Kollsman Instrument Corporation 575 UNDERHILL BOULEVARD, SYOSSET, N. Y. 11791

14 September 1967

Mr. James J. Collins

Mr. Norman J. Lindner

Gentlemen:

Patent No. 3,339, 147 has just been issued by the United States Government to Kollsman Instrument Corporation. Copies of this patent are attached for your personal files. It should be noted that while Kollsman owns the patent, your names as inventors appear thereon.

It is with a great deal of pleasure that, on behalf of the President, a copy is forwarded to each of you, for it is through the efforts of engineers such as yourselves that Kollsman will continue to grow and maintain its position in the forefront of our industry.

Mr. Nichinson has directed that a copy of this letter be placed in your personnel folders, for we are sure that all levels of management are interested in knowing of your achievement on behalf of the company.

Sincerely yours,

FOR THE PRESIDENT

Lee B. Ledford

LBL:bb
Attach.

cc: Personnel File: Mr. J. J. Collins
Mr. N. J. Lindner

A-C AMPLIFIER LINEARLY CONTROLLED BY A D-C SIGNAL

Filed Jan. 14, 1965

FIG. 1

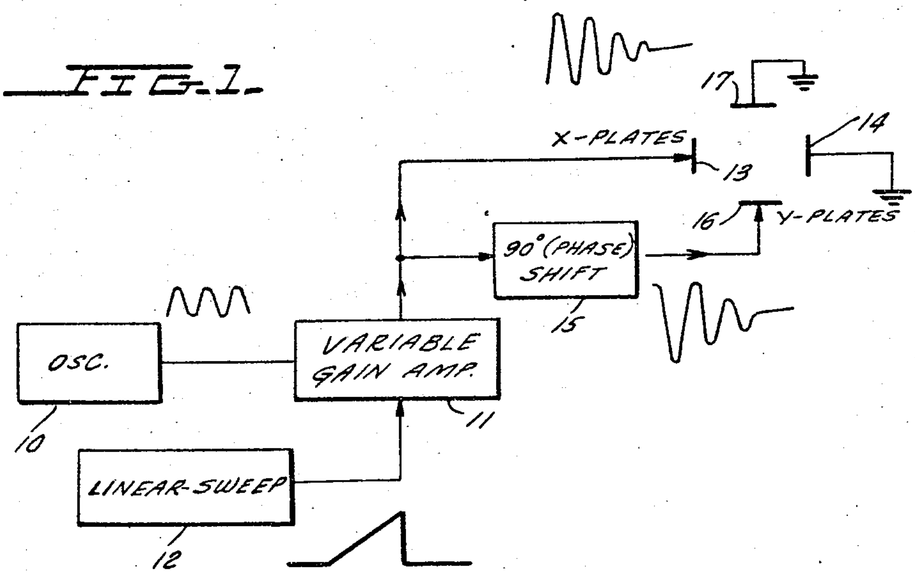
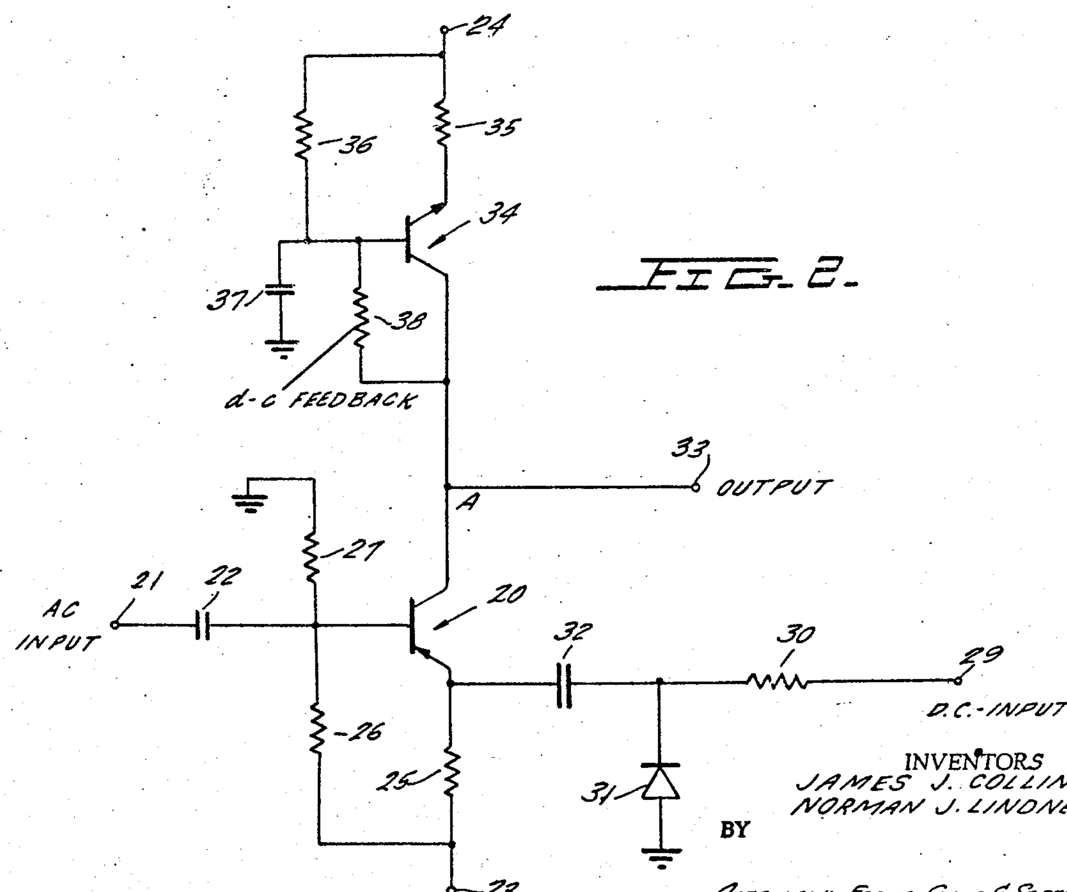


