United States Patent [19]

Pear, Jr.

[11] **3,843,955**

[45] **Oct. 22, 1974**

[54] **HELICAL BAR STRIP CHART RECORDER**

[75] Inventor: **Charles B. Pear, Jr.,** Greenlawn, N.Y.

[73] Assignee: **Potter Instrument Company Inc.,** Plainview, N.Y.

[22] Filed: **Oct. 19, 1972**

[21] Appl. No.: **298,834**

[52] **U.S. Cl.** .... **346/35,** 346/65, 346/78, 346/101, 101/93 C, 335/277

[51] **Int. Cl.** **G01d 9/00**

[58] **Field of Search** 346/35, 101, 78, 65; 101/93; 335/277, 247, 257; 307/270

[56] **References Cited**

UNITED STATES PATENTS

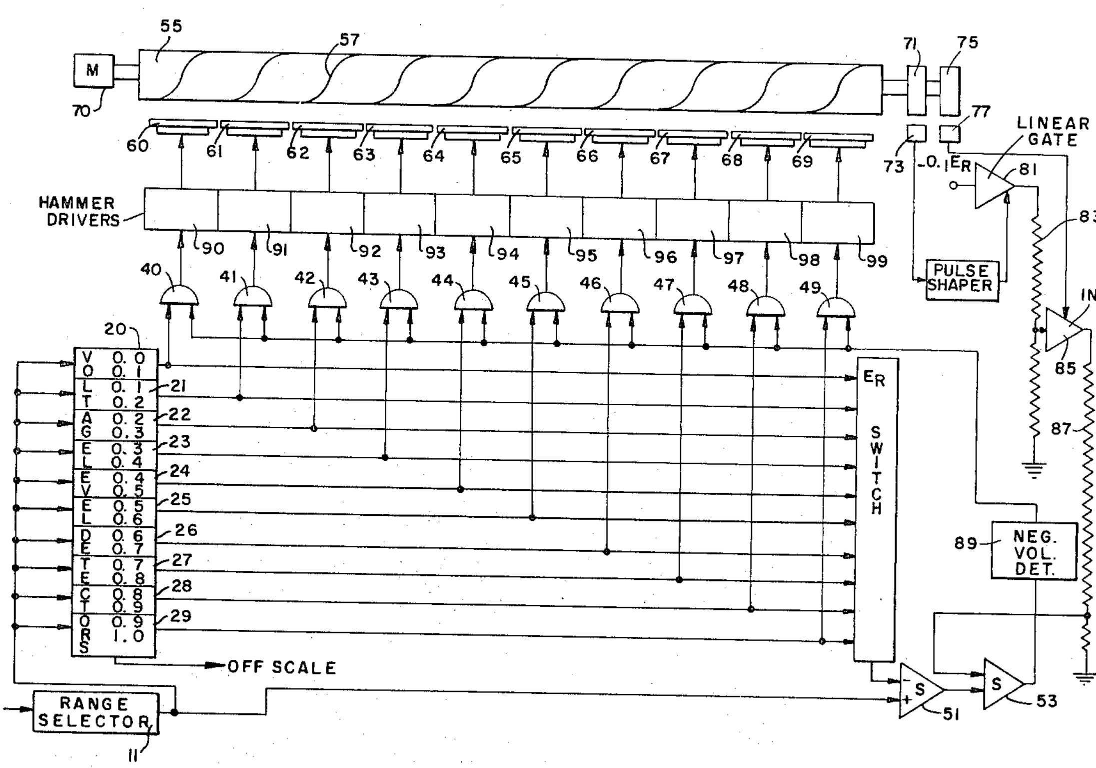
3,214,764	10/1965	Williams, Jr.	346/35
3,409,904	11/1968	Maiershofer	346/101
3,564,537	2/1971	Lee	346/35
3,678,847	7/1972	Pear, Jr. et al.	335/277

