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[54] **PARTICLE PULSE ANALYZING APPARATUS
 EMPLOYING LINEAR AMPLIFICATION AND
 LOGARITHMIC CONVERSION**
 10 Claims, 3 Drawing Figs.

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 G06g 7/24
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 129-130, 138, 140; 307/230, 235-237, 229;
 328/145, 150; 250/201, 218-219; 324/71 CP

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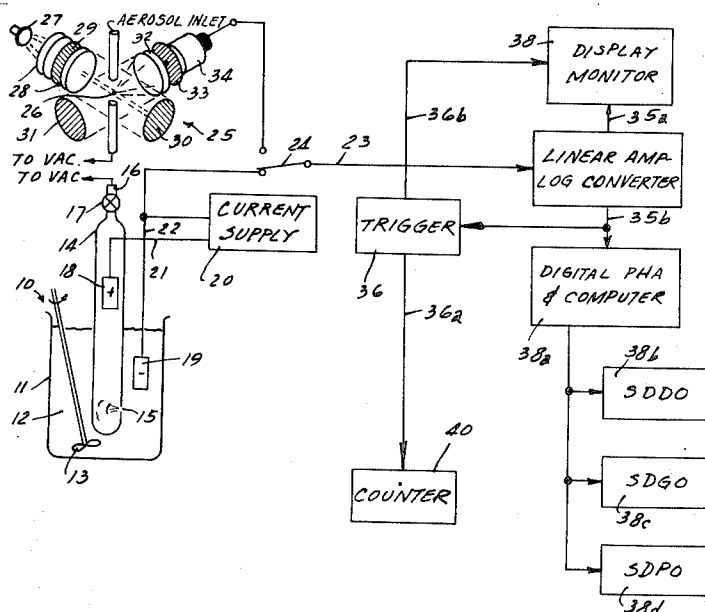
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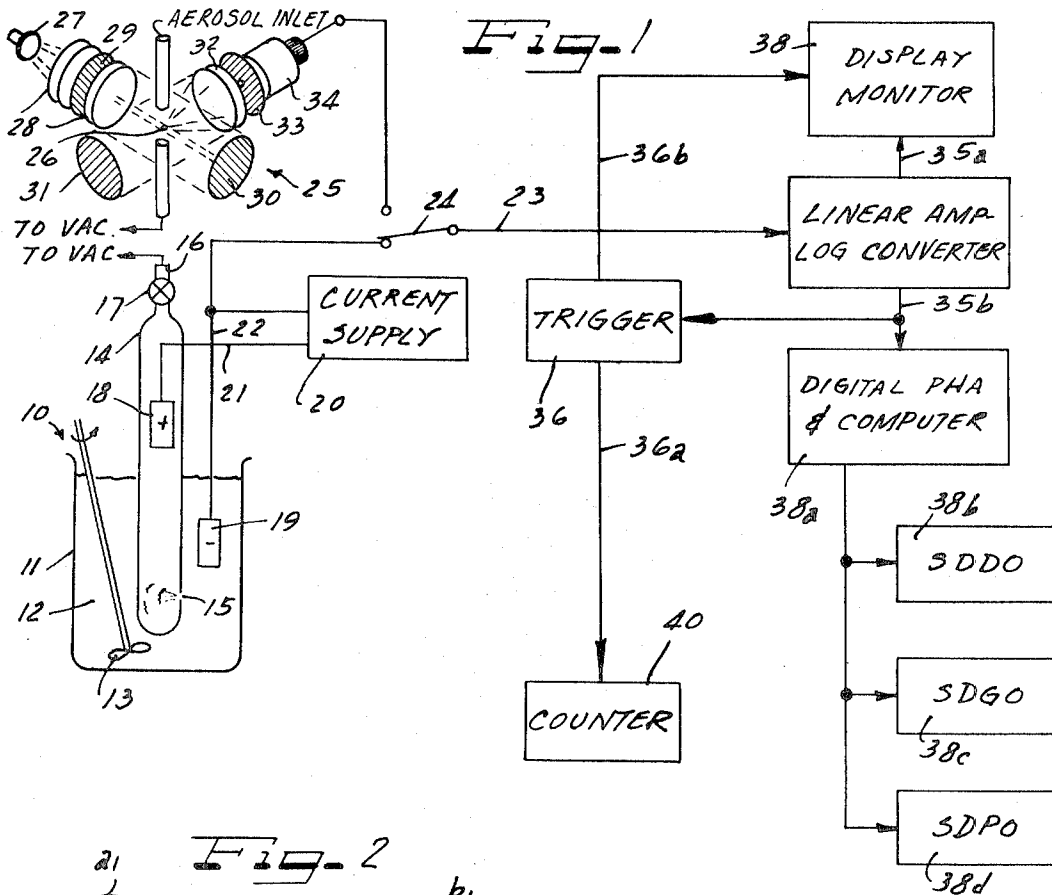
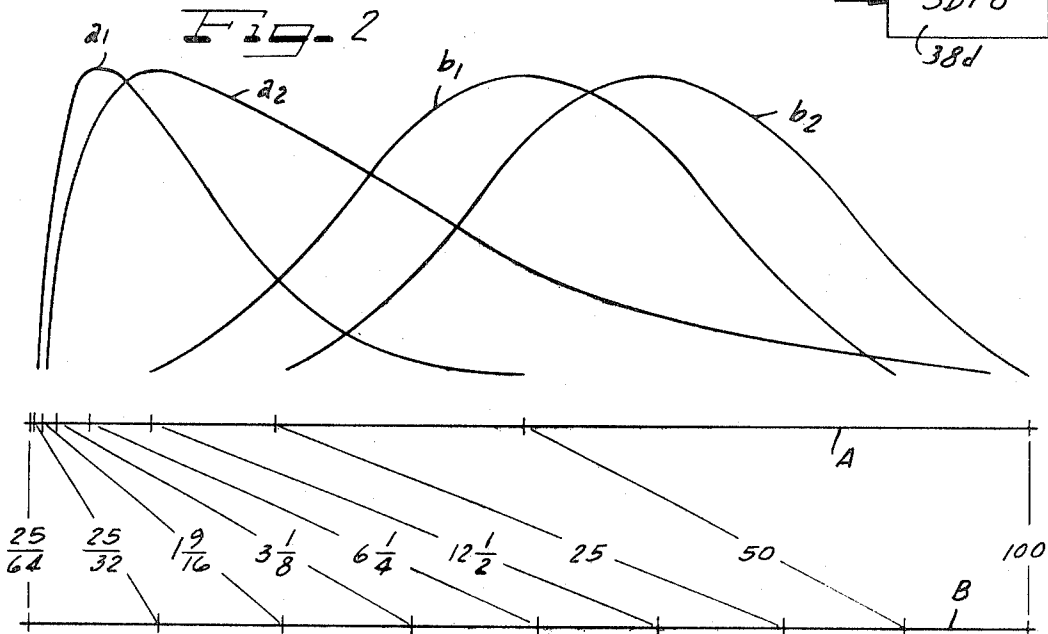
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ABSTRACT: Analysis of particle populations on a logarithmic size basis is provided by electronic apparatus including a linear amplifier for receiving particle size pulses and a logarithmic converter for providing corresponding logarithmically scaled pulses to a pulse monitor oscilloscope and other signal processing and display devices. The linear amplifier includes a plurality of amplifying stages which increase signal strength and enhance signal quality, one of the stages having selectively switched resistors therein for providing a geometric progression of amplifier gain steps for the pulses being processed so that upon logarithmic conversion a display on the oscilloscope or other readout device may be adjusted through a like progression of display to greatly facilitate analysis of particle size pulses at all size levels.