FIG. 2



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A-C AMPLIFIER LINEARLY CONTROLLED BY A D-C SIGNAL

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ABSTRACT OF THE DISCLOSURE

An A-C transistor amplifier having a forward biased diode in the emitter circuit which is connected to a variable input to alter the dynamic impedance of the diode and thus the impedance of the emitter circuit to control the gain of the amplifier. The output circuit, connected to the transistor collector, includes a second transistor which forms a high A-C collector impedance, and a low D-C collector impedance for the A-C amplifier stage. The second transistor contains a feedback resistor in its collector-base circuit.

This invention relates to A-C amplifiers, and more specifically relates to a novel A-C amplifier construction whose gain is linearly controlled by an input D-C signal which controls the dynamic impedance of a diode in the emitter circuit of a transistor in the amplifier stage.

In addition, a novel artificial load circuit is provided in the transistor collector circuit which provides a high A-C collector impedance, and a low D-C collector impedance for the transistor amplifier stage.

There are many applications which require the gain of an A-C amplifier to be controlled in a linear fashion from D-C input signal. By way of example, and in order to generate a spiral scan for a cathode ray tube or for use in various types of tracking equipment, it is possible to connect an oscillator through a variable gain amplifier so that one pair of C.R.T. plates is connected to the oscillator signal, while the other pair of plates is conected to the same oscillator signal which is phase shifted by 90° from that applied to the first pair of plates.

Where the amplitude of this common frequency signal applied to both pairs of plates is equal, a perfect circle will be generated. If now, the variable gain amplifier is connected to a suitable linear sweep means, the amplitude of the circle can be constantly varied so that the resulting generated pattern will be a spiral.

The present invention relates to a particular novel A-C amplifier wherein the gain of the amplifier is linear with an input D-C signal. Therefore, in the previously noted application of the amplifier, if a saw-tooth voltage is used for the linear sweep, the resulting pattern generated will be a mathematically perfect spiral.

The novel A–C amplifier of the invention is provided with a transistor amplification stage wherein the emitter base circuit includes a forward biased diode therein connected to the input D-C source. It has been found that by varying the D-C input to the diode, the A-C impedance thereof will inversely vary with the bias over a large range. The bad impedance in the transistor collector circuit is then caused to remain relatively constant by other novel circuit means, whereupon the gain of the transistor amplifier will vary linearly with the input D-C current over a large range.

Accordingly, a primary object of this invention is to provide a novel A-C amplifier circuit whose gain varies linearly with an input D-C current.

Yet another object of this invention is to provide a novel A-C transistor amplifier which uses a forward biased diode in the emitter circuit thereof.