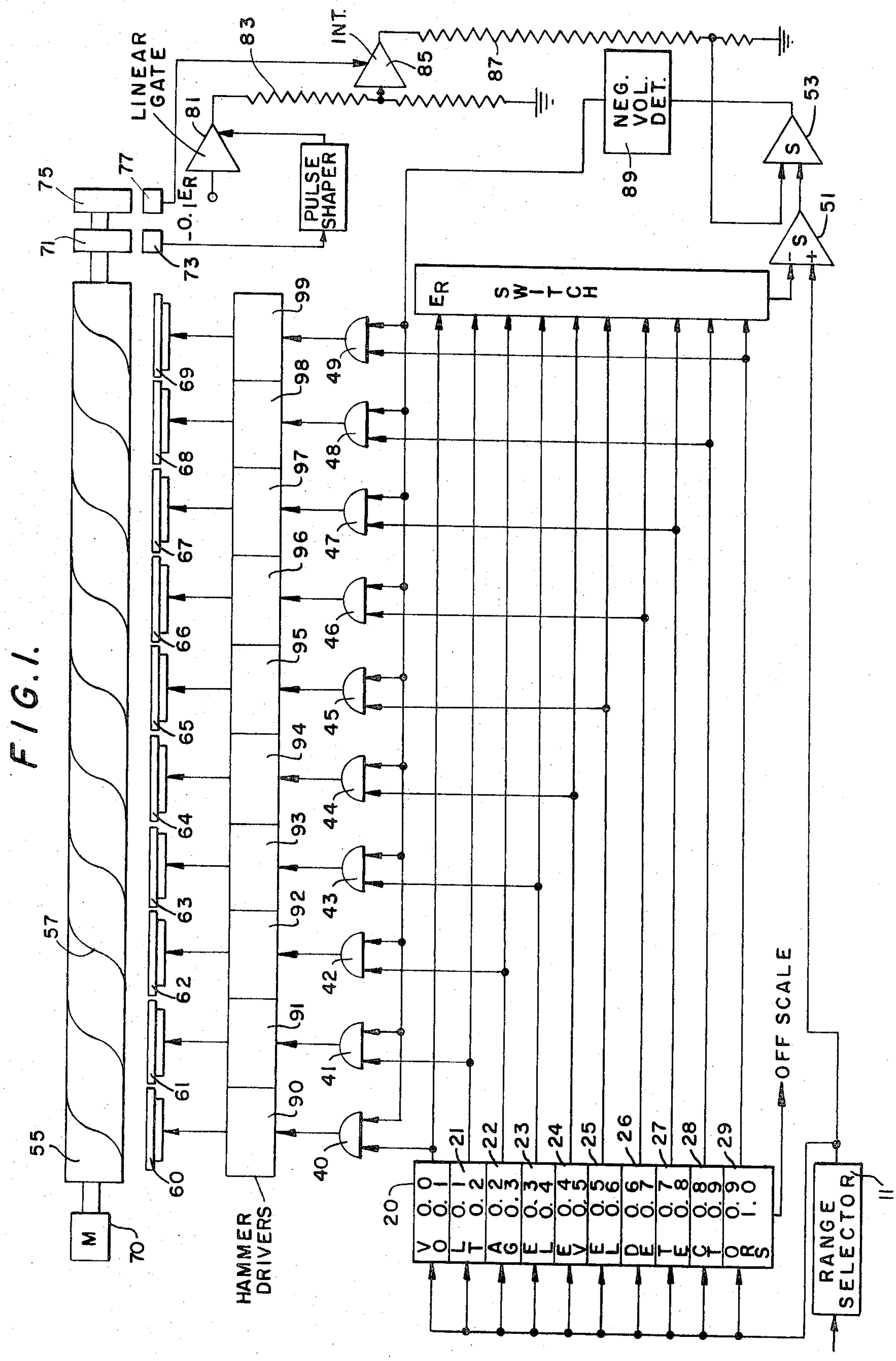
Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Vit W. Miska
Attorney, Agent, or Firm—Lane, Aitken, Dunner & Ziems

[57] **ABSTRACT**

In a strip chart recorder, the graph of the signal to be recorded is generated by a helical bar printer comprising a helical bar of several convolutions with a blade hammer positioned to strike each convolution of the helical bar. The analog value to be recorded is converted into a digital representation with a radix equal to the number of convolutions of the helical bar. One of the hammers is selected in accordance with the value of the digital representation and the selected hammer is actuated to strike the bar to print a dot at a time corresponding to the difference between the value of the digital representation and the analog value being recorded to thus print the dot in a position corresponding to the analog value. The hammers are repeatedly actuated to effect the recording of a graph by the resulting pattern of printed dots.

12 Claims, 4 Drawing Figures




LINEAR GATE
INT.
NEG. VOL. DET.
PULSE SHAPER
-0.1 E_R
E_R SWITCH
HAMMER DRIVERS
VOLTAGE LEVEL DETECTORS
RANGE SELECTOR
OFF SCALE
M

F/G. 1.

