about 10 volts. The input impedance of the circuit is thousands of megohms.

WHAT WE CLAIM IS:—

1. An electronic amplifier arrangement including a modulating network comprising a single pair of matched variable-capacity semiconductors and a single capacitor having a value substantially twice the nominal capacity of one of said semiconductors, an electrode of one semiconductor being connected at a junction point to an opposite polarity electrode of the other semiconductor, first impedance means connected across said semiconductors, second impedance means, and said capacitor and said second impedance means being connected in series between said first impedance means and said junction point.

2. An electronic amplifier arrangement wherein an input carrier wave is modulated by a relatively low level input signal to give an output carrier wave having a modulated component proportional to the input signal but of a relatively much higher level, said arrangement including a modulating network comprising an input winding across which the input carrier wave is applied, a single pair of matched variable-capacity semiconductors connected together at a junction point and connected in series and with opposite polarity across said input winding, an output winding across which said output carrier wave is obtained, a single capacitor having a value substantially twice the nominal capacity of one of said semiconductors, said capacitor and said output winding being connected in series between said junction point and a point on said input winding, and means to apply said low level input signal to said semiconductors to vary their capacity.

3. An electronic amplifier arrangement as claimed in claim 2, wherein the input winding is the secondary winding of a first transformer having a primary winding to which said carrier wave is applied, and the output winding is the primary winding of a second transformer having a secondary

winding from which said modulated output carrier wave is obtained, said secondary winding of said first transformer being centre-tapped, and presenting a balanced impedance across itself, and said capacitor being connected to the centre tap on said secondary winding.

4. An electronic amplifier arrangement as claimed in claim 3, wherein said primary winding of said second transformer is centre-tapped and said low level input signal is applied between said centre-taps.

5. An electronic amplifier arrangement as claimed in claim 3 or 4, including oscillator means for generating said carrier wave connected to the primary winding of said first transformer.

6. An electronic amplifier arrangement as claimed in claim 5, wherein said oscillator means is connected through a third transformer to the primary winding of said first transformer, said first and third transformers having step-down ratios from primary to secondary and being physically isolated from each other so as to reduce unwanted pick up from said oscillator means.

7. An electronic amplifier arrangement as claimed in claim 6, wherein said first and second transformers have bifilar windings in order to reduce the capacity between the windings.

8. An electronic amplifier arrangement as claimed in any of the preceding claims 3 to 7, wherein said transformers each have a toroidal magnetic core and have their primary and secondary windings wound respectively on opposite sides of the core.

9. An electronic amplifier arrangement as claimed in any of the preceding claims 3 to 7, including an adjustable resistor capacitor balancing network connected between the secondary of said second transformer and the primary of said first transformer.

10. An electronic amplifier arrangement as claimed in any of the preceding claims 2 to 9, wherein for zero input signal, said network is substantially balanced at the frequency of said carrier wave and allows substantially no carrier wave at said output winding, and for an increase in said input signal allows proportionally more and more carrier wave at said output winding.

11. An electronic amplifier arrangement as claimed in any preceding claim, wherein said variable capacity semiconductors are variable-capacity semiconductor diodes.

12. An electronic amplifier arrangement substantially as hereinbefore described with reference to the accompanying drawing.