Still another object of this invention is to provide a

novel A-C amplifier which has a variable gain which is linear with an input D-C current wherein the resistance in the emitter circuit of a transistor used as the amplifier element varies linearly with the impressed D-C current, while the resistance in the collector circuit of the transistor is held relatively constant.

Still another object of this invention is to provide a novel amplifier circuit used in the generation of spiral patterns.

These and other objects of this invention will become apparent from the following description when taken in connection with the drawings, in which:

FIGURE 1 schematically illustrates a spiral scanning generator which uses a variable gain amplifier which is linearly controlled.

FIGURE 2 is a circuit diagram of the novel amplifier used in FIGURE 1 in accordance with the invention.

Referring first to FIGURE 1, we have illustrated therein a novel spiral generator wherein an oscillator **10** is connected to the input terminals of a variable gain amplifier **11**. A linear sweep generator **12** which generates a repetitive saw-tooth pattern, as illustrated adajacent linear sweep generator **12**, is then connected to other input terminals of the variable gain amplifier. The output terminals of the variable gain amplifier are then connected directly across a first set of deflection plates **13** and **14** of some suitable display means such as a cathode ray tube or any other similar type apparatus which electrostatically modulates the position of an electrical charge.

The output of amplifier **11** is further connected through a 90° phase shift network **15** to deflection plates **16** and **17** which creates an electrostatic field perpendicular to the field of plates **13** and **14**. When the amplitude of the signals applied to plates **13–14** and **16–17** is equal, it is well known that the charge medium controlled by these plates will be caused to execute a circular deflection.

In accordance with the invention, the variable gain amplifier **11** has the gain thereof linearly and repetitively changed as a function of time by means of the linear sweep generator **12** whereupon the amplitude of the signal applied to plates **13, 14, 16** and **17** will repetitively increase, thus repetitively increasing the diameter of the circuit generated thereby, whereupon the resulting pattern formed will be a spiral.

FIGURE 2 illustrates a circuit diagram of the variable gain amplifier **11** of FIGURE 1. Thus, in FIGURE 2, the amplifier is comprised of a transistor **20** which has an A-C input terminal **21** coupled to the base thereof through a coupling capacitor **22**. The terminal **21** in FIGURE 2 is equivalent to the input circuit from oscillator **10** in FIGURE 1.

A biasing voltage source is then provided at terminals **23** and **24** which could, for example, apply +12 volts with respect to ground to terminal **23** and −12 volts with respect to ground at terminal **24**. Suitable biasing resistors **25, 26** and **27** are then provided in the usual manner. Biasing resistor **25** may be a 5K resistor.

A D-C input terminal **29** which is equivalent to the input from linear sweep generator **12** in FIGURE 1 is then connected through a 27K resistor **30**, and forward biases a diode **31** which is connected to ground. Resistor **30** is also connected through a blocking condenser **32** to the emitter circuit of transistor **20**. Transistor **20** is then connected to an output terminal **33** which is equivalent to the output circuit of variable gain amplifier **11** in FIGURE 1 leading to deflection plates **13, 14, 16** and **17**.

In addition to this, the collector circuit of transistor **20** includes a high A-C impedance-low D-C load impedance circuit which includes transistor **34** having an emitter resistor **35** connected to terminal **24** and a 22K emitter base resistor **36** connected to a capacitor **37** and a D-C feedback resistor **38** which could be 22K.

The following is a list of components that have given satisfactory operation for the circuit.

Transistor 20		Type No. 2N404
Transistor 34		Type No. 2N1304
Capacitor 22	microfarads	10
Capacitor 32	do	40
Capacitor 37	do	10
Resistor 25		5.1K
Resistor 26		22K
Resistor 27		9.1K
Resistor 30		27K
Resistor 35		1K
Resistor 36		22K
Resistor 38		22K

The principle of operation of the circuit shown in FIGURE 2 involves the fact that the dynamic impedance of diode **31** changes inversely with the D-C current applied to terminal **29** over a large range. The gain of the amplifier transistor **20** is equal to the ratio of the collector circuit resistance to the emitter circuit resistance.

In the circuit of FIGURE 2, the emitter resistor **25** is used as a D-C bias for the stage. However, for A-C gain considerations, the effective emitter resistance is the resistance of resistor **25** in parallel with the dynamic resistance of diode **31**. This dynamic resistance or A-C impedance can be controlled from 27K which is the value of resistor **30**, assuming that the impedance of diode **31** is infinite, down to as low as 20 ohms by changing the reverse current through diode **31**. Therefore, when the collector load resistance is fixed, it will be apparent that gain can be linearly controlled over a very large dynamic range by varying the D-C voltage at terminal **29**.