PATENTED OCT 22 1974

SHEET 2 OF 2

3,843,955

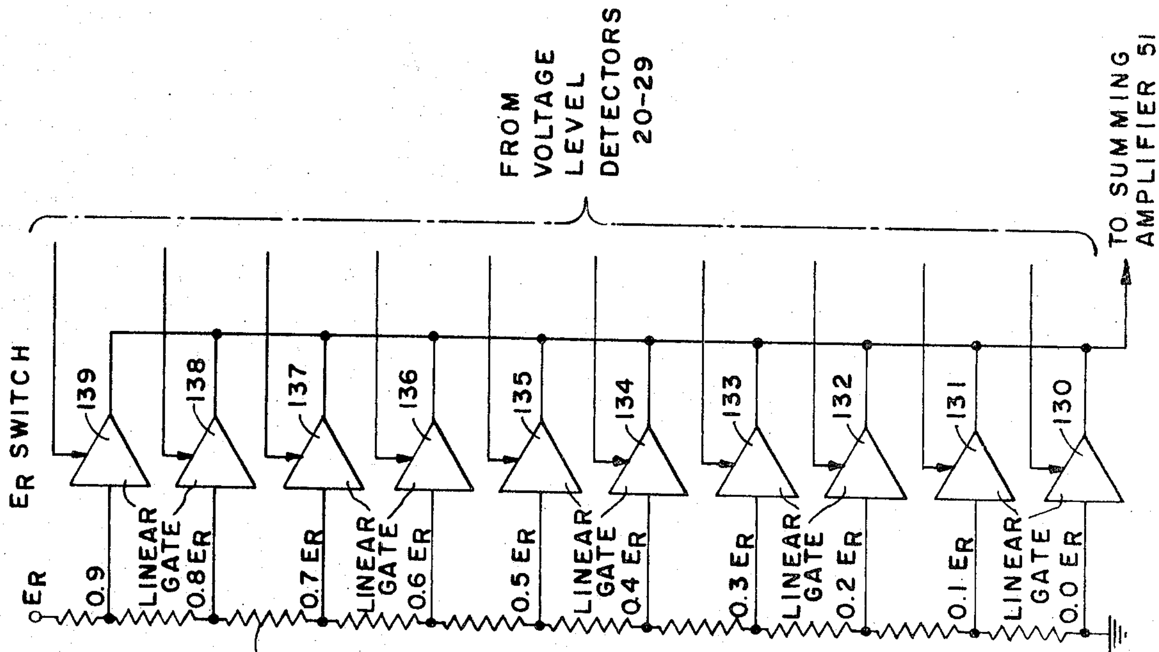


FIG. 4.

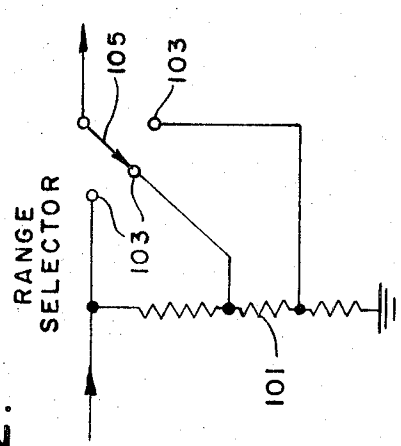


FIG. 2.

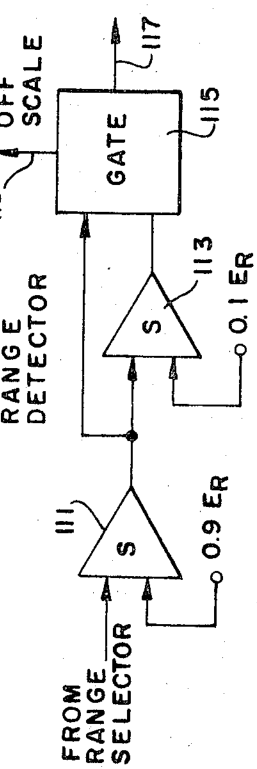


FIG. 3.

HELICAL BAR STRIP CHART RECORDER

BACKGROUND OF THE INVENTION

This invention relates to a strip chart recorder, and more particularly to a recorder which records a graph of a variable value by means of a helical bar dot printer.