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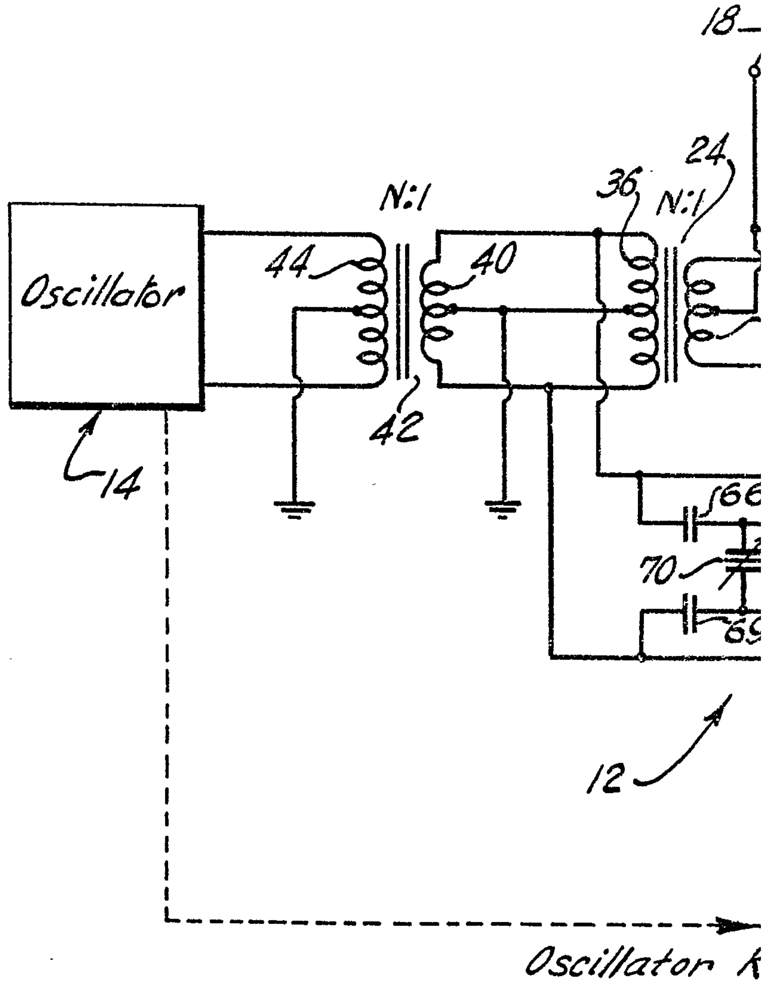
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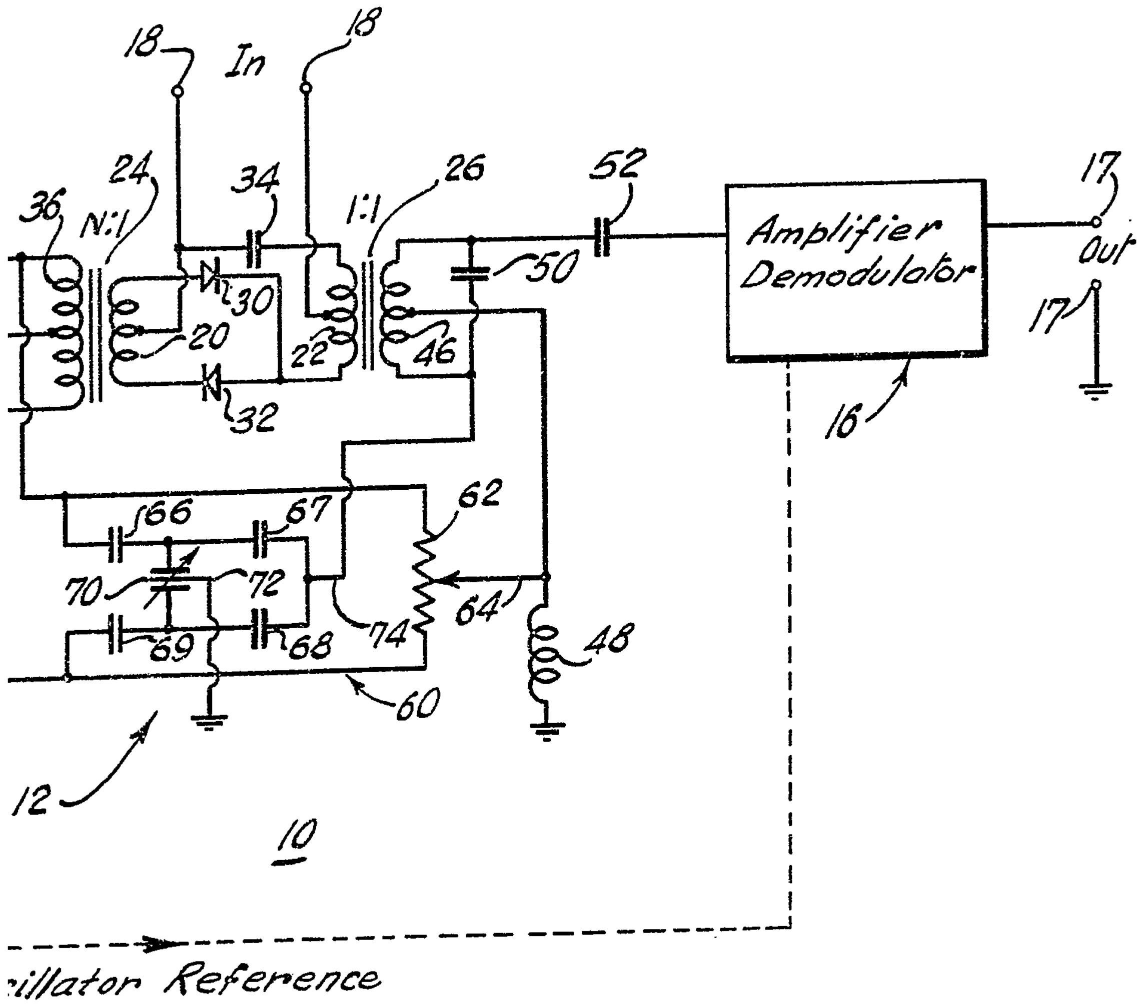
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illator Reference

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.