INVENTORS

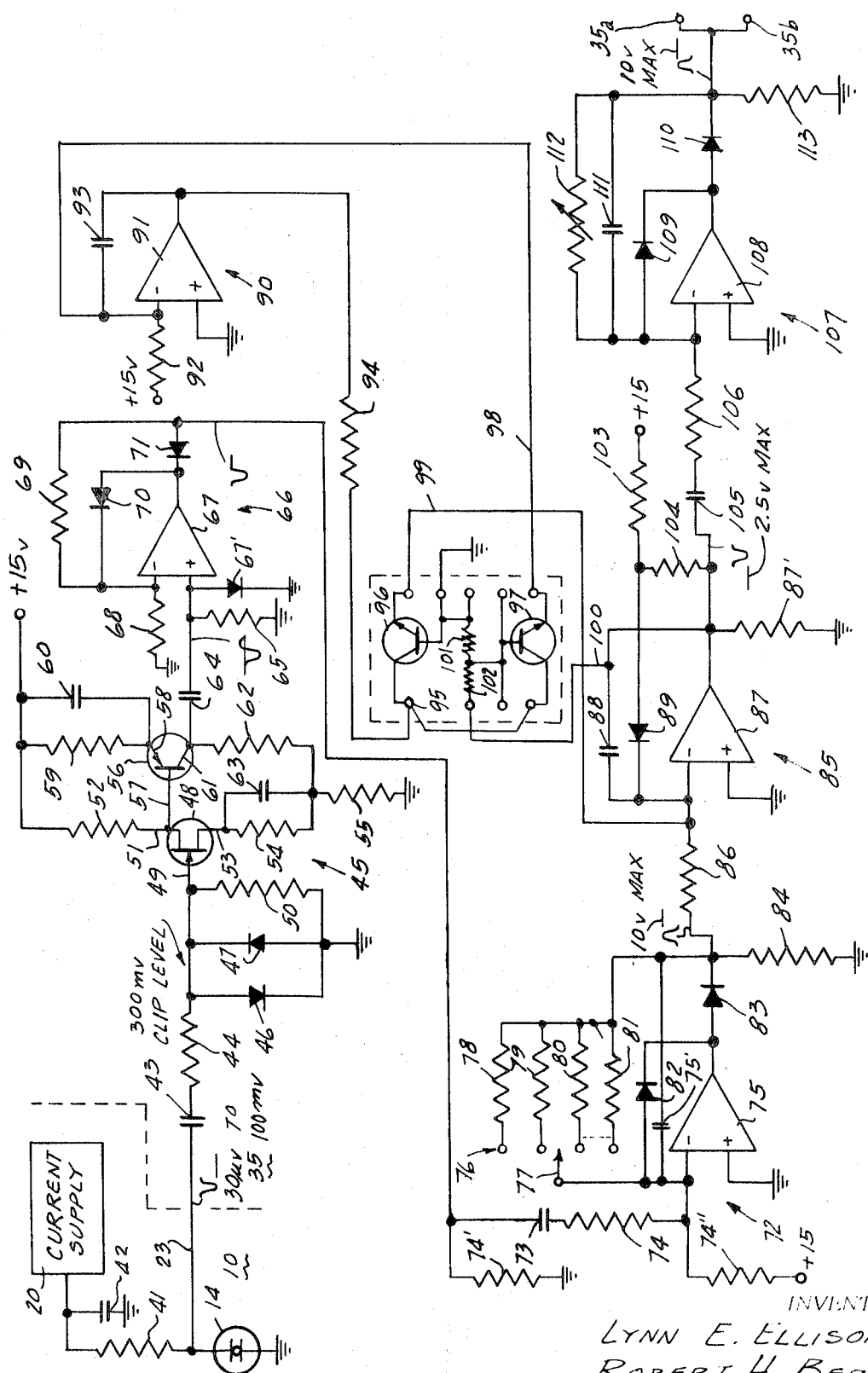
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PARTICLE PULSE ANALYZING APPARATUS EMPLOYING LINEAR AMPLIFICATION AND LOGARITHMIC CONVERSION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to particle size analysis apparatus, and more particularly to apparatus for analyzing on a logarithmic basis the amplitudes of electrical pulses caused by particles passing through a flowing stream zone sensor.

2. Description of the Prior Art

High-speed analysis equipment for particles generally includes some type of stream sensing zone device for producing a sequence of electrical pulses representative of particle size and population. Fluctuations in the stream and in the sensing energy, random particle size, variant particle population concentration and inherently variant particle velocity in different radial loci of the sensing zone place extreme requirements on particle pulse amplifying apparatus in terms of noise, frequency response, linearity, overrange protection, etc.

Shank et al. in the Oct. 1969 issue of the Journal of Laboratory and Clinical Medicine, page 630, and R. J. Harvey in Methods in Cell Physiology, Vol. 3, Academic Press, New York (1968) discuss the requirements for amplifier frequency response in particle size analysis which are that it be fast enough to pick up signals accurately for both slowly and fast moving particles.

Some existing particle pulse amplifier designs employ a more or less current sensitive amplifier input which, according to the response equation for an electric zone type of sensor, eliminates the parameter of stream conductivity but at the sacrifice of amplifier quietness; however, the particle pulses are generally in the range of a few tens of microvolts to a few tens of millivolts and noise must be minimized to obtain the greatest sensitivity and maximum range of particle size sensing.

However, with any linear particle-pulse amplifier, in some degree satisfying the above requirements, the coupling of its output directly to a pulse height analyzer (PHA) leaves one with a usually undesirable form of size distribution presentation.

In U.S. Pat. No. 3,345,502 by Berg et al. an approach to a geometric progression of levels in particle size analysis is described which requires a multiplicity of trigger circuits corresponding to the multiplicity of such levels. The attendant stability limitations of such circuits results in limits to the narrowness of size level increments achievable for generally acceptable particle data.

