United States Patent

Haigh

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[54] **COMPRESSION/EXPANSION TECHNIQUES FOR TIME VARYING SIGNALS**

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[52] **U.S. Cl.** **328/145,** 307/229, 328/128, 328/145, 333/14

[51] **Int. Cl.**.....**H03b 3/02**

[58] **Field of Search**.....328/127, 128, 142, 145; 333/14; 307/229, 230, 264

[56] **References Cited**

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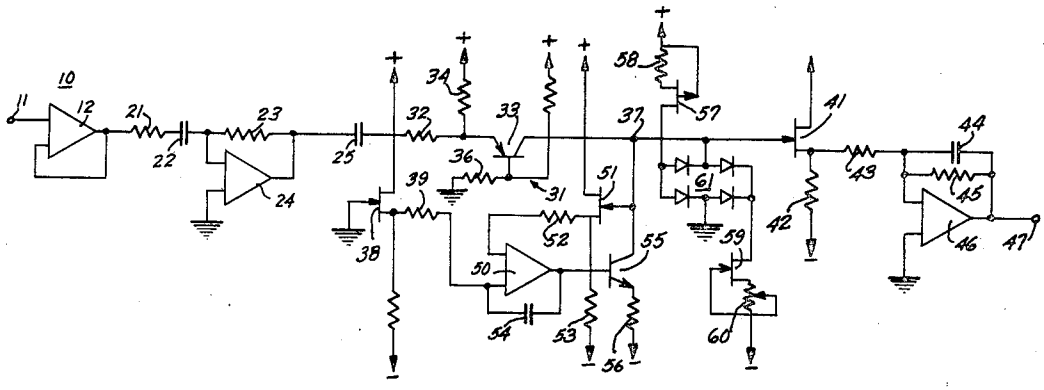
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[57] **ABSTRACT**

A signal translation circuit includes a buffer amplifier which feeds a differentiator to provide for a signal $f(t)$, the function $d\,f(t)$ to present to a bipolar AC log amplifier to change the waveform to log $[d\,f(t)/dt$. An integrator is then provided to restore the signal to its input waveform and at an amplitude which is the log of the amplitude of the original waveform.

7 Claims, 4 Drawing Figures



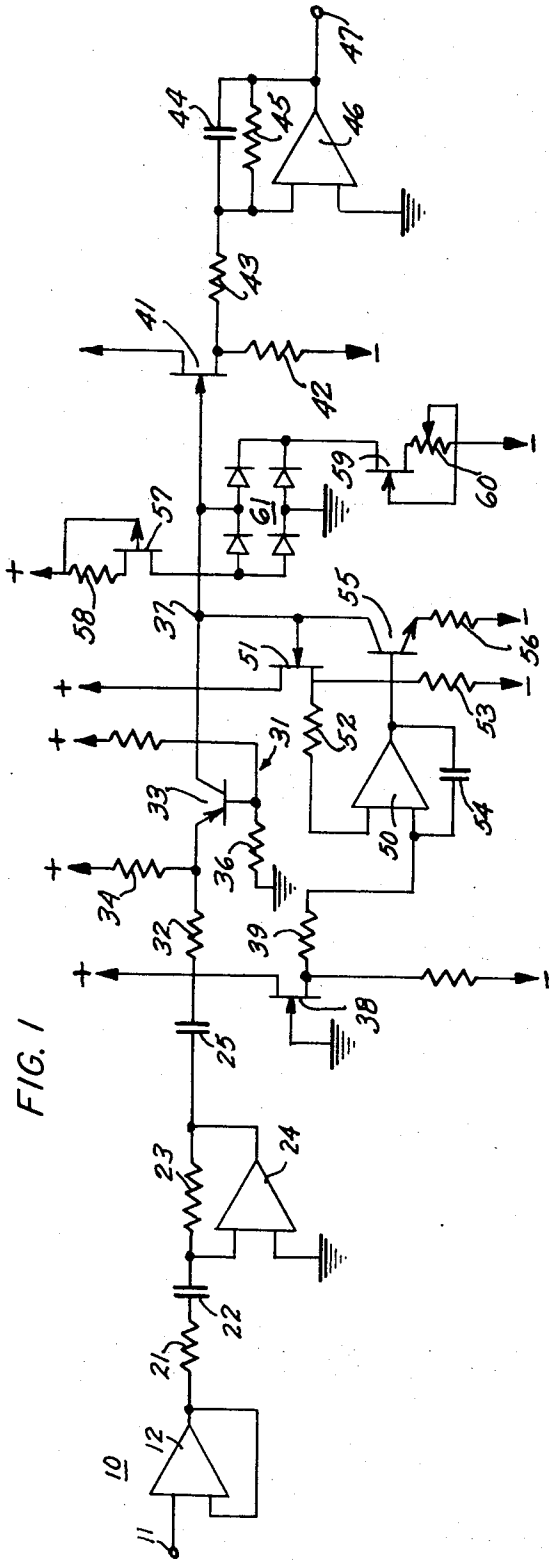


FIG. 1



FIG. 2a



FIG. 2b



FIG. 2c

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COMPRESSION/EXPANSION TECHNIQUES FOR TIME VARYING SIGNALS

This invention relates to compression/expansion techniques, and is particularly concerned with a circuit for providing a logarithmic compression of an input signal.

