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(54) Time of flight measurement for ink jet printers.

(57) Apparatus for giving an indication of the time of flight of the ink stream of an ink jet printer comprises detector means (16) towards which one or more selected droplets of the ink stream may be directed by a deflection system comprising charging electrode (5) and deflecting electrodes (8). The detector means detects the presence of the selected droplets to give an indication of the time of flight of the said droplets.

The time of flight may be calculated and displayed, or employed to control printing paramaters such as ink supply pressure, deflecting charge or the rate at which items to be printed are conveyed past the printer. The time of flight also acts as a useful "state of health" monitor, to detect blockages or other malfunctions of the printer.

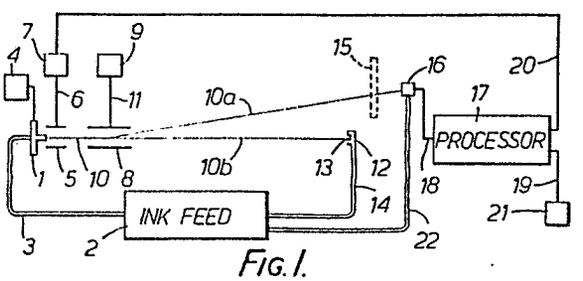

FIG. 1.

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Time of Flight Measurement for Ink Jet Printers

This invention relates to a method and apparatus for giving an indication of the time of flight of the ink jet stream of an ink jet printer.

In ink jet printing, a stream of ink is ejected from a nozzle and strikes a recording member. Means are provided for controllably electrically deflecting individually charged droplets in the ink stream before they strike the recording member, the member usually being moved past the ink stream so that a printed trace, code or other indicia can be formed.

Ink jet printers are known which can achieve the printing of alpha-numeric characters at extremely fast print out rates. To enable the printing of complex characters and patterns, the accurate placement of individual ink droplets on to the recording member must be achieved. Hence the ink jet stream must be very closely controlled in order to prevent inaccuracy of drop placement significantly reducing the legibility of the printed indicia.

One type of control for the ink stream is described in UK Patent no 1211955. This provides a method of synchronising a vibratory signal applied to the ink stream to break it into droplets, with the signal applied to a charging electrode in order to charge that droplet. This ensures that the electric field is applied just as each droplet breaks away from the ink stream, rather than before or after it breaks away. It is an object of the present invention to provide further data regarding the performance of an ink jet printer, in order to enable the ink stream to be more accurately manipulated.

Accordingly there is provided apparatus for giving an indication of the time of flight of the ink stream of an ink jet printer

comprising detector means, deflection means for selectively causing one or more droplets of the ink stream to be directed towards the detector means, said detector means being adapted to detect the presence of the selected one or more droplets at a predetermined position thereby to give an indication of the time of flight of said droplets between the deflecting means and the predetermined position.

Obtaining an indication of the time of flight of the ink stream of an ink jet printer is not only of use in controlling that stream. The time of flight is a monitor of the pressure at which ink is issuing from the nozzle of the printer. Furthermore, the time of flight is a useful 'state of health' monitor for the jet printer. If the time of flight starts to increase, or alternatively starts to vary erratically, this is an indication that the ink jet printer is running less than optimally. Blockages at the jet nozzle, or in the ink feed system will all show up as increased time of flight measurements, indicating that the printer requires maintenance or attention.

There is preferably provided timing means adapted to determine the time elapsed between actuation of the deflection means to cause the selected one or more droplets to be directed towards the detector means and the detection of said droplets at the predetermined position. The elapsed time may be displayed visually or recorded as performance data to be evaluated as desired. Alternatively the elapsed time may be used to actuate an alarm if the time exceeds a predetermined value. The time data may also be used to exert control over some aspect of the ink jet printer, for example the deflection means or alternatively the ink feed pressure. In another alternative arrangement the elapsed time data may be used to control the operation of associated equipment, for example the speed of movement of the recording member.

The deflection means conveniently comprises at least one charging electrode positioned in the region at which the ink jet breaks into droplets, means for applying a charging signal to said charging electrode so as to apply a corresponding charge to

droplets forming thereat, and at least one deflecting electrode adapted to provide an electric field thereby to cause said charged droplets to be directed towards the detector means.

In order to determine an elapsed time it is necessary to actuate the timing means to begin measurement. This is preferably achieved by means of a 'start' signal, conveniently in the form of a step voltage change in the charging signal applied to the charging electrode. In one arrangement the charging signal is in the form of a square wave. Preferably the charging signal is a stepped voltage, adapted to charge successive droplets to differing degrees. Such a stepped voltage can be made to produce a 'bar' of droplets directed towards the detector means.

The detector means conceivably comprises a conductor element on which there can be generated an induced charge on the approach of a charged droplet. With this arrangement there is conveniently provided trigger means adapted to be actuated when the induced charge exceeds a predetermined value.

Alternativly the said predetermined position is at the detector means. Preferably the detector means comprises a conductor element against which the selected one or more droplets are allowed to impinge, the conductor element being adapted to receive an electric charge from the said one or more droplets and provide an electric current in response thereto. Such a current can be amplified and employed to actuate a logic circuit constituting part of the aforementioned timing means.

In an alternative arrangement the detector means comprises an element of piezoelectric material against which the selected one or more droplets are allowed to impinge, the piezoelectric element being adapted to produce electric signals in response thereto. As before, such electric signals can be amplified and employed to actuate a logic circuit.

In another alternative arrangement the detector means comprises an energy responsive element, and an energy source adapted to produce a beam of energy, which beam may be interrupted by the

passage of the selected one or more droplets. Conveniently the energy source is a light emitting diode and the energy responsive element a photodetector.

According to a further aspect of the present invention there is provided an ink jet printer incorporating apparatus for giving an indication of the time of flight of the ink stream as previously described.

According to a still further aspect of the present invention there is provided a method of obtaining an indication of the time of flight of the ink stream of an ink jet printer comprising the steps of selectively causing one or more droplets of the ink stream to be directed towards a detector means, detecting the presence of the selected one or more droplets at a predetermined postion, and giving an indication of the time of flight of said droplets between their being caused to be directed and being detected at said predetermined position.

Preferably the above method includes the step of measuring the time elapsed between said one or more droplets being caused to be directed towards the detector means and the detection of said droplets at the predetermined position.

Some embodiments of the invention will now be described in further detail, by way of example only, with reference to the accompanying drawings in which,

Figure 1 is a schematic diagram of an ink jet printer incorporating time of flight measuring apparatus according to the invention,

Figure 2 is a schematic view of the detector of figure 1,

Figure 3 is a circuit diagram of the amplifier of figure 1,

Figure 4 shows a typical trace obtained from the amplifier of Figure 3 with one type of signal applied to the charging electrode of Figure 1,

Figure 5 shows a typical trace obtained form the amplifier of Figure 3 when an alternative signal is applied to the charging electrode of Figure 1,

Figure 6 is a schematic diagram of a detector according to an alternative embodiment of the invention,

Figure 7 is a schematic diagram of a detector according to another alternative embodiment of the invention, and

Figure 8 is a schematic diagram of a detector according to yet another alternative embodiment of the invention.

Referring to Figure 1, an ink jet printer comprises a nozzle 1 provided with a supply of ink from ink feed 2 via pipe 3. A stream of ink 10 issuing from the nozzle 1 is encouraged to break up into discrete droplets by the vibration of the nozzle 1 by means of a vibratory source 4. In the region where the ink stream 10 breaks up into droplets there is positioned a cylindrical charging electrode 5 connected via line 6 to an electrical voltage source 7. Positioned further downstream of the ink stream 10 is a pair of plates constituting a deflection electrode 8. The electrode 8 is connected to a voltage source 9 by means of a line 11.

In use voltage source 7 is selectively variable so as to produce a variable charge on the charging electrode 5. Thus a correspondingly variable charge is applied to different droplets as they break up and pass the charging electrode 5. In contrast, voltage source 9 produces a substantially constant electric field between the plates of the deflection electrode 8. Thus droplets passing through this field are deflected by an amount dependent upon the charge which they carry. In the example illustrated in Figure 1 the ink stream 10 is split into a deflected stream of droplets 10a which have been charged by the charging electrode 5, and an

undeflected stream of droplets 10b which have been left uncharged by electrode 5.

Coaxially aligned with the nozzle 1 is a gutter 12 having an aperture 13 into which may be received ink drops from the undeflected ink stream 10b. Ink collected by the gutter 12 passes along a return pipe 14 and is returned to the ink feed 2. A pump (not shown) may be employed to assist in the movement of the ink along the return pipe 14.

The deflected ink stream 10a may be caused to impinge on the surface of a recording medium 15 such as a series of passing envelopes. By selectively varying the signal applied to the charging electrode 5 by the source 7, the ink stream may be switched between trajectories 10a and 10b, causing ink to be applied to the recording medium at will.

A detector 16 is positioned behind the recording member 15, the position of the detector being such that in the absence of the member 15 the deflected ink stream 10a is intercepted thereby. The detector 16 communicates with a processor 17 via line 18. Ink intercepted by the detector 16 is returned to the feed 2 via a second return pipe 22. The processor 17 has in turn two output lines 19 & 20, line 19 connecting the processor to a display unit 21, and line 20 connecting the processor to the voltage source 7 supplying the charging electrode 5.

In order to obtain an indication of the time of flight of the ink stream 10, the voltage source 7 is actuated such that a selected batch of droplets are charged to be deflected by electrode 8 along trajectory 10a. So that the selected batch of droplets may reach the detector 16, the recording member 15 must be removed or, alternatively in the case where the recording member is an intermittent entity such as a succession of envelopes, the batch must be timed to pass therebetween. When the droplets arrive at the detector 16, their presence is detected thereby and an

electrical signal is passed along line 18 to the processor 17. The processor 17 includes a timer (not shown) which calculates the time elapsed between actuation of the voltage source 7 and the detection of the droplets at the detector 16. The processor 17 uses this information to generate electrical output signals, one along line 19 to actuate the display 21, and another along line 20 to control the operation of the voltage source 7. Thus not only is a visual indication given regarding the time of flight of the ink stream, but the data may also be used in controlling the further operation of the printer.

Figure 2 shows one type of detector 16 suitable for use with the apparatus of Figure 1. The detector 16 comprises a cylinder cup 25 of metal or other electrically conductive material, the cup defining a chamber 23 therein. An open face 24 of the cylindrical cup 25 allows access to the chamber 23 from a direction left to right as shown in Figure 2. The cup 25 is mounted on a hollow neck 30 to which is attached the return pipe 22 of Figure 1. An aperture 26 is provided in the cup 25 to allow communication between the chamber 23 and the return pipe 22 via the hollow neck 30.

The conductive cup 25 is electrically connected by means of line 18 with the processor 17. The processor is constituted by an amplifier 27 and a timer 28 connected in series by line 29. The outputs from the processor can actuate a display or the electrode source 7 as previously described.

In use charged droplets 50 enter the chamber 23 and strike the conductive cup 25. The charge on the droplets 50 is transferred to the cup 25 and causes an electrical signal to be transmitted along line 18. The signal is amplified by amplifier 27 and used to operate timer 28 to give the required indication of flight time. The ink droplets 50, after striking the cup 25, pass through aperture 26 and are returned to the ink feed supply via return pipe 22.

Figure 3 shows an amplifier suitable for use as the amplifier 27 of Figure 2. The circuit comprises two operational amplifiers 30 employed as a two stage amplifier. Resistors 32, 33, and 34 are all typically 1k ohm, resistor 35 typically 1M ohm and resistor 36 typically 100 k ohm. The output from the two stage amplifier is fed to a Schmitt trigger 37 which transforms the output into a square wave prior to its processing by the timer 28.

Figure 4 shows a typical trace obtained from the amplifier of Figure 3. The vertical axis represents voltage and the horizontal axis time. The top trace 40 is the signal applied to the charging electrode 5 from the voltage source 7. The middle trace 41 is the signal generated by the detector 16 after amplification by the two stage amplifier 27. The bottom traced 42 is the output signal from the amplifier after the operation of Schmitt trigger 37. The time of flight indication to be obtained by the timer is the time t between the applying of the signal 40 and the detection of the signal at the detector as represented by the first square wave 43.

Figure 5 shows a similar trace, obtained by the application of a stepped voltage as shown at 44 to the charging electrode. Successive droplets will each be charged to a slightly greater degree and hence the signal 45 received at the amplifier will be correspondingly stepped. It should be noted that the differing charges carried by successive droplets will cause them to be deflected by slightly differing amounts. Hence a detector of a relatively larger area may be required in order to receive all the intended droplets.

The action of the Schmitt trigger 37 will cause a regular square wave 46 to be produced. A plurality of time calculations t_1 to t_4 can be obtained for each droplet detected.

Figure 6 shows an alternative embodiment of detector 16. The detector comprises a disc 51 of conductive material connected to

an amplifier 27 by means of a wire 70. The disc has a central aperture 71 to allow the passage of droplets 50. Charged droplets 50 approaching the disc 51 induce in the disc an electric signal which is amplified by the amplifier 27. As previously described a Schmitt trigger 37 converts the induced signal to a square wave which can be input to a timer 28.

Figure 7 shows another alternative embodiment of detector 16. This detector comprises a light emitting diode (L.E.D) 52 which emits a beam of light 53 which is detected by a photodetector 54. Ink droplets 60 passing between the LED 52 and photodetector 54 interrupt the light beam 53 and cause an electric signal to be passed along a line 55 to an amplifier 27. The amplified signal is passed to a timer 28 to give an indication of the time of flight as previously described.

Figure 8 shows yet another alternative embodiment of detector 16. In this detector a cylindrical cup 25 similar to that described with relation to Figure 2 acts to define a chamber 23 therein. Aperture 26, neck 30 and return pipe 22 are all as previously described. However unlike the previously described arrangement, the chamber 23 further contains a piezoelectric crystal 61. A line 62 passing through a further aperture 63 in the cup 25 provides an electric connection between the crystal 61 and an amplifier 27. Ink droplets 60 impinging on the piezoelectric crystal 61 cause it to deform and hence become charged. The electrical signal thus resulting travels along line 62 and is amplified by amplifier 27. The resulting signal is converted to a square wave by a Schmitt trigger 37 and fed to a timer 28 as previously described.

It should be noted that the detectors described above with reference to figure 7 and 8 are able to detect the presence of droplets 60 regardless of whether or not they carry an electric charge. The detectors of Figures 2 and 6 employ the charge on the droplets in order to detect their presence and hence can be used only where the droplets to be detected are charged accordingly.

It will be obvious to those skilled in the art that other detector configurations are possible still falling within the scope of the present invention.

CLAIMS

1. Apparatus for giving an indication of the time of flight of the ink stream (10) of an ink jet printer characterised by detector means (16), deflection means for selectively causing one or more droplets of the ink stream to be directed towards the detector means (16), said detector means being adapted to detect the presence of the selected one or more droplets at a predetermined position thereby to give an indication of the time of flight of said droplets between the deflection means and the predetermined position.

2. Apparatus according to claim 1 characterised in that there is provided timing means adapted to determine the time elapsed between actuation of the deflection means to cause the selected one or more droplets to be directed towards the detector means (16), and the detection of said droplets at the predetermined position.

3. Apparatus according to claim 1 or claim 2 characterised in that the deflection means comprises at least one charging electrode (5) positioned in the region at which the ink jet breaks into droplets, means (7) for applying a charging signal to said charging electrode(5) so as to apply a corresponding charge to droplets forming thereat, and at least one deflecting electrode (8) adapted to provide an electric field thereby to cause said charged droplets to be directed towards the detector means (16).

4. Apparatus according to claim 3 characterised in that the charging signal is in the form of a square wave.

5. Apparatus according to claim 4 characterised in that the charging signal is a stepped voltage, adapted to charge successive droplets to differing degrees.

6. Apparatus according to any of claims 1 to 5 characterised in that the detector means (16) comprises a conductive element (51) on which there can be generated an induced charge on the approach of a charged droplet.

7. Apparatus according to claim 6 characterised in that there is provided trigger means (37) adapted to be actuated when the induced charge exceeds a predetermined value.

8. Apparatus according to any of claims 1 to 5 characterised in that said predetermined position is at the detector means.

9. Apparatus according to claim 8 characterised in that the detector means (16) comprises a conductor element (25) against which the selected one or more droplets are allowed to impinge, the conductor element (25) being adapted to receive an electric charge from the said one or more droplets and provide an electric current in response thereto.

10. Apparatus according to claim 8 characterised in that the detector means (16) comprises an element of piezoelectric material (61) against which the selected one or more droplets are allowed to impinge, the piezoelectric element (61) being adapted to produce electric signals in response thereto.

11. Apparatus according to claim 8 characterised in that the detector means (16) comprises an energy responsive element (54), and an energy source (52) adapted to produce a beam of energy (53), which beam may be interrupted by the passage of the selected one or more droplets.

12. Apparatus according to claim 11 characterised in that the energy source (52) is a light emitting diode.

13. An ink jet printer characterised in that it incorporates apparatus for giving an indication of the time of flight of the ink stream, as claimed in any of claims 1 to 12.

14. A method of obtaining an indication of the time of flight of the ink stream (10) of an ink jet printer characterised in that it comprises the steps of selectively causing one or more droplets of the ink stream to be directed towards a detector means (16), detecting the presence of the selected one or more droplets at a predetermined position, and giving an indication of the time of flight of said droplets between their being caused to be directed and being detected at said predetermined postion.

15. A method according to claim 14 characterised in that it includes the step of measuring the time elapsed between said one or more droplets being caused to be directed towards the detector means (16) and the detection of said droplets at the predetermined position.

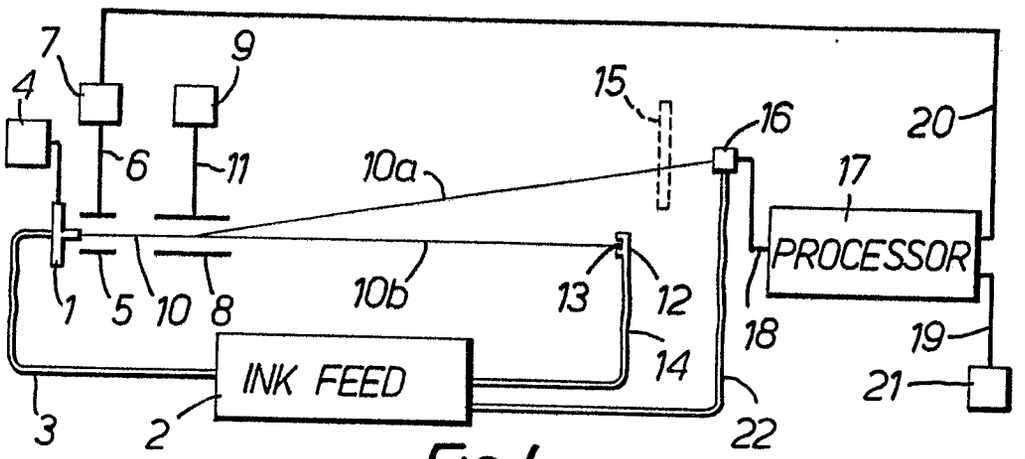

FIG. 1.

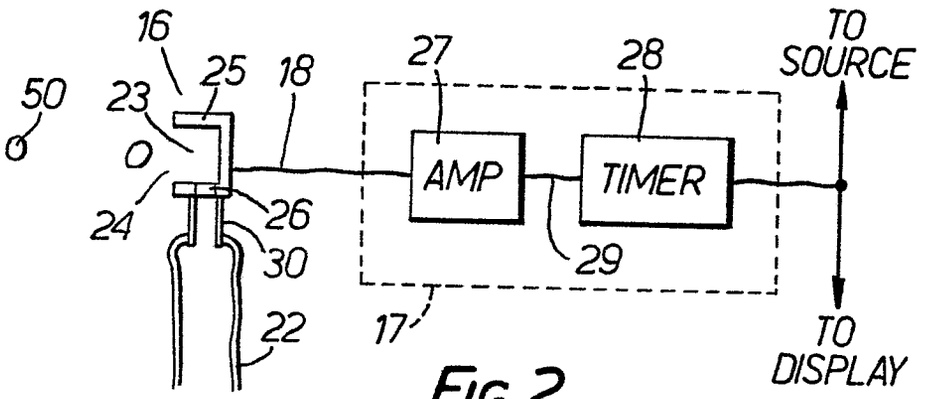

FIG. 2.

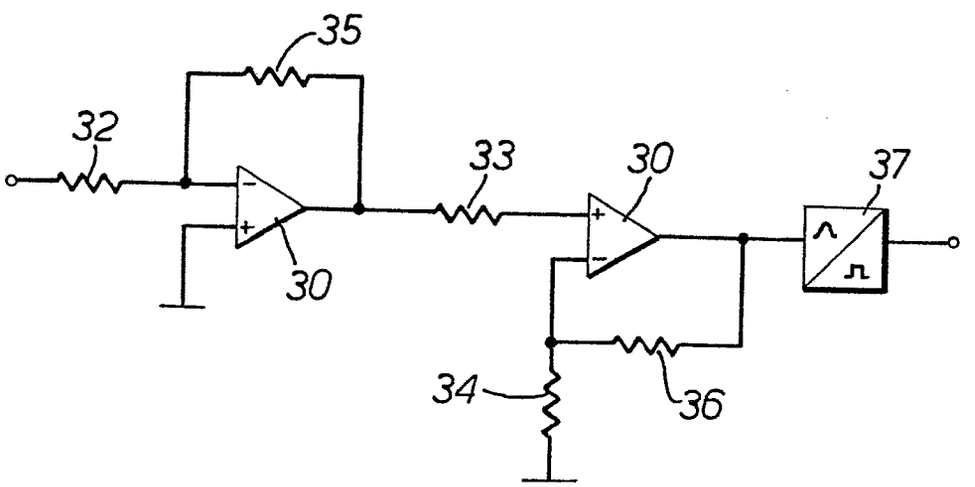

FIG. 3.

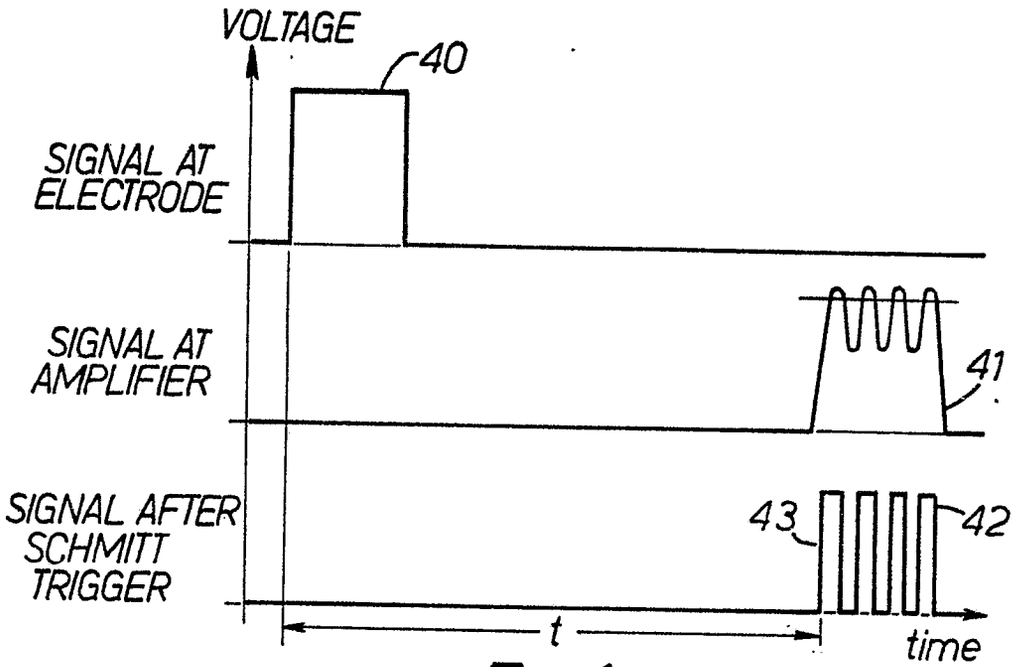
VOLTAGE
40
SIGNAL AT ELECTRODE
SIGNAL AT AMPLIFIER
41
SIGNAL AFTER SCHMITT TRIGGER
43
42
t
time

FIG. 4.

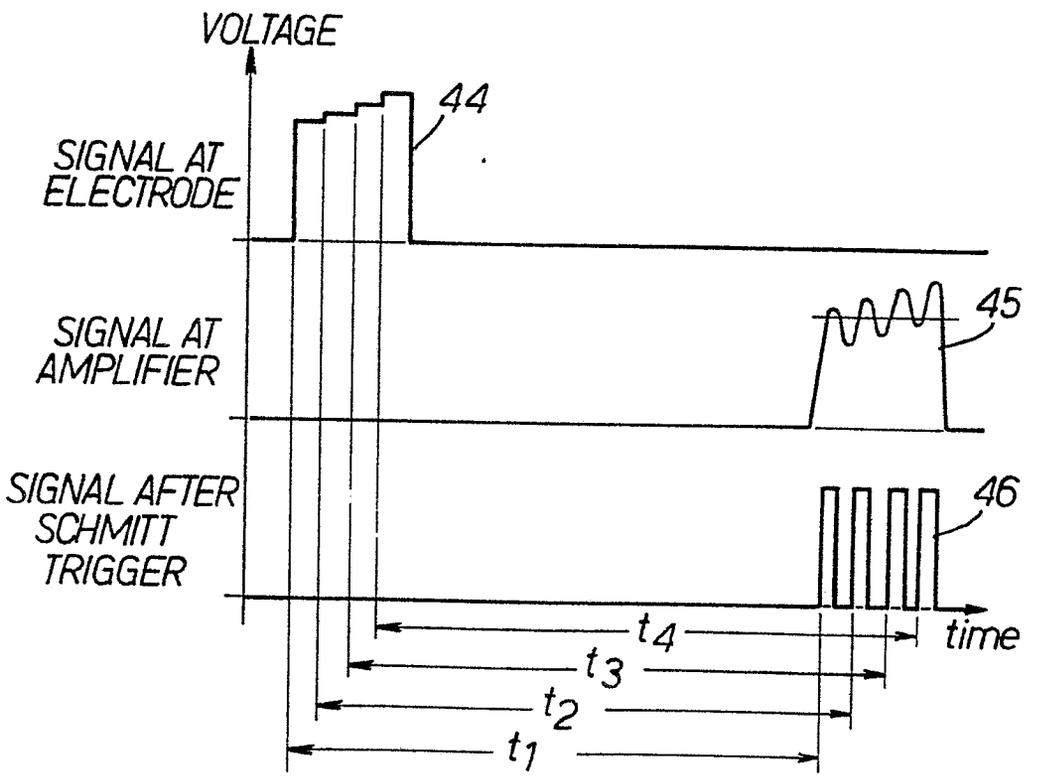
VOLTAGE
44
SIGNAL AT ELECTRODE
SIGNAL AT AMPLIFIER
45
SIGNAL AFTER SCHMITT TRIGGER
46
t_4
t_3
t_2
t_1
time

FIG. 5.

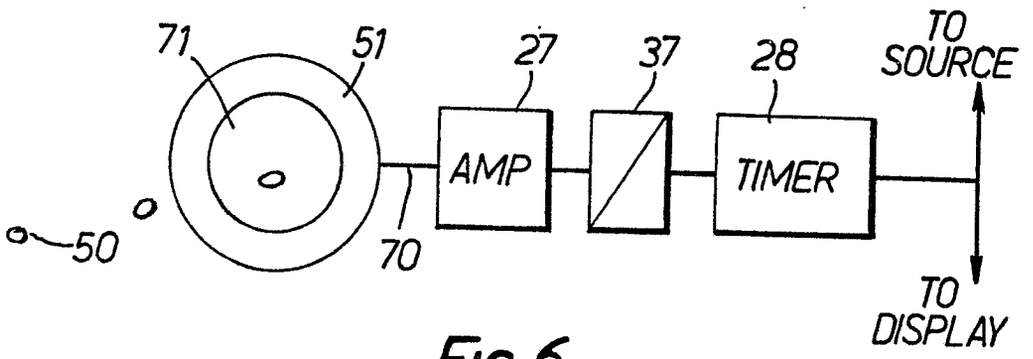

FIG. 6.

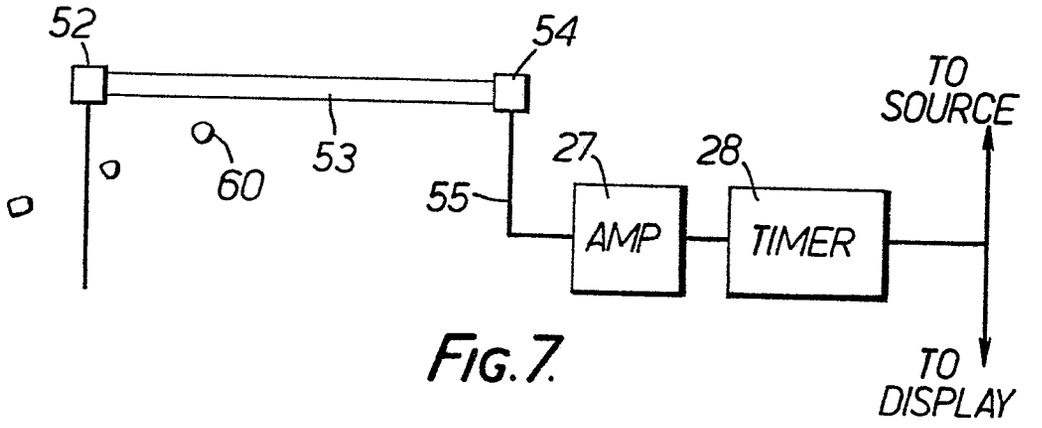

FIG. 7.

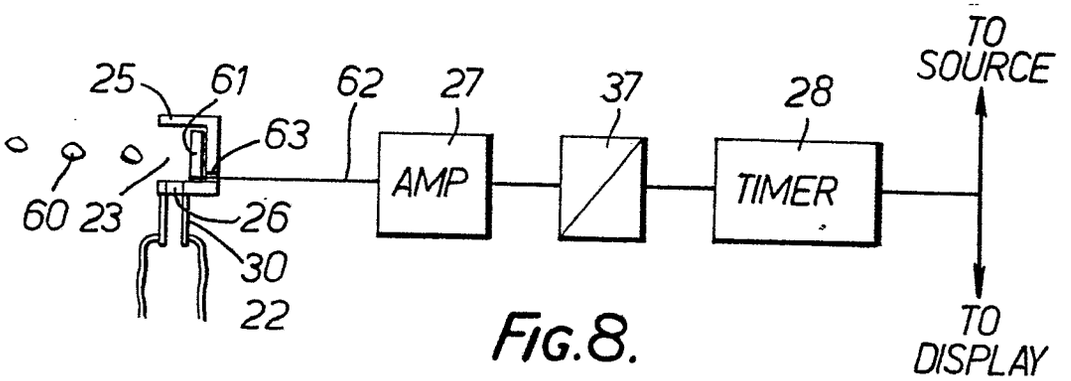

FIG. 8.