SUMMARY OF THE INVENTION

Benefits of the Inventions

A benefit of the instant invention is that it permits, in addition to the aforementioned approach by Berg et al. the direct usage of existing, highly developed PHA circuitry of the amplitude-to-time conversion type, for application to particle size analysis on a logarithmic basis, and thus provides size increments at least an order of magnitude narrower than practically achievable via the multiple trigger level approach and thus correspondingly greater resolution of particle size analysis.

The display of particle size analysis data on for example a PHA oscilloscope, is more advantageous to the observer if the display is made on a logarithmic size scale in that log-normal, Gaussian symmetry and/or deviations from same can be seen easily, while on the linear scale a skewness away from a Gaussian distribution is difficult to recognize and accurately interpret. Further, it is common practice to express size distribution of particulate materials logarithmically as to size. Not only are log-normal distributions readily seen, but equal resolution in all regions of the size of scale results from logarithmic presentations.

Further, the logarithmic signal display better facilitates proper setting and makes more reliable the counting trigger

level for certain uses, such as in blood cell and platelet counting, because the span of pulse amplitude for setting a lower level discriminator is greatly increased.

It is a further benefit of this invention that, in achieving four or more doublings of particle volume in a single display scale, a substantially greater effective size range of presentation is achieved at any given amplifier gain setting. For example, the measurement of particulate pollution in air and water is greatly advanced by such logarithmic presentations, in view of the usually broad size spectra of such particles and the desirability of equal size resolutions in all ranges of the size spectrum as provided by a logarithmic particle size scale.

STRUCTURE OF THE INVENTION

The present invention may advantageously include, but is by no means limited to the following structural features.

Particle pulse analyzing apparatus includes a linear amplifier for sensing particle pulses and feeding selectively amplified representations thereof to a logarithmic converter. The linear amplifier comprises:

A first amplifier section comprising a field effect transistor stage followed by a transistor stage. The field effect stage is preceded by a clipping circuit to ensure fast amplifier recovery, and said stage provides noise rejection and includes the feedback circuit from the succeeding transistor stage to insure linear operation. Said succeeding transistor stage and field effect transistor stage are biased for Class A operation.

A second amplifier section comprises an operational amplifier, a first diode for clamping its gain to unity in response to certain polarity of input signals, and a second diode for passing amplified signals of only the other polarity. A third amplifier section comprises an operational amplifier which includes a plurality of gain determining resistors which are selectively switched into the feedback circuit thereof for determining the range of input particle pulse amplitude available at the output of the linear amplifier for feeding to a logarithmic converter.

Such log converter comprises a pair of operational amplifiers, each of which includes a nonlinear feedback circuit and one of which drives both nonlinear feedback circuits as a means of establishing a reference for the other operational amplifier. The last-mentioned operational amplifier includes a further feedback circuit for establishing a maximum gain for the operational amplifier to prevent an extremely high gain and undesirable response to very small input signals (noise), or even "ringing" in response to input signals of an undesirable polarity. The output of the last-mentioned amplifier is logarithmically related to the current through its input resistor due to the nonlinear resistance of its feedback network.

The log converter includes a further operational amplifier having a variable gain controlling resistance in a feedback circuit thereof to permit adjustment of the resolution of any succeeding pulse analyzing equipment.

The gain of the individual amplifiers of the linear amplifier increases from stage to stage to improve signal quality before log conversion. For example, the gain of the first amplifier may be approximately 4, the gain of the second amplifier may be 10 and the gain of the third amplifier may be selective between unity and 50. In the log converter one amplifier has its gain limited by means including a biased diode in the aforementioned feedback circuit to some value, say about 20-50, while the last operational amplifier may have a gain of approximately 4.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the invention, its organization, construction and operation will be best understood from the following detailed description of an exemplary embodiment thereof taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic representation of a particle analysis system employing the principles of the present invention;

FIG. 2 is a graphical illustration of particle-pulse population with comparisons thereof based on linear and logarithmic scales; and

FIG. 3 is a schematic circuit diagram of an embodiment of a linear amplifier-log converter circuit constructed in accordance with the principles of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates apparatus for establishing, for example an electric or photic sensing zone for particle analysis referenced 10 and 25, respectively comprising in the case of the electric sensing zone 10, a container 11 holding therein a conductive liquid 12 containing particles to be analyzed and 2 stirrer 13 operable to continuously keep the particles suspended in the liquid 12. An orifice tube 14 which is also filled with said liquid is disposed in the liquid 12 and includes an orifice 15 to pass the liquid into the tube 14 and to establish an electrical circuit between an electrode 18 within the tube 14 and an electrode 19 within the container 11 below the surface of the liquid 12. The tube 14 includes an open end 16 for connection to a source of negative pressure, a vacuum supply, and the application of such negative pressure is controlled by an interposed valve 17.