Heretofore, non-linear signal translation circuits have been advantageously utilized in many areas, for example in signal transmission systems. These circuits have suffered from various drawbacks including degradation of the waveform in order to obtain the desired compression or expansion, particularly in the generation of second harmonics, the necessity for a relatively large amount of equipment with the attendant disadvantage of requiring a great amount of space such as in radio broadcasting systems, and excessive delays resulting in poor signal attack.

It is therefore the primary object of this invention to overcome the aforementioned disadvantages and to provide a new and improved non-linear signal translation circuit.

Another object of the invention is to provide a non-linear signal translation circuit having zero attack time and which effects faithful reproduction of the input waveform.

The foregoing and other objectives of the invention are achieved through the provision of a non-linear signal translation circuit which includes means for differentiating the input signal waveform, means for varying the amplitude of the differentiated signals in accordance with a predetermined non-linear function, and means for integrating the differentiated and non-linearly varied signals to provide an output signal having an amplitude which is related to the amplitude of the input signal in accordance with the non-linear function and the same waveform as the input signal whereby total signal reproduction is faithfully effected.

In a particular embodiment disclosed herein, a bipolar AC log amplifier is provided to accomplish the non-linear variation of the differentiated waveform. Although other non-linear circuits may be employed in practicing the invention to achieve a desired result in accordance with desired objectives, the bipolar AC log amplifier is disclosed herein because of its unique applicability for use in particle pulse analysis. For example, the apparatus disclosed herein could be advantageously employed in the particle analysis apparatus disclosed in Berg et al U.S. Pat. application Ser. No. 28,703, now U.S. Pat. No. 3,626,166, filed Apr. 15, 1970. The apparatus of the Berg et al system employs a linear amplifier followed by a logarithmic converter in order to achieve data for a logarithmic presentation of particle population over a wide range of particle sizes. Apparatus constructed in accordance with the principles of the instant invention may advantageously be utilized in the Berg et al system, as well as in other areas such as radio broadcasting, telephonic signal transmission and record production systems.

Other objects, features and advantages of the invention, its organization, construction and operation will be best understood from the following detailed description of a preferred embodiment thereof taken in conjunction with the accompanying single sheet of drawing, in which:

FIG. 1 is a schematic circuit diagram of a logarithmic compression circuit constructed in accordance with the principles of the present invention; and

FIGS. 2*a* - 2*c* is a graphical presentation of a logarithmic conversion performed in accordance with the principles of the present invention wherein FIG. 2*a* is a waveform of the function A $f(t)$ having an amplitude A_1, FIG. 2*b* illustrates a differentiation of the waveform of FIG. 2*a*, and FIG. 2*c* is the integrated waveform of FIG. 2*b* having an amplitude A which is equal to log A_1 and which has the same waveform as that of FIG. 2*a*.

Referring to the drawing, the circuit of FIG. 1 is generally seen to comprise an input buffer amplifier 10, a differentiator 20, a bipolar AC log amplifier 30, and an integrator 40.

The input buffer amplifier 10 comprises an input terminal 11 for receiving the signal $f(t)$ and an operational amplifier 12 for improved impedance matching purposes.

The differentiator 20 comprises a first resistor 21 connected between the output of the amplifier 12 and a differentiator capacitor 22, which in turn is connected to the (−) input of an operational amplifier 24 having its (+) input connected to ground. A differentiator resistor 23 is connected to the capacitor 22 and further between the output and the (−) input of the operational amplifier 24.

A capacitor 25 couples the differentiator circuit 20 to the bipolar AC log amplifier 30 which comprises a common base amplifier 31 including an input resistor 32 connected to the emitter of a transistor 33. The emitter is further connected to a potential +V by way of a resistor 34. The base of the transistor 33 is connected in a voltage divider circuit between the supply +V and ground by way of a pair of resistors 35, 36. The collector of the transistor 33 is connected to a point 37 which serves as the output terminal for the circuit, and which will be discussed in greater detail below.

A field effect transistor 38 has its emitter connected to ground, a second electrode connected to the supply +V and a third electrode connected to a supply −V by way of a resistor. Another resistor 39 is connected to the third electrode for coupling a reference signal to the (−) input of an operational amplifier 50 having a capacitor 54 connected between that input and its output to reduce the gain thereof to zero for alternating current.

A second field effect transistor has its emitter connected to the point 37, a first electrode connected to the supply +V, and a third electrode connected by way of a resistor 53 to the supply −V. Another resistor 52 is provided to couple the third electrode of the transistor 51 to the (+) input of the operational amplifier 50.