The best conventional strip chart recorders of the prior art, such as those employing pen and ink techniques to generate the graph of the recorded value, are relatively slow in response time requiring at least 250 milliseconds to cover the full scale of the graph. This slow response time results from the inertia of the marking instrument which produces the graph. Instead of recording by means of a pen and ink marking instrument, it has been proposed in the prior art to generate the graph by means of pressure between a rotating helical bar and a pressure bar, such as used in facsimile reproduction, to produce the strip chart graph. These helical bar printers of the prior art suffer from reduced resolution without dramatically improving the recording response time. The present invention utilizes the helical bar principle to effect generation of the graph, but achieves a much faster full scale response time of 100 milliseconds or better. This greatly improved response time is achieved with a resolution comparable to that of the highest quality strip chart recorders.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with the present invention, the recording instrument is a helical bar printer comprising a rotatable drum on which is mounted a helical bar extending around the drum in 10 convolutions. The drum and helical bar are rotated about their common axis at a constant speed. Adjacent to the drum and helical bar are 10 blade hammers, each spanning one convolution, and each adapted when actuated to strike the adjacent convolution of the helical bar. The strip chart on which the recording is to take place is positioned between the blade hammers and the helical bar, and is moved in a direction past the drum and hammers in a direction perpendicular to the axis of the drum. When one of the hammers is actuated, it will strike the adjacent helical bar through the strip chart and effect the printing of a dot on the strip chart. This printing is preferably achieved by an inking ribbon also positioned between the hammers and the helical bar, but may be achieved by using a strip chart comprising pressure sensitive paper. The scale of the graph to be recorded extends over all of the ten convolutions of the helical bar. The analog signal to be recorded is converted to a digital representation having a radix of 10 equal to the number of hammers and convolutions of the helical bar. The hammer is selected in accordance with the value of the digital representation and then this hammer is actuated at a time corresponding to the difference between the analog value being recorded and the value of the digital representation. To record a dot at a position on the strip chart corresponding to the analog value, the strip chart moves continuously past the row of hammers and helical bar, and as the strip chart moves, the hammers are repeatedly actuated, as described above, to print dots to effect a graph of the analog signal printing one dot per revolution of the drum. The high response time together with the improved resolution is achieved because the range of the graph being recorded extends over several convolutions of the helical bar and several blade hammers.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating the strip chart recorder of the present invention;

FIGS. **2–4** illustrate circuits of components of the system illustrated in FIG. **2.**

DESCRIPTION OF A PREFERRED EMBODIMENT

In the system of the invention, as shown in FIG. **1,** the analog input signal to be recorded is in the form of a voltage with a positive polarity. It is first applied to a range selector in which a selective attenuation may be applied to the input signal to thus select a range for the recording of the input signal. The positive input signal voltage, after being attenuated by the range selector **11,** is applied to a series of voltage level detectors **20–29,** each of which detects whether the input signal is within a given range or increment relative to a reference signal voltage E_R. The voltage level detector **20** detects whether the input signal is within the range or increment from 0 to $0.1E_R$, and if so, producres an output signal which is applied to an E_R switch **31** and also enables a gate **40.** The voltage level detector **21** determines whether the input signal is within the range or increment of $0.1E_R$ to $0.2E_R$, and if so, produces an output signal which is applied to the E_R switch **31** and also enables a gate **41.** Similarly, the voltage level detector **22** determines whether the applied signal is within the range of $0.2E_R$ to $0.3E_R$, and if so, enables a gate **43.** The output signal of the voltage level detector **22** is also applied to the E_R switch **31.** The voltage level detectors **23–29** function in a similar manner to detect whether the input signal falls in successively higher consecutive ranges, each one tenth of the reference voltage E_R in width. Thus, the voltage level detector **29** detects whether the input signal is within the range $0.9E_R$ to E_R. Each of the voltage level detectors **23–29** is connected to enable a corresponding gate **43–49** if the input signal falls within the voltage increment to which the detector is sensitive and is also connected to apply a signal to the E switch **31.** The voltage level detector **29** will produce an output signal indicating that the applied input signal is off scale if the input signal is greater than E_R. Thus, one of the voltage level detectors **20–29** will produce an output signal indicating within a tenth of the reference voltage E_R where the input signal falls if the input signal is less than E_R, and will enable a corresponding one of the output gates **40–49.** The voltage level detector will also apply a signal to the E_R switch **31** indicating in what increment the input signal falls.

The E_R switch **31** in response to the applied signal from one of the voltage level detectors will produce an output signal equal to the lower limit of the increment in which the input signal falls as detected by the series of detectors **20–29.** For example, if the input signal is within the range of 0.5 to 0.6, the voltage level detector **25** will produce an output signal enabling gate **45,** and in response to this output signal, the E_R switch **31** will produce an output signal equal to $0.5E_R$. The output signal of the E_R switch **31,** which has a negative polarity, is applied to a summing amplifier **51,** which also receives the positive output signal directly from the range selector **11.** Thus, the magnitude of the output signal of the E_R switch **31** is subtracted from the magnitude of the output signal of the range selector **11** by the summing amplifier **51**, which produces an output signal voltage representing the difference in the magnitude between these two signals, or in other words, representing the amount that the magnitude of output signal of the range selector exceeds the magnitude of the output signal of the E_R switch **31**. Thus, th output signal of the summing amplifier **51** represents the amount that the output signal of the range selector **11** exceeds the lower limit of the voltage increment in which the signal falls as detected by one of the voltage level detectors **20–29**. The output signal of the summing amplifier **51** is positive and is applied to a summing amplifier **53**.

The recording of the voltage signal is carried out by a helical bar printer, such as that disclosed in copending application Ser. No. 284,274, entitled "Helical Bar Printer Logic Circuitry," filed Aug. 28, 1972, invented by Henry P. Kilroy and Harold J. Murphy and assigned to the assignee of the present application. As disclosed in the above mentioned copending application, the printing mechanism comprises a drum **55**, on a cylindrical surface of which is mounted a helical bar **57** making a plurality of convolutions about the drum. In the system of the present invention, the helical bar makes 10 convolutions about the drum. Adjacent to each convolution of the helical bar **57** is a blade hammer which when actuated will strike the bar **57** and cause a dot to be printed on a strip chart (not shown) positioned between the hammers and the drum **55**. Thus, each of the blade hammers and the opposite convolution of the helical bar comprises a separate dot marker. The blade hammers are designated by the reference numbers **60–69**. The actual printing may be carried out by providing an inking ribbon (not shown) between the drum **55** and the hammers or by making the strip chart out of pressure sensitive paper. If desired, several copies may be printed simultaneously by the conventional carbon copy technique used with typewriters.

The drum **55** is continuously rotated by a motor **70** so that the lateral position of the dot printed by a given hammer depends upon the time that the hammer is actuated. The gross positioning of the dot is determined by the hammer that is actuated. Thus, the position that a dot is printed over the entire range of the strip chart can be controlled by selecting the hammer to be actuated, and then selecting the time of actuation of the hammer. The hammer is selected in accordance with the voltage increment in which the output signal of the range selector **11** falls as detected by one of the voltage level detectors **20–29**. The time of actuation of the hammer is determined by the amount that the output signal voltage of the range selector **11** exceeds the lower limit of the voltage increment in which the signal falls as detected by one of the voltage level detectors **20–29**. In this manner, the position of the dot printed on the strip chart between the drum **55** and the hammers **60–69** represents the amplitude of the output signal of the range selector **11**. By repeatedly selecting and actuating one of the hammers **60–69** in accordance with this signal, a graph of the value of the signal is recorded.

The motor **70** is connected to drive with the drum **55** a tone wheel **71** which by means of a transducer **73** produces one hundred and forty output pulses for each revolution of the drum **55** at equal angular intervals of the drum **55**. A second wheel **75** produces one output pulse by means of a transducer **77**, each time the drum **55** passes through the start position, which is the position at which each convolution of the helical bar **57** is opposite the extreme left-hand side of each of the hammers **60–69**. The rotation of the drum **55** is in the direction in which continued rotation of the drum **55** from the start position will advance the intersection of the bar **57** with the adjacent hammers from left to right as viewed in FIG. **1**. The output pulses produced by the transducer **73** are shaped by a pulse shaper **79** and applied to a linear gate **81** to enable it. A linear gate is a circuit which passes an analog signal voltage from its input to its output when enabled. The linear gate **81** has a voltage of $0.1E_R$ applied to its input with a negative polarity so that the linear gate **81** produces output pulses having an amplitude of $-0.1E_R$ each time a pulse is produced by the transducer **73**, or in other words, each time the drum **55** passes through one 1/140th of a revolution. The output signal pulses of the linear gate **81** are attentuated to one-tenth of their value by a voltage divider **83**, and then are applied to an integrator **85** which integrates the applied pulses and produces an output signal voltage equal to the sum of the amplitudes of the applied input pulses from the time that the integrator **85** was last reset to zero. The integrator **85** is reset to zero each time the transducer **77** produces an output pulse when the drum **55** passes through the start position. Thus, the integrator **85** will produce an output signal voltage representing the number of pulses that have been produced by the transducer **73** since the last pulse was produced by the transducer **77** or since the drum **55** last passed through the start position. Accordingly, the output signal voltage of the integrator **85** will represent the angular position of the drum **55** with respect to the start position. The output signal of the integrator **85** is applied to a voltage divider **87** which attenuates the output voltage to one 1/14th of its value. The output of the attenuator **87** will thus be $N/140 \times 0.1E_R$, where N is the number of pulses produced by the transducer **77** since the drum **55** last passed through the start position. The output signal voltage of the attenuator **87** is applied to the summing amplifier **53**.

As pointed out above, the summing amplifier **53** is also connected to receive the output signal voltage of the summing amplifier **51**, which is positive. Since the output signal voltage from the voltage divider **87** will be negative, the summing amplifier **53** will produce an output signal equal to the difference in magnitude between the two input signals. The output signal voltage of the summing amplifier **53** will be positive until the magnitude of the output signal voltage of the amplifier **51** is exceeded by the output signal voltage from the voltage divider **87** whereupon the output signal voltage of the summing amplifier **53** will become negative. The output signal voltage of the summing amplifier **53** is applied to a negative voltage detector **89**, which will produce an output signal at the time that the output signal voltage of the summing amplifier **53** becomes negative. As pointed out above, the output signal voltage of the summing amplifier **51** represents the amount that the output signal of the range selector **11** exceeds the lower limit of the voltage increment in which the output signal falls as detected by one of the detectors **20–29**. The summing amplifier **53** will become negative and cause the negative voltage detector **89** to produce an output signal at a time following the production of a start pulse by the transducer **77** corresponding to the output signal voltage of the summing amplifier **51**. The angular position of the drum **55** relative to the start position at the time that the negative voltage detector **89** produces an output signal thus will correspond to the output signal voltage of the summing amplifier **51** and thus will correspond to the amount that the output signal of the range selector **11** exceeds the lower limit of the voltage increment in which the signal voltage falls as detected by one of the voltage level detectors **20–29**.

The output signal produced by the negative voltage detector **89** is applied to the gates **40–49** and will pass through the enabled one of the gates to a corresponding one of the series of the hammer drivers **90–99**, which then applies a firing pulse to the corresponding one of the hammers **60–69**. In this manner, one of the hammers **60–69** will be selected to be fired corresponding to the voltage increment in which the voltage signal level falls as detected by one of the detectors **20–29** and the time that the hammer is fired will correspond to the amount that the signal voltage exceeds the lower limit of the voltage increment in which the signal falls. Thus, a dot will be printed in a position displaced from the left side of the strip chart as would be viewed in FIG. **1**, corresponding to the amplitude of the output signal voltage of the range selector **11** at the proper time after each start pulse produced by the transducer **77**. The strip chart on which the printing is being carried out is continuously advanced so that the series of dots printed in this manner will form a graph representing continuously the amplitude of the output signal voltage of the range selector **11** and in this manner, the system records the output signal voltage of the range selector **11**. The speed of the strip chart is preferrably selected so that adjacent dots representing the same signal amplitude are substantially contiguous. Different ranges of amplitudes of the input signals applied to the range selector **11** are readily accommodated by changing the attenuation selected by the range selector **11**.

The series of voltage level detectors **20–29** is actually an analog to digital converter which converts the output signal voltage of the range selector into a digital representation with a radix of ten. The hammer to be fired is selected in accordance with the value of this digital representation. The fact that the time of actuation of the hammer is in response to a number of pulses produced can be considered to mean that the input analog signal is digitized into two digits, one digit selecting the hammer, and the second digit corresponding to the number of pulses selecting the time of actuation of the hammer. The radix of the two digits, however, is different, the first being ten corresponding to the number of hammers, and the second being one hundred and forty corresponding to the number of pulses produced per revolution of the drum **55**.

The circuitry of the range selector **11** is illustrated in FIG. **2**. As shown in FIG. **2**, the analog input signal is applied across a voltage divider **101** having a plurality of tabs which are connected to different contacts **103** of a range selector switch. The range selector switch has a movable pole **105**, which can selectively connect the output of the range selector to any of the contacts **103**, as shown. One of the contacts **103** provides a direct connection of the input signal to the output of the range selector. By moving the pole **105** to the desired contact, the attenuation of the input signal can be selected and thus a range for the recording of the signal can be selected.

FIG. **3** illustrates the circuit of the voltage level detector **29**. The remaining voltage level detectors **20–28** are similar to the voltage level detector **29**, as shown in FIG. **3**, except they do not have an output indicating that the input signal is off scale. As shown in FIG. **3**, the output signal of the range selector **11** is applied to an input of a summing amplifier **111**. A reference voltage of $-0.9E_R$ is applied to the other input of the summing amplifier **111**. Accordingly, the output of the summing amplifier **111** will be positive if the output voltage received from the range selector **11** is greater than $0.9E_R$ and will be negative if the output voltage from the range selector is less than $0.9E_R$. The output from the summing amplifier **111** is applied to another summing amplifier **113** and to a gate **115**. A reference voltage of $-0.1E_R$ is applied to a second input of the summing amplifier **113**. Thus, if the output of the summing amplifier **111** is positive, but is less than $0.1E_R$, the output of the summing amplifier **113** will be negative, and if the output of the summing amplifier **111** is positive and is greater than $0.1E_R$, the output of the summing amplifier **113** will be positive. Accordingly, the output of the summing amplifier **111** will be positive and at the same time, the output of the summing amplifier **113** will be negative only if the output signal from the range selector **11** is between $0.9E_R$ and E_R. The gate **115** operates to detect the combination of polarities from the summing amplifiers **111** and **113** and will produce a signal on its output **117** if the output signal from the summing amplifier **111** is positive and at the same time the output signal from the summing amplifier **113** is negative. If the output signal from the summing amplifier **111** is positive and the output signal from the summing amplifier **113** is also positive, this will mean that the output signal from the range selector is greater than E_R which will be off scale for the recorder. The gate **115** detects this, and provides an off scale indicating signal on output **119**. The off scale signal could be used to automatically change the range in the range selector **11**. If the output signal from the range selector **11** is less than $0.9E_R$, the output signal from the summing amplifier **111** will be negative, and accordingly, the output signal from the summing amplifier **113** will also be negative. Thus, under these conditions, the gate **115** will not produce an output signal. The remaining voltage level detectors **20–28** are the same as that shown in FIG. **3** except that the reference voltage applied to the summing amplifier **111** is selected to correspond with the lower limit of the voltage increment being detected by the detector. For example, the voltage level detector **25** will have a reference voltage of $0.5E_R$ applied to its summing amplifier **111**.

As shown in FIG. **4**, the E_R switch comprises a voltage divider **121** comprising 10 equal resisotrs connected in series from the reference voltage E_R to ground. Taps are taken off between each adjacent pair of resistors and at ground and connected to the inputs of linear gates **130–139**, which as pointed out above, pass the applied analog voltage to their outputs when enabled. The outputs of the linear gates **113** are connected in common to the output of the E_R switch. Each of the linear gates is selectively enabled by the output of the corresponding voltage level detector so the E_R switch will produce an analog output voltage equal to the lower limit of the voltage increment in which the input signal falls as detected by the voltage level detectors **20–29.**

The invention as described above in its narrower aspects employs a helical bar printer with a plurality of convolutions to achieve the dramatically reduced full scale response time with high resolution and precision. However, the invention in its broader aspects contemplates other dot printing means in place of the helical bar printer in combination with the voltage level detectors or other equivalent means to establish consecutive voltage ranges in which the input signal may fall or to convert the input signal to a digital representation.

Moreover, it is contemplated that the multi-convolution helical bar arrangement might be used to print electrostatically rather than by impact or by pressure. In such an arrangement, the graph would be printed on electrosensitive paper. Instead of hammer blades, electrically conducting marking blades would be employed to coact with an electrically conducting helical bar. The marking blades or the helical bar, or both, would be in light contact with the electrosensitive paper. When a selected blade is energized, the resulting electrostatic action between the blade and the helical bar will print a dot on the electrosensitive paper. The system would select one of the marking blades in response to the analog input in the same manner as the printer described above and the selected blade would be electrically energized at the proper time to print a dot in the appropriate position to represent the input analog signal.

Many other modifications may be made to the above described specific embodiment of the invention without departing from the spirit and scope of the invention, which is defined in the appended claims.

I claim:

1. A recorder for recording a graph of a variable value comprising a plurality of adjacent dot printing means arranged in a row each operable to print a dot in any selected one of adjacent dot positions along a print line extending in the direction of said row, each dot printing means comprising a single dot marker having at least a portion movable to each of the dot positions corresponding to such dot printing means and being operable to print a dot at any one of said dot positions along said print line by movement of said portion to the selected dot position and actuation of such dot marker to print a dot at the selected dot position, means to establish a plurality of consecutive analog ranges into which variable value may fall, each of said ranges corresponding to a different one of said dot printing means, and control means to select the dot printing means corresponding to the range in which said variable value falls and to actuate the dot marker of the selected dot printing means to print a dot in position along the print line thereof selected in accordance with where said variable value falls in the range corresponding to the selected dot print means.

2. A recorder as recited in claim **1,** wherein said plurality of dot printing means comprises a helical bar having a plurality of convolutions, and a plurality of marking blades positioned adjacent to said bar, each spanning one of said convolutions, each of said dot markers comprising one of said convolutions and one of said marking blades and being operable to print a dot at the intersection between the blade and said bar when actuated.

3. A recorder as recited in claim **2,** wherein there is provided means to rotate said helical bar continuously about its axis and wherein said control means comprises timing means to actuate the dot marker of the selected dot printing means at a time interval after said helical bar has passed a predetermined start position corresponding to where said variable value falls in the range corresponding to the selected dot printing means.

4. A recorder as recited in claim **3,** wherein said timing means comprises means to generate pulses as said helical bar rotates and means responsive to the number of pulses generated to actuate the dot marker of the selected dot printing means when the number of pulses generated reaches a value corresponding to where said variable value falls in the range corresponding to the selected dot printing means.

5. A recorder as recited in claim **2,** wherein each of said marking blades comprises a hammer operable to strike said helical bar to print a dot.

6. A recorder for recording a variable value comprising means to convert said variable value into a digital representation, a plurality of adjacent dot printing means arranged in a row, each operable to print a dot in any selected one of a plurality of adjacent dot positions along a print line extending in the direction of said row, each of said dot printing means corresponding to a different value of said digital representation, each dot printing means comprising a single dot marker having at least a portion thereof movable to each of the dot positions corresponding to such dot printing means and operable to print a dot at any one of said dot positions along said print line by movement of said portion to the selected dot position and actuation of such dot marker to print a dot at the selected dot position, and control means responsive to said digital representation to select the dot printing means corresponding to the digital value of said digital representation and to cause the dot marker of the selected dot printing means to print a dot in a position along the print line thereof selected in accordance with the amount that said variable value varies from the value of said digital representation.

7. A recorder as recited in claim **6,** wherein said plurality of dot printing means comprises a helical bar having a plurality of convolutions, and a plurality of marking blades positioned adjacent to said bar, each spanning one of said convolutions, each of said dot markers comprising one of said convolutions and one of said marking blades and being operable to print a dot at the intersection of the blade and said bar when actuated.

8. A recorder as recited in claim **7,** wherein there is provided means to rotate said helical bar continuously about its axis and wherein said control means comprises timing means to actuate the dot marker of the selected dot printing means at a time interval after said helical bar has passed a predetermined start position corresponding to the amount that said variable value differs from the value of said digital representation.

9. A recorder as recited in claim **8,** wherein said timing means comprises means to generate pulses as said helical bar rotates and means responsive to the number of pulses generated to actuate the selected dot printing means when the number of pulses generated reaches a value corresponding to the amount that said variable value differs from the value of said digital representation.

10. A recorder as recited in claim 6, wherein each of said marking blades comprises a hammer operable to strike said helical bar to print a dot.

11. A method of recording a graph of a variable value with a dot printer having a plurality of adjacent dot markers arranged in a row along corresponding segments of a print line, each of said dot markers having at least a portion thereof movable to a plurality of dot positions in the corresponding segment and being operable to print a dot in any selected one of said dot positions along the corresponding segment by motion of said portion to the selected dot position and actuation of such dot marker at the selected position, comprising the steps of converting said variable value into a digital representation comprising a most significant digit having a radix equal to the number of said dot markers, selecting one of said dot markers in accordance with the value of said most significant digit, moving the movable portion of the selected dot marker to a position along the corresponding segment thereof selected in accordance with the difference between the value of said variable value and said most significant digit, and actuating the selected dot marker to print a dot at the selected position.

12. A method of recording a graph of a variable value as recited in claim 11, wherein the movable portions of said dot markers are moved to a selected position and actuated to print a dot at the selected position by cyclically scanning the movable portions of said dot markers through the corresponding segments thereof and timing the actuation of the selected dot marker to print a dot at the selected position as the movable portions of the selected dot marker scans past the selected position.

* * * * *