The electrodes 18, 19 are connected by way of a pair of respective conductors 21, 22 to a current supply 20 to establish a current flow in the circuit including the electrodes 18, 19 as well known in the art. Further, and as also known in the prior art, the passage of particles through the orifice 15 modulate the current flow during their passage to establish corresponding voltage pulses on the conductor 22. The frequency of these pulses and their amplitudes represent the particle population and size of particles in the liquid 12.

In the case of the photic sensing zone 25, a photomultiplier may be employed to sense the particles in moving stream containing the particles and providing corresponding electrical pulses to a linear amplifier-log converter 35 by way of the conductor 23 and a switch 24 which represents the alternative utilization of either an electric or photic sensing device. The photic sensing zone 25 may comprise a light source 27 the light rays of which are directed through the moving stream by lenses 28 an aperture plate 29 to a sensing point 26 of the stream. Right angle light scattering effected by the particles in the stream is detected by a photo multiplier 34 through a lens 32 and an aperture plate 33. A light trap 31 prevents the sensing of background light and a light trap 30 prevents reflections of the light beam. Either gaseous or a liquid media may be used for the stream in that sufficient optical clarity, rather than electrical conductivity, is required; therefore photic sensing is quite advantageously utilized in monitoring particle populations in air and nonconducting liquids.

The particle pulses are extended to the linear amplifier-log converter circuit 35 by way of the conductor 23, whereupon the pulses are evaluated and processed on a logarithmic basis and then extended from a pair of output terminals 35a, 35b respectively of the circuit 35 to a display monitor oscilloscope 38 for visual evaluation by an operator and to a digital PHA and computer 38a. The PHA and computer 38a may be provided with a plurality of readout devices 38b-38d which are respectively a visual size distribution display readout device (SDDO), a size distribution graphout device or recorder chart (SDGO), and a size distribution printout device (SDPO). The logarithmic presentation may therefore take analog, digital, temporary, or permanent form by the utilization of any or all of the above readout devices.

The output 35b is also connected to a trigger circuit 36 (or multiple trigger circuits as in the above-identified patent to Berg et al. U.S. Pat. No. 3,345,502) which effects trigger pulses at its output 36a for operating a digital counter 40 (or plurality of counters as in Berg et al.). The output pulses of the trigger circuit 36 is also connected to trigger the display monitor scope 38 by way of a conductor 36b.

FIG. 2 illustrates some of the advantages of the provision of a continuous logarithmic presentation of particle size, particularly at the lower end of a range of particle sizes. The representation of size in a particle population as shown in curve a1 based on a linear scale A carries little ascertainable data at the lower end of the scale; however, the same data presented in logarithmic form in curve b1 based on a log scale B shows Gaussian symmetry of particle size. The same data upon a single doubling, as shown in curve a2, provides only slightly more data capable of interpretation; however, note the consistent legibility of the correspondingly doubled curve b2.

Attention is particularly invited that more doublings would increase the legibility at the lower end of the linear scale, but the data representing larger particle sizes would be far off the scale on the right. The patching together of curve portions in such situations has proven difficult and inadequate on a linear basis; however, the same is easily accomplished and highly informative if done on a continuous logarithmic basis.

Referring to FIG. 3, a particular embodiment of a linear amplifier-log converter circuit 35 which has been found to provide advantageous results when utilized to provide signals to a display monitor. The circuit receives input pulses from particle pulse generating apparatus 10 including a current supply 20 which is connected to an orifice tube 14 by way of a resistor 41 to form a divider for deriving the pulses which are generally in the range of from 30 microvolts to 100 millivolts, but which are frequently much larger in value. The pulses are coupled to a first amplifier 45 by way of the conductor 23, a coupling capacitor 43, a resistor 44 and a pair of oppositely poled shunt connected silicon diodes 46, 47 which clip pulses at a 300 millivolts level when required.

The first amplifier 45 provides a good high impedance matching to the apparatus 10 and preferably has a low gain for example a gain of four, as a signal quality control. The amplifier 45 includes a first stage having a field effect transistor 48 having a gate electrode 49 which is connected to ground by way of a gate bias resistor 50. The transistor 48 also has a drain electrode 51 connected to a supply by way of a drain load resistor 52, and a source electrode 53 connected to ground by way of a source bias resistor 54 and a bias resistor 55. The amplifier 45 also comprises a second stage including a transistor 56 having a base electrode 57 connected to the drain electrode 51 of the field effect transistor 48. The transistor 56 also has an emitter electrode 58 connected to a direct current supply potential by way of a resistor 59, and a collector electrode 61 connected to ground by way of a resistor 62 and the resistor 55. The gain of the circuit is effectively the ratio of the values of the resistors 62, 55, and the circuit between the collector electrode 61 and the source electrode 53 including the resistor 62 and the resistor 54 provides inverse feedback for stable operation, and the resistor 59 and a capacitor 60 in shunt therewith bias the stage and provide an AC path so that the transistor 56 operates in Class A. A capacitor 63 connected in shunt with the resistor 54 decouples the source and connects it AC wise to the resistor 55. A capacitor 64 is connected to the collector electrode of the transistor 56 couples the output signal therefrom to an input of a second operational amplifier 66.