The collector load resistance circuit is held relatively constant by the novel use of the transistor circuit including transistor **34**. Thus, transistor **34** performs two functions. It first serves as a very low D-C impedance which is necessary for biasing considerations which will hereinafter be discussed, and at the same time, it will have a very high equivalent A-C impedance which is necessary for a large dynamic range. This is accomplished by using a D-C feedback circuit which includes resistor **38** and an A-C by-pass which includes capacitor **37**. Thus, the D-C feedback resistor **38** will fix the D-C voltage appearing at point A so that point A is caused to appear as a voltage source which has a low D-C impedance. The capacitor **37** then forms an A-C short circuit on the base of transistor **34** which will prevent any A-C signal from being fed back through transistor **34**. The resistor **38** will also appear as the A-C load in the collector circuit of transistor **20** and thus forms the required high A-C impedance in this collector circuit.

The need of a low D-C collector resistance and high A-C impedance for transistor **20** is that the D-C current through diode **31** will determine its dynamic impedance, while the A-C current through diode **31** will determine the stage gain. Therefore, it is necessary that the A-C current be smaller than the D-C current to prevent unwanted interaction which would degenerate the linearity of the amplifier.

Since the A-C current through diode **31** must be small, the A-C collector resistance in the transistor must be correspondingly large to give a sufficient voltage swing. At the same time, and if a large resisto. is placed in the collector circuit, this would make bia.ing very difficult, if not impossible.

A close examination of FIGURE 2 reveals that there is in fact another diode in series with the control diode **31** which is defined by the base-to-emi.ter diode junction of transistor **20**. To insure that the gain of transistor **20** is controlled only by the current through diode **31**, it is necessary that the impedance of this transistor junction be as small as possible. This is accomplished by having a large D-C current flow through the base-to-emitter diode junction of transistor **20**. The equivalent diode impedance of this transistor diode is given by $25/I_{dc}$ in milliamperes, where I_{dc} is the current through the base-to-emitter junction.

In order to guarantee sufficient D-C current flow, the second requirement mentioned above of low D-C impedance occurs. Thus, the resistance of diode **31** is approximately equal to $25k/I_{dc}$ where k varies from 1 to 2 for silicon and is about 1 for germanium.

Therefore, the instantaneous voltage gain at point A will be equal to

$$\frac{R_c}{R_e}=\frac{R_c}{R_{\text{diode 31}}}=\frac{R_c}{25k}I_{dc}$$

where R_c is the impedance of the collector circuit connected to the collector of transistor **20** and R_e is the emitter resistance of transistor **20**.

It will, therefore, be apparent that the voltage at point A will be linearly related to the D-C current applied at terminal **29**.

Although this invention has been described with respect to its preferred embodiments, it should be understood that many variations and modifications will now be obvious to those skilled in the art, and it is preferred, therefore, that the scope of the invention be limited not by the specific disclosure herein but only by the appended claim.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

An A-C amplifier having a linear gain comprising a first transistor having a base, emitter, and collector electrode, an A-C input circuit connected to said base electrode, a variable D-C input circuit connected to said emitter electrode for controlling the gain of said first transistor, and an output circuit connected to said collector electrode; said D-C input circuit including a forward biased diode in series with the emitter-base circuit of said first transistor; the dynamic impedance of said forward biased diode being inversely related to the D-C current of said D-C input circuit whereupon the gain of said first transistor is linearly related to the D-C current of said D-C input circuit; and a second transistor for forming an impedance in the collector circuit of said first transistor having a low D-C impedance and a high A-C impedance; said second transistor having second base, emitter and collector electrodes; said collector electrode of said first transistor directly connected to said collector electrode of said second transistor; said second transistor base to collector circuit having a feedback resistor connected thereacross; said second base electrode having a capacitor connected thereto and extending to said base electrode of said transistor; and biasing circuit means connected in series with said emitter and collector electrodes of said first and second transistors.

References Cited

UNITED STATES PATENTS

3,023,369	2/1962	Horowitz	330—145 X
3,223,937	12/1965	McDonald	330—29 X

FOREIGN PATENTS

852,059	10/1960	Great Britain.
853,870	11/1960	Great Britain.

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