The output of the operational amplifier 50 is connected to the base of a transistor 55 which has its emitter connected to the −V supply by way of a resistor 56 and its collector connected to the point 37. The transistors 38, 51 and 55 and the operational amplifier 50 and their associated components maintain the point 37 at zero volts DC. The alternating voltage variations at point 37 are compared with the reference signal derived by way of the transistor 38, whereby the operational amplifier 50 and the transistor 55 function as a DC source and an AC generator to maintain the point

37 at zero volts DC whereby the alternating signal operates about the zero volt DC level.

The bipolar AC log amplifier 30 further includes a constant current source comprising a field effect transistor 57 and its associated resistor 58, and a field effect transistor 59 and its associated potentiometer 60 which constitutes a logarithmic balance adjustment. Connected in circuit with the last-mentioned elements and between the supply potentials of +V and −V is a set of matched diodes 61 which are provided by way of point 37 with a zero volt DC potential across two of the bridge terminals thereof whereby any varying signal is provided with alternate paths for traversing the set of diodes 61. The diodes are a matched set, as mentioned above, and are selected for a characteristic whereby the voltage across a diode is proportional to the log of the current through the diode. The direct current at point 37 is utilized to vary the otherwise constant current of the diode circuit to provide a logarithmic response in the voltage.

During operation, the current at point 37 is proportional to the voltage at the output of the differentiator 20. With this current applied to the diodes and with the voltage of a diode proportional to the log of the current through a diode, it is readily seen that the voltage at the point 37 is proportional to the log of the voltage at the output of the differentiator 20.

In view of the foregoing, the signal applied to the integrator 40 is proportional to the log of the signal provided by the differentiator. The integrator 40 comprises a field effect transistor 41 having an emitter connected to the point 37, a second electrode connected to the supply +V and a third electrode connected by way of a resistor 42 to the supply −V. An operational amplifier 46 has an output 47 which serves as the output terminal for the apparatus an is provided with a capacitor 44 and a resistor 45 connected in parallel across the input (−) and output terminals of the operational amplifier 46. The (+) terminal of the operational amplifier 46 is connected to ground and a coupling resistor 43 is provided to connect the operational amplifier to the third electrode of the transistor 41. The capacitor 44 and the resistor 43 are provided to effect the integration function in combination with the operation amplifier 46.

Although I have described my invention by reference to a particular illustrative embodiment thereof, such has been done as a means of non-limitive illustration. Other circuits may be employed to accomplish nonlinear amplitude variation of the waveform in combination with the general principles of utilizing such a circuit between differentiation and integration stages. The foregoing apparatus provides zero attack time and faithful reproduction of the input waveform by preventing the elimination of complex waveforms which may occur within a given signal, and by looking "forward" with respect to the input wave by differentiation and then looking "backward" with respect to the wave by integration.

Many other changes and modifications of the invention may become apparent to those skilled in the art without departing from the spirit and scope of the invention and it is to be understood that I intend to include within the patent warranted hereon all such changes and modifications as may reasonably and properly be included within the scope of my contribution to the art.

I claim as my invention:

1. A nonlinear signal translation circuit comprising:
means for receiving signals;
means for differentiating the received signals;
nonlinear circuit means for instantaneous transformation of the amplitude of the differentiated signals to vary the amplitude thereof including bipolar AC log amplifier means for providing the log of the differentiated signals, said log amplifier means comprising a constant current source, matched diodes having a log characteristic connected in circuit with said constant current source, and means connected to said diodes for receiving the differentiated signals and operable in response thereto to maintain the connection point with said diodes at zero volts DC; and
means for integrating the transformed signals to obtain the same received waveform at a different amplitude.

2. The circuit according to claim 1, wherein the last-mentioned means includes a first amplifier connected between said differentiator means and said point, means for sensing the current at said point, means for comparing the sensed current to a reference including a second amplifier having a zero gain for alternating current coupled back to said point to effect AC signal generation.

3. The circuit according to claim 1, wherein said diodes comprise a diode bridge having first terminals connected in circuit with said constant current source and a second pair of terminals connecting said bridge across said point and a reference potential.

4. A nonlinear signal translation circuit comprising:
means for receiving signals;
means for differentiating the received signals;
nonlinear circuit means for instantaneous transformation of the amplitude of the differentiated signals to vary the amplitude thereof including bipolar AC log amplifier means for providing the log of the differentiated signals, said log amplifier means comprising a constant current source, a plurality of matched nonlinear impedances having a log characteristic connected in circuit with said constant current source, and means connected to said nonlinear impedances for receiving the differentiated signals and operable in response thereto to maintain the connection point with said nonlinear impedances at zero volts DC; and
means for integrating the transformed signals to obtain the same received waveform at a different amplitude.

5. The circuit according to claim 4, wherein said means for receiving signals includes a buffer amplifier.

6. The circuit according to claim 4, wherein said differentiator means includes an operational amplifier, a capacitor coupled between said operational amplifier and said means for receiving signals and a feedback resistor connected across said operational amplifier and to said capacitor.

7. The circuit according to claim 4, wherein said means for integrating comprises an operational amplifier having a feedback capacitor connected thereacross, a resistor connected to said capacitor and to said

operational amplifier, and an amplifier connected between said nonlinear means and said resistor.

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