The resistor 44 is a current-limiting resistor which is provided to protect the diodes 46, 47 and the field effect transistor in case of transient groundings of the conductor 23 due to accidental shorting by an operator. The resistor 44 also limits current flow upon the discharge of the capacitor 43, which charge is effected upon a clogging of the orifice 15 of the tube 14, and which current flow is effected upon clearing of the orifice.

The second operational amplifier 66 includes a forward amplifier circuit 67 having a resistor 65 connected to an input thereof and to the capacitor 64 to form a differentiator, the resistor and capacitor being selected to cause the frequency response of the amplifier to effect rejection of all frequencies below a predetermined frequency, say below 200 Hz. A resistor 68 connects the second input of the amplifier circuit 67.

A diode 67' connects the + input of the amplifier circuit 67 to ground with respect to positive signals to prevent latching of the amplifier in response to large positive signals. A resistor 69 connected from the output of the operational amplifier 66 to the resistor 78 establishes the gain of the amplifier normally again of 10, i.e., the value of the resistor 69 divided by the value of the resistor 68; however, a diode 70 effects unity gain in response to positive portions of the input signals across the resistor 65, and a diode 71 causes the amplifier 66 to function as a rectifier by coupling only negative output pulses to the subsequent circuitry. The positive overshoot of the signal coupled by the capacitor 64, as indicated in the drawing, is the positive signal which causes unity gain through the conduction of the diode 70. A coupling capacitor 73 couples the output signal from the second amplifier 66 to a third operational amplifier 72.

The third operational amplifier 72 includes an amplifier circuit 75 having a pair of diodes 82 and 83 for effecting unity gain and rectifier operation, respectively, of the amplifier as did the diodes 70, 71. The gain of the amplifier 72 is the ratio of the value of feedback resistance of the amplifier circuit divided by the value of the input resistor 74. The feedback resistance is variable and, as here illustrated, is established by the selective connection of a plurality of resistors 78-81 by way of a switch 76 having a movable contact 77. Gain is in steps of from one-half to approximately 48 or 50, to provide a multiplicity of doublings for the display of particle-pulse data when employed with log conversion as detailed below. On a linear scale with a full scale to 100 percent eight doublings down take the form of 50, 25, 12.5, 6.25, 3.125, 1.5625, 0.78125 and 0.390625. A 10-volt-maximum signal effects maximum signal responses of 0.039 on the eighth doubling down; therefore signals become very difficult to read at lower percentages of maximum signal input. However, on a logarithmic basis lower percentage signals are more easily read since each doubling becomes an equal fraction of full scale, e.g., one-eighth. The third amplifier 72 is an inverting amplifier and is constructed to be driven to saturation at an output of 10 volts. A resistor 84 provides the load for the operational amplifier 72.

The positive output pulses from the third operational amplifier 72 are coupled over a resistor 86 to an input of an amplifier circuit 87 of an operational amplifier 85. The operational amplifier 85 is provided with a reference input from an operational reference amplifier 90 having a feedback circuit connected to the same input of the amplifier circuit 87 as the input resistor 86.

There are several important features of the operational amplifiers 85 and 90 which merit particular attention. The first feature is that the output current of the amplifier circuit 87 is the log of the current through the resistor 86 due to the non-linear resistance of the feedback circuit of the amplifier 90. For example, a maximum input signal of 10 volts at the input of the amplifier 87 with the resistor 86 rated at 10K provides an input current of 1 milliampere. Therefore a 1-milliampere-input current is required at the input of the amplifier circuit 91 through a 15K resistor 92 connected to a +15 volt regulated supply. The output of the amplifier circuit 91 is connected by way of a current-limiting resistor 94 to a common connection 95 to the collectors of a pair of transistors 96, 97. The collector of the transistor 97 is connected back to the input terminal of the amplifier circuit 91 by way of a conductor 98. The emitter of the transistor 96 is connected by way of a conductor 99 to the input of the amplifier circuit, and the output of the amplifier circuit 87 is connected to the bases of the transistors 96, 97 by way of a conductor 100 and a pair of resistors 101, 102, so that the output voltage of the operational amplifier 85 is the log of the input current to the amplifier, while the reference amplifier 90 compensates for changes in reference current by the effect of its feedback circuit through the transistor 97.

