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(54) Droplets-generating device for an ink jet printer.

(57) Printing apparatus suitable for use as a dot matrix printer is provided with an elastic medium, such as an elongate metal or alloy member 18, extending across the print field, the member being associated with some form of ink deposition mechanism (not shown) such as an inked fibre provided on the member, or a trough arrangement containing ink. Pulses P_s, P_m are transmitted in opposite directions along the member 18, either from two transducers T_1, T_2 or from one transducer in two series of pulses, the first being reflected at the end of the member opposite the transducer and returning to meet the second series. The pulses travelling in opposite directions combine constructively to provide momentary stationary impulses P_c which actuate the ink deposition mechanism. Pulses of smaller amplitude do not actuate the mechanism thereby avoiding spurious printing. Thus relative timing of the pulses produced by the transducer(s) will determine the positions of the printed dots.

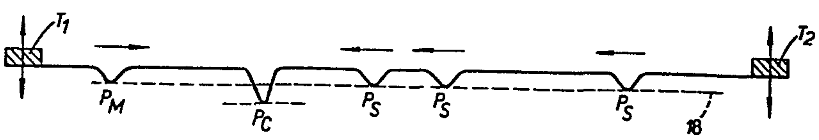

FIG. 4.

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Croydon Printing Company Ltd.

TITLE MODIFIED
see front page

PRINTING APPARATUS

The present invention relates to printing apparatus of an improved type.

Many different types of printing apparatus are used to provide permanent or hard copy in a variety of specific applications. For example, in the data processing or computer industries, so-called dot matrix printers are widely used which generate a printed image by means of a number of closely spaced dots. In general, these and other types of printers are complex mechanisms which are expensive to produce and which tend to be unreliable in operation compared with the associated electronics. Some types include a carriage arranged to traverse or scan a field of print with an ink depositing mechanism mounted on the carriage and being actuated on command. If no moving carriage is provided, a sufficient number of dot-printing elements must be included across the field of print to create sufficient resolution of the printed image, and again some means of selectively activating these elements is necessary.

U. S. Patent No. 4,167,742 discloses a printer of the latter type wherein the technique used is to produce a jet of ink sequentially from a series of orifices and then selectively to direct the ink either on to the paper or to an ink catcher for saving excess ink, the selective directing being achieved by electrostatic means interacting with appropriately charged ink droplets. The sequential production of ink jets from the orifices provided in an elastic plate is achieved by mechanically stimulating the orifice plate by a stimulating probe which causes a series of bending waves to travel along the orifice plate in the direction of the rows of orifices, whereby the arrival of each bending wave at a particular orifice or column of orifices causes a jet or droplet of ink to be ejected therefrom.

A problem with this type of printer is that of clogging of the individual orifices by the solid ink particles when the solution in which they are dissolved evaporates. Furthermore, either a moving carriage must be provided, or a sufficient number of individual orifices in the plate to generate a complete line of dot printing. In addition, the electrostatic deflecting mechanism must be finely adjusted so that a correct electrostatic "address" is generated at the exact moment when a corresponding ink droplet is suitably positioned either to be directed on to the paper, or to the ink catcher.

It is an object of the present invention to provide improved printing apparatus of the excited elastic medium type which overcomes or substantially alleviates the above problems.

The present invention provides a printing apparatus comprising an elastic medium means, an ink deposition means associated with said elastic medium means and positioned proximate to a material for printing thereon, and a pulse excitation means arranged to induce pulses to travel through said elastic medium means and thereby cause said ink deposition means to deposit ink on the material, characterised in that said pulse excitation means is arranged to generate pulses travelling in two converging directions through said elastic medium means so that a combined impulse is produced when pulses converge and meet, and said ink deposition means is responsive only to the combined impulses to deposit ink on the material, no ink deposition resulting from single generated pulses.

In one embodiment of the invention, an exciter transducer is positioned at each end of the elastic medium means which is in the form of an elongate member. Pulses travel down the member in opposite directions, and where they combine, the resulting impulse is sufficient to activate the ink deposition mechanism to generate an ink droplet.

In another embodiment, a single exciter transducer is positioned at one end of the elongate elastic member, and provision is made at the other end for reflection of the pulses to occur. The mode of operation is then for one pulse or series of pulses of one polarity to be generated, and then for further pulses of opposite polarity to be generated from the transducer. The first pulses undergo a polarity reversal upon reflection, and when returning towards the transducer, they encounter further pulses; their polarities now being identical, the pulses combine to produce the ink depositing impulses.

By this process, selective addressing of the locations at which a dot is to be printed is achieved, without the need for providing further means such as the electrostatic deflecting mechanism of the prior art document discussed above.

In order that the present invention may be more readily understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a partly schematic front view of one embodiment of the invention;

Figure 2 is a cross-section of the embodiment shown in Figure 1 taken along the line 2-2;

Figure 3 is a cross-section of the embodiment shown in Figure 1 taken along the line 3-3;

Figure 4 is a representative diagram showing pulses travelling along the elastic medium in accordance with the invention;

Figure 5A and 5B are similar cross-sectional views of an elastic medium and ink deposition means of another embodiment of the invention in two operating conditions;

Figure 6 is a partly schematic plan view of parts of the other embodiment showing an ink feed system; and

Figure 7 is a block diagram of a circuit for use in the invention.

Referring to Figures 1,2 and 3 of the drawings, one embodiment of printing apparatus includes a U-shaped frame 10 rotatably supporting a relatively small diameter high friction roller 11 by means of bearings 12,13 in respective extensions 14, 15 of the frame 10. As shown specifically in Figure 3, the roller 11 is sprung against two low friction pads 16,17 and in this form provides a paper feed mechanism, the paper (not shown) being fed between the roller 11 and the low friction pads 16,17 and tending to follow the roller in view of the relatively higher friction between paper and roller. An elastic strip 18 of a suitable material such as steel is stretched across the print field on the frame 10. An ink feed, such as an inked fibre 20, is incorporated in a central channel in the strip 18. As shown most clearly in Figure 2, a field coil 21 and magnet 22 arrangement are provided at one end of the frame 10; as will be explained below, a further field coil and magnet may also be provided at the opposite end of the frame 10. The field coil 21 receives signals representative of dots to be printed and the magnet 22 responds accordingly to cause the strip 18 to be excited. The use of the field coil 21 and magnet 22 arrangement provides a degree of damping, e.g. so as to prevent a single oscillation of the excitation means generating a number of corresponding oscillations in the strip. The relatively lightweight strip 18 responds to a relatively high frequency excitation, i.e. a fast pulse train, to produce a corresponding series of dots as will now be described.

Referring to Figure 4, the operation will initially be described with reference to the mode wherein two field coil/magnet transducers T_1, T_2, are provided at either end of the elastic member 18; subsequently operation with a single transducer will also be described.

In the case where two transducers are provided, if both transducers produce a pulse in the elastic member 18 simultaneously, these pulses will travel down the member at the relevant propagation velocity in the material of which the member is made, and will intercept at the centre. Momentarily, the pulses will overlap to form an effectively stationary combined pulse of greater magnitude than that of the individual pulses. Under appropriate conditions, the pulses will overlap, in accordance with Fourier synthesis, to form a pulse of double the magnitude of each individual pulse. This difference in pulse height between individual and combined pulses is used to trigger the ink deposition mechanism, so causing a dot to be produced in the centre of the field of print. In other words, the ink deposition mechanism is arranged to deposit ink only when a pulse above a certain threshold is produced, and that threshold is arranged to be greater than the height of individual pulses, but less than the height of combined pulses.

By varying the timing of the pulses from either end, a dot may be placed at any desired position. If the energy required to deposit a dot of ink is negligible compared with that invested in a pulse, a whole train of signal pulses P_S may be transmitted from one transducer T_2 to successively intercept a master pulse P_M from the other transducer, thus producing a whole row of dots where pulses superpose to form combined pulses P_C in a single traverse of the master pulse P_M. In this case it will be apparent that the timing between signal pulses will be related to the actual spacing of the dots to be printed. Different schemes of operation may be utilised wherein combinations of pulses from either end meet to print dots appropriately, but the mode using a single master pulse is the easiest to implement.

Rather than use two excitation transducers, a single unit, say T_2, may be used and a reflector substituted for the other transducer T_1. The resulting mode of operation is that a negative-going master pulse is transmitted followed after a suitable delay by a train of positive-going signal pulses. The master pulse is reflected at the reflector and undergoes a polarity reversal whereby it becomes positive and is able to combine constructively with the train of signal pulses (in similar manner to the two transducer mode) to produce a line of print. On the other hand, once the first of the signal pulses is reflected and returns in the opposite direction, it also undergoes a polarity reversal and hence will tend to cancel with the other oncoming signal pulses, rather than reinforce them, and thus spurious printing is avoided. The exciting transducer may also be used to dampen the returning pulse train and indeed may be used as a generator to recover the energy in the pulse train being damped and to recycle this energy for further operation. Thus, the overall power consumption of the printer may be reduced sufficiently to permit portable operation powered by suitable batteries.

The ink deposition mechanism described with reference to Figures 1,2 and 3 comprises a strip 18 with an inked fibre running in a channel provided in the strip. The ink deposition in this case results simply from mechanical vibration as a result of the combined impulse being sufficiently powerful to overcome the surface tension of the ink and any other forces tending to retain the ink in place, so that an ink droplet is ejected from the position where the pulses meet and combine, thus producing the required dot. However, any other ink deposition mechanism is suitable as long as it is arranged or can be adapted to react to a relatively small mechanical impulse at required locations across the print line. It is envisaged that a channel could be filled with liquid ink, and the ink itself act as the elastic medium means with the pulse travelling through the liquid.

Figures 5A and 5B show a different form of ink deposition mechanism which operates in a manner having similarities with ink jet systems. Instead of the elastic strip 18 described earlier, there is provided a trough 30, shown in cross-section, containing ink 31.

The trough 30 is typically of high aspect ratio and is made up of two walls 32,33 joined securely at the base, although not necessarily so. Indeed, the trough 30 may even be completely open at the bottom with support for the two side walls 32,33 being provided by ancilliary fixtures. One or both walls 32,33 are made from appropriate elastic material and these are arranged to respond to the transducer(s) to conduct the mechanical pulses along the length of the trough. The trough may be allowed to fill with ink under the influence of the capillary action of the ink meniscus. Progressive filling from the bottom of the trough with the subsequent elimination of bubbles may be expedited by the use of a tapering base to the trough, as shown in Figures 5A and 5B.

When a mechanical pulse is transmitted down the or each wall, the inclination of the wall will generate pressure in the ink which will cause displacement of the ink as shown in Figure 5B. The trough dimensions and pulse characteristics may be controlled so that a single pulse will not cause ink ejection, whereas the coincidence of two pulses travelling in opposite directions will cause such ejection and hence printing.

The width of the slot between the two walls 32,33 is typically 10-15 microns, and thus precautions against ink spillage need to be taken, since a slot width of about one micron would be needed if surface effects were to be relied on to retain the ink. The trough must clearly be kept full of ink for successful printer operation but no spillage should occur when the printer is moved or carried. A suitable ink feed system is shown in Figure 6. The trough 30 communicates with ink containers 35,36 at each end. These may conveniently be flexible walled vessels with sufficient capacity to store all the ink in the system. The surface tension forces at the meniscus in the trough 30 will retain the ink while the trough is level. When it is tilted, however, the ink will generate a head of hydrostatic pressure. If the trough length is appreciable it will not be difficult for this pressure to exceed that of the meniscus and leakage will occur. However, the resistance to fluid in the trough may be organised so that viscous drag substantially counteracts the effect of the hydrostatic head. If the inlets to the ink container 35,36 are correctly engineered, the ink will flow preferentially into the containers, rather than out through the ends of the trough. Such a system should provide the possibility of a relatively leakproof ink feed.

Producing profiles on the trough walls may control the ink flow without disturbing the meniscus and associated ink jet functions; also other profiles can be provided to improve the ink ejection.

In other respects, the remainder of the printer is similar to that shown in Figures 1,2 and 3.

Suitable materials for the trough 30, as also for the strip 18 in the first embodiment, are selected for the elasticity and low attenuation to elastic waves travelling through the material. Various metals and alloys thereof, such as aluminium, are found to be suitable in this respect.

Attenuation tends to approximate to a linear function with distance travelled, and the effect of this in the above-described system is that the summed or combined signal will tend to have a substantially similar amplitude to a first order of magnitude, irrespective of position. The reason for this is that the attenuation will be approximately proportional to the summed distance travelled by both pulses, and it will be seen that this summed distance will be a constant.

Although the system described with reference to Figures 5A and 5B includes essentially a trough with an open slot running the full length of the slot, a number of discrete openings could be provided instead if this were required for structural or any other reasons, as long as the "bridges" between openings did not have an excessively adverse affect on the attenuation factor, and as long as no positions where dots may be required were blocked by these "bridges".

The structure of Figures 5A and 5B is particularly effective in preventing clogging of the aperture by the ink. The normal operation of the mechanism itself provides a certain degree of self-cleaning by virtue of the continual flexing of the walls and variation in the width of the slot. Further cleaning and unclogging can be routinely effected by passing a "cleaning" pulse of greater magnitude (and possibly pulse width) which would serve to remove solid ink deposits. Clogging could also be minimised by designing the opening of the slot (possibly by having a slight closing taper to the slot cross-section similar to that shown in Figure 5B under pressure) so that the diffusion rate of the solid ink is matched with that of the vaporisation of the liquid solution, allowing the solid ink to diffuse back into the solution thus leaving no solid or crystalline deposition at the mouth of the slot.

The paper feed mechanism requires some means of feeding the paper on after each line of dots has been printed; this can be operated by a separate low-geared motor acting on the paper roller to step to the next line after a line has been completed, the motor and line printing being synchronised. An alternative feed mechanism dispenses with a separate motor and instead includes a large mass core disposed adjacent the field coil 21 of the excitation transducer arrangement. The first embodiment described with reference to Figures 1, 2 and 3 includes such a feed mechanism. Referring specifically to Figure 2, the roller 11 includes a recessed toothed gear arrangement 35 which is acted on by ratchet levers 36, 37 pivoted about point 38. The levers 36, 37 are suitably spring-biased and the lever 36 is made of, or includes, material which is responsive to the field coil 21 such that a low frequency signal fed to the field coil 21 attracts the lever 36 causing it to advance the paper feed roller by one line, by interaction with the toothed gear arrangement 35 provided on the roller 11. The roller is prevented from rotating in the opposite direction by spring-biased ratchet lever 37. As previously mentioned, the elastic member, whether the strip 18 or trough arrangement 30, is responsive to relatively high frequency excitation signals to print dots, but will not print if low frequency signals are applied; the high mass core (such as the lever 36), on the other hand, will only respond to low frequency signals and not to the relatively fast print pulse trains. Thus the field coil may be supplied with a combination of high and low frequency signals which will respectively result in printing and paper feed. This allows the complete printer operation to be controlled by a single signal path, i.e. two wire control.

In the embodiment provided with a single transducer, good reflection with minimum attenuation is achieved by clamping or anchoring the reflection end of the elastic member in a material having a high acoustic impedance compared to that of the elastic member. Acoustic impedance of a material is the product of the density and the velocity of sound in that material.

The pulse exciting transducer arrangement has previously been described in relation to a magnet/field coil system; however, other acoustic transducers can be utilised instead, one alternative being a piezo-electric transducer with an acoustic horn coupling the transducer to the elastic member. The acoustic horn may be of solid metal which then acts as an acoustic amplifying and transmitting medium.

Figure 7 shows a circuit suitable for use with the apparatus previously described. A computer 50, or other data processing equipment, sends a character train representative of characters or other matter to be printed to a character buffer 51 which stores this information and interreacts with a character generator reference memory 52 to provide a representation of the dots to be printed, line by line, to make up the required characters or the like. The dot representational pulse train is then fed to a signal train buffer 53 which stores this information. Thus far, the circuit is similar to that provided in conventional known dot matrix printers. The information stored in the signal train buffer 53 then needs to be read out at a suitable timing reference to provide dots in the required places. In the circuit as shown, this is achieved by generating clock pulses in a clock 54 which then read out the stored information serially from the buffer 53 (typically a shift register) to the signal pulse transducer T_2. The timing of the clock pulses is such that (referring to Figure 4) a complete line of signal pulses will have been produced across the print position; i.e. the clock pulses are produced at a rate equal to the length of the complete print scan divided by the maximum number of dots which can be produced and by the speed of wave propagation in the elastic medium. The clock 54 also produces a divided-down clock pulse to activate the master pulse transducer T_1. Typically, a single master pulse will be generated half-way through the signal pulse clock train, and this will "centre" the printed information on the material being printed. At the end of the required number of signal pulse clock signals, the clock 54 will reset and restart the process for a subsequent line of dots.

Since there are no discrete ink orifices provided in the above-described systems, it will be seen that the maximum resolution is not fixed but depends on the ink-ejection or depositing capabilities of an individual system, and the maximum clock rate which can be used therewith. Also, there is no requirement that the possible dot positions in consecutive lines need be located directly above each other; furthermore, if a given line is "scanned" more than once with offset dot-spacing between scans, resolution can be improved by "building up" the printed line with further information per additional scan. The present invention thus allows a very flexible approach to printing.

CLAIMS:

1. Printing apparatus comprising an elastic medium means (18), an ink deposition means (20) associated with said elastic medium means and positioned proximate to a material for printing thereon, and a pulse excitation means (21, 22) arranged to induce pulses to travel through said elastic medium means and thereby cause said ink deposition means to deposit ink on the material, characterised in that said pulse excitation means is arranged to generate pulses travelling in two converging directions through said elastic medium means so that a combined impulse is produced when pulses converge and meet, and said ink deposition means is responsive only to the combined impulses to deposit ink on the material, no ink deposition resulting from single generated pulses.

2. Printing apparatus according to claim 1, characterised in that said elastic medium means comprises an elongate member (18).

3. Printing apparatus according to claim 2, characterised in that said elastic medium means comprises an elongate receptacle (30) arranged to contain ink (31) and disposed across a material printing position, said ink deposition means being constituted by an opening in said receptacle adapted to eject ink when a combined impulse is produced by the meeting of two converging pulses in said receptacle.

4. Printing apparatus according to claim 3, characterised in that said elongate receptacle comprises a trough (30) formed by two walls (32, 33) at least one of which is made of elastic material, the walls being separate along one side of the trough to provide such opening for ejecting ink.

5. Printing apparatus according to claim 4, characterised in that said two walls (32, 33) of the trough (30) are joined securely at the base, the walls tapering towards the join so as to avoid production of air bubbles in the ink during filling.

6. Printing apparatus according to claim 3, 4 or 5, characterised in that an ink feed system is provided which comprises ink containers (35, 36) at either end of the elongate receptacle (30) and communicating therewith to provide the receptacle with ink.

7. Printing apparatus according to any one of claims 1 to 6, characterised in that said pulse excitation means comprises two excitation transducers (T_1, T_2) disposed relative to the elastic medium means (18), to provide converging pulses through the elastic medium means.

8. Printing apparatus according to any one of claims 1 to 6, characterised in that said pulse excitation means comprises an excitation transducer (21, 22) diposed relative to the elastic medium means (18) to provide a direct series of pulses from the transducer and a reflected series of pulses having been reflected at an interface of the elastic medium means, the direct and reflected series of pulses being arranged to converge.

9. Printing apparatus according to any one of the preceding claims, characterised in that said pulse excitation means (21, 22) receives signals at low and high frequencies, the high frequency signals providing the induced pulses in said elastic medium means for printing, the low frequency signals operating a feed mechanism for the material being printed.

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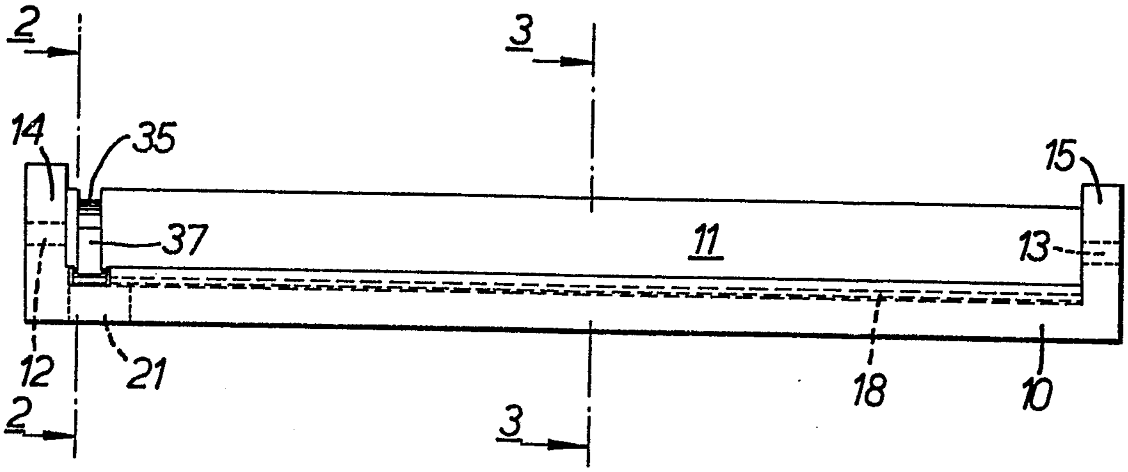

FIG. 1.

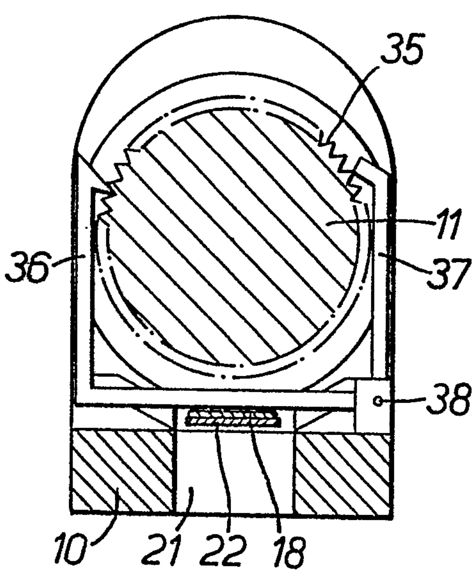

FIG. 2.

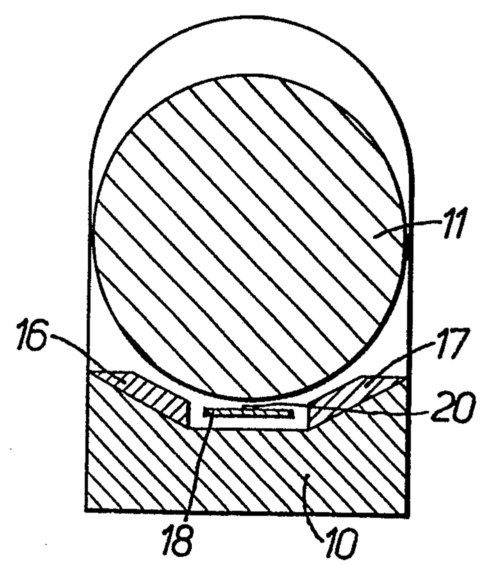

FIG. 3.

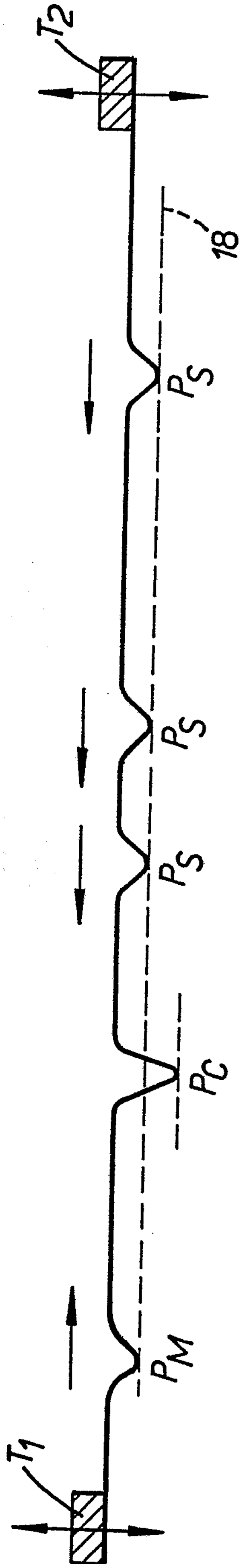

FIG. 4.

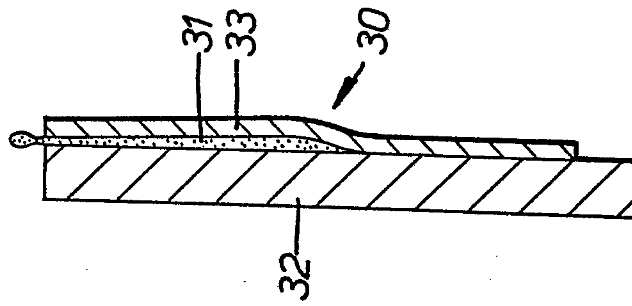

FIG. 5B.

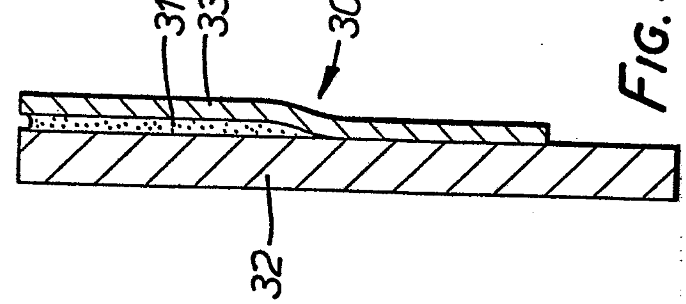

FIG. 5A.

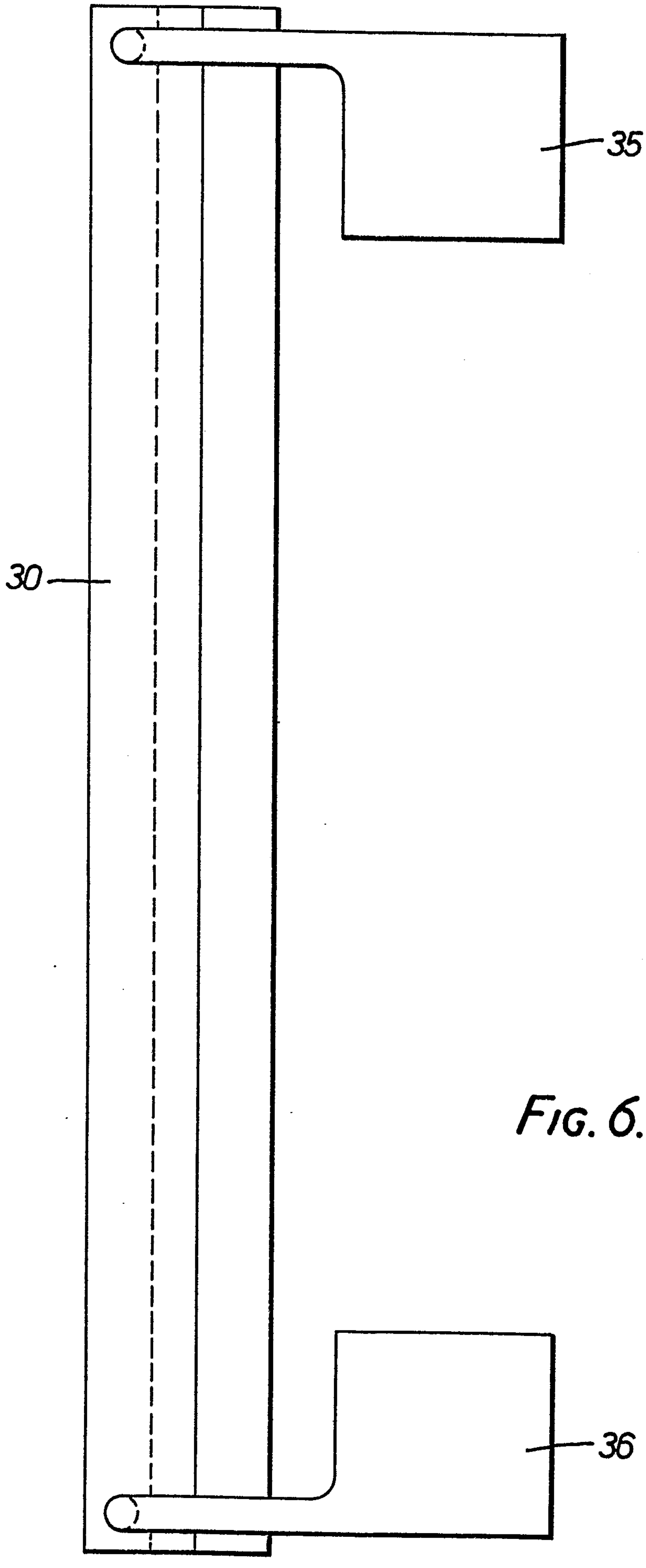

FIG. 6.

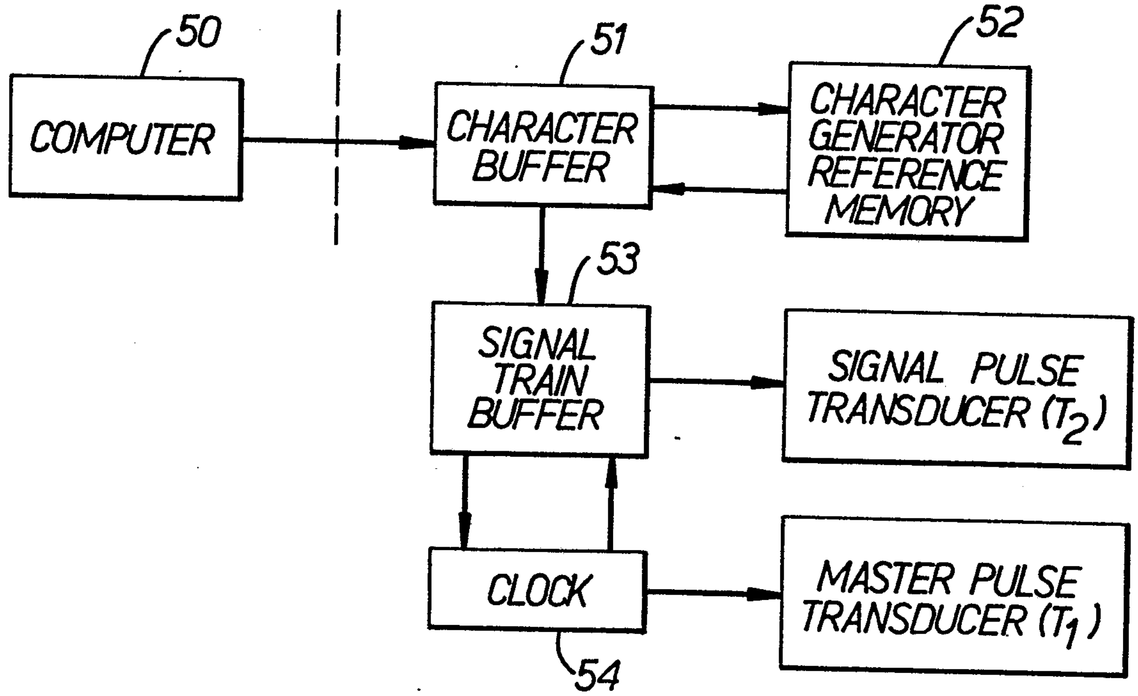
50
COMPUTER
51
CHARACTER BUFFER
52
CHARACTER GENERATOR REFERENCE MEMORY
53
SIGNAL TRAIN BUFFER
SIGNAL PULSE TRANSDUCER (T_2)
CLOCK
54
MASTER PULSE TRANSDUCER (T_1)

FIG. 7.

European Patent Office

EUROPEAN SEARCH REPORT

0072685
Application number

EP 82 30 4297

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Y	MÜLLER-POUILLETS: "Lehrbuch der Physik", vol. 1, part 3, edition 11, Fr. Vieweg & Sohn Akt.-Ges., 1929, Braunschweig (DE); Chapter I, ç12: "Interferenz sich begegnender Wellen. Stehende Wellen". & Chapter VII ç3:"Messung der Schallgeschwindigkeit aus Wellenlänge und Schwingungszahl". *Pages 31 till 35,389 till 393*	1	B 41 J 3/04
Y	US-A-4 104 645 (K.H.FISCHBECK) *Columns 7,65 till columns 9,15; figures 13,14*	1,7	
A	US-A-3 701 476 (P.H.HOUSER) *The whole document*	2,3	

TECHNICAL FIELDS SEARCHED (Int. Cl. 3)

G 01 D
B 41 J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	09-11-1982	VAN DEN MEERSCHAUT G

CATEGORY OF CITED DOCUMENTS

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