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(54) **Automatic identification apparatus.**

(57) An identification system is provided wherein one senses the position of optically significant features along the length of one or more fingers, such as the length and/or the optical characteristics of the under surface of one or more fingers. The finger to be measured is placed over a slot on the sensing device and at least a portion of the under surface of the finger is illuminated. A light pick-up device under the slot determines the position of optically significant features by means of light reflected from the finger.

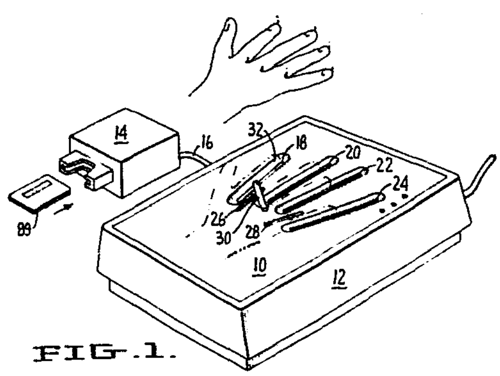

FIG. 1.

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IDENTIMAT

It has previously been determined that a reliable method of checking the identification of an individual is to measure the dimensions of a human hand and particularly the lengths of the various fingers. For instance, when it is desired to know whether an individual who presents a credit card is the proper holder of the credit card, one can compare the lengths of the fingers with stored data to determine with a high degree of accuracy whether the person presenting the card is the one to whom the card was issued.

The advantages of such identification systems are fully set forth in U.S. patents 3,576,538 and 3,648,240 both of which relate to identification systems based on the lengths of fingers. The former patent employed mechanical probes to determine finger lengths and it was found that this was objectionable by many people. The second patent was an improvement thereon in that one merely held his hand over a flat surface having a plurality of light pick up means imbedded within the surface; a light was placed over the identification plate so that one could scan the light pick up points and determine the finger lengths. This apparatus had the disadvantage of being affected by the length of the fingernails. Thus, when fingernails grew or were cut, an authorized person's identity would fail to be verified by the machine. Also, the only biometric information sensed by the previous inventions was the location of the fingertips and webbing