The amplifier circuits 87, 91 have integrating or rolloff capacitors 88, 93 respectively.

A second feature which deserves particular attention resides in the provision of a diode 89, a resistor 103 and a resistor 104. The amplifier circuit has a characteristic whereby small signals effect a tremendous gain and negative signals can effect oscillatory ringing, i.e., on the order of 50-100,000 gain, but a gain of only 20-50 is preferred. The resistors 103, 104 along with the supply voltage bias the diode 89 to hold the input of the amplifier circuit 87 at a predetermined level, say at a positive 30 millivolts, to eliminate any possibility of extremely small or negative-going voltages at the input of the amplifier circuit 87.

The output of the operational amplifier 85 is coupled to the input of an amplifier circuit 108 by way of a capacitor 105 and a resistor 106. A variable feedback resistor 112 establishes, with respect to the value of the input resistor 106, a gain range of about two to one for the operational amplifier 107 providing the capability of varying the number of channels per doubling for greater or lesser resolution as desired. A rolloff capacitor 111 is connected across the resistor 112 and a pair of diodes 110, 109 clamp the circuit to unity gain in response to positive input signals and provide rectifier circuit operation, respectively. A resistor 113 provides the load for the operational amplifier 107, and an output terminal 35 for connection to a pulse height analyzer or other suitable utilization means.

The amplifier circuit illustrated herein by the triangular symbols and referenced 67, 75, 91 and 108 were advantageously realized by integrated circuits of the 709 type currently available from a number of manufacturers. The amplifier circuit referenced 87 was realized from a type 148A circuit provided by Analogue Devices of Cambridge, Massachusetts and the feedback transistors 96, 97 and the resistances 101, 102 within the broken line box of FIG. 3 was realized by a model 751N logarithmic module, also provided by the Analogue Devices firm.

Attention is invited that there are many features of the invention which solved formidable problems in attaining a workable realization thereof for particle pulse processing in addition to or resulting from the aforementioned problems and requirements relating to noise, frequency response, linearity, and the enormous range of input pulse amplitudes of a million to one, etc.

For example, accuracy requires linear amplification since an accurate log converter will faithfully operate with respect to signals which poorly represent data as well as to signals which accurately represent data. As the linear amplification performs in accordance with this requirement, however, the first FET stage is susceptible to damage from abnormally large signals as may occur when a combination of orifice current and particle size relative to the orifice produces a signal exceeding e.g., 30 volts. This may happen in the case of the electric sensing zone when the fluid container is removed and then replaced or when the orifice is blocked and then cleared. The resistor 44 limits the discharge current from the capacitor 43 and the diodes 46, 47 protect the input of the amplifier by conducting at a predetermined potential, say 300 millivolts, and prevent the voltage from rising to an excessive level across the resistor 50.

Inasmuch as the amplifier 45 is operated in Class A, any positive signals will appear across capacitor 64. The aforementioned diode 67', as another example, conducts in response to a predetermined level of positive overshoot, say at 0.3 volt, to prevent latch-up of the amplifier 67.

As another example the third amplifier section 72 of the linear amplifier is provided with a resistor 74' to restore the voltage across the capacitor 73 to near zero or its quiescent state following a pulse. When a pulse from the amplifier 66 goes negative and returns to zero, the change voltage across the capacitor 73 due to the pulse remains, since the diode 71 is reverse biased. The resistor 69 provides a long time constant in conjunction with the capacitor 73 and the resistor 74' is necessary to discharge the capacitor returning the amplifier section to its quiescent state. The amplifier circuit 75 is selected to have zero offset voltage and is trimmed to zero out-

put by a resistor 75' when no signal is present. Also, in this circuit a capacitor 75' is provided across the amplifier 72 to attenuate any frequencies available at that point which are higher than those produced in the sensing zone.

Inasmuch as a capacitive coupling between the linear amplifier and the logarithmic converter would cause nonrepeatable pulse evaluation due to negative voltages produced by capacitor recovery, direct coupling is required. A resistor 87' is connected between the capacitor 105 and ground to provide a discharge path for the capacitor, as was discussed above with respect to the resistor 74' and the capacitor 73. The resistor 86 is selected to provide a 1 ma. current for example, into the logarithmic converter at maximum signal without increasing the rise time of the pulse; higher resistances, say above 10K, have such an effect.

The foregoing improved circuitry has enabled us to maximize the ability to accurately respond to extremely small signals from particles of 2percent of orifice diameter and less.

The results obtained in practicing the instant invention were beyond our expectations in that, for example, the piecing together of curves was made a practical reality, the order of resolution of data was greatly increased, such extremely accurate response to small signals was achieved, and data could be obtained over a great range of particle sizes with circuit recovery capable of handling both the size range and the random occurrence of particles through the sensing zone, i.e., a small particle immediately following a large particle.

While the present invention has been disclosed herein by reference to a specific illustrative embodiment, many changes and modifications thereof will become apparent to those skilled in the art without departing from the spirit and scope of the invention, and we wish to include within the patent warranted hereon all such changes and modifications as may reasonably and properly be included within the scope of our contribution to the art.

We claim as our invention:

1. Apparatus for providing continuous logarithmic representations of particle size data for analysis of particulate materials, comprising:

a sensing zone;

means for sensing a stream of fluid containing suspended particles moving through said sensing zone and operable to generate random amplitude, random width, random time-spaced and noise garbled particle pulses in response to respective particles traversing said zone, the amplitudes of said particle pulses representing the size of the respective particles over a wide dynamic range of particle sizes;

means connected to said sensing means for receiving the particle pulses; and

a logarithmic converter connected to said receiving means and operable in response to the particle pulses to provide output signals which are logarithmically related to the amplitudes of the particle pulses.

2. Apparatus for providing continuous logarithmic representations of particle size data for analysis of particulate materials, comprising:

a sensing zone;

means for sensing a stream of fluid containing suspended particles moving through said sensing zone and operable to generate random amplitude, random width, random time-spaced and noise garbled particle pulses in response to respective particles traversing said zone, the amplitudes of said particle pulses representing the size of the respective particles over a wide dynamic range of particle

sizes;

means connected to said sensing means for receiving the particle pulses; and

a logarithmic converter connected to said receiving means and operable in response to the particle pulses to provide output signals which are logarithmically related to the amplitudes of the particle pulses, said logarithmic converter including first and second operational amplifiers each having first and second inputs and an output, said first inputs connected to a reference potential, said second input of said first operational amplifier connected to said receiving means, said second input of said second operational amplifier connected to a reference current source, a nonlinear impedance network, a first nonlinear feedback network including said nonlinear impedance network connected between said output and said second input of said second operational amplifier, and a second feedback network including said nonlinear impedance network and said first operational amplifier connected between said output and said second input of said first operational amplifier.

3. Apparatus according to claim 2, comprising gain limiting means connected to said second input of said first operational amplifier to prevent a sharp increase in the gain thereof at input signal levels less than a predetermined input level.

4. Apparatus according to claim 3, wherein said gain means includes a diode connected to said second input and biasing means for said diode effective to maintain said second input above said predetermined input level.

5. Apparatus according to claim 2, wherein said logarithmic converter further comprises a third amplifier having an input and an output, a coupling capacitor connected between said output of said first operational amplifier and said input of said third amplifier, and a resistor connected between said capacitor and ground as a discharge path for said capacitor during intersignal intervals.

6. Apparatus according to claim 2, wherein said receiving means comprises a linear amplifier which includes a first amplifier circuit, a second amplifier circuit, a coupling capacitor connected between said first and second amplifier circuits and responsive to the operation of said first amplifier circuit to couple a pulse of one polarity followed by an overshoot signal of the opposite polarity, and gain clamping means in said second amplifier circuit for controlling operation thereof at unity gain in response to said overshoot signal.

7. Apparatus according to claim 6, wherein said gain clamping means includes a diode connected between the output and the input of said second amplifier circuit, and means for biasing said diode to a predetermined potential.

8. Apparatus according to claim 7, wherein said second amplifier circuit further comprises a diode serially connected to its output and poled to pass only the pulses of said one polarity.

9. Apparatus according to claim 6, wherein a first resistor is serially interposed with said coupling capacitor between said first and second amplifier circuits, and said second amplifier circuit comprises a feedback circuit including a plurality of second resistors and means for selectively connecting said second resistors in said feedback circuit to selectively establish resistance relationships with said first resistor to define the selectable gains of said second amplifier circuit.

10. Apparatus according to claim 9, comprising a resistor connected between said coupling capacitor and ground as a discharge path for said capacitor during intersignal intervals.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,626,166

Dated December 7, 1971

Inventor(s) Robert H. Berg and Lynn E. Ellison

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

Column 3, line 14, for "2", read --a--.

Column 5, line 5, for "78", read --68--.

Column 7, line 1, for "75' ", read --74'--.

Signed and sealed this 18th day of July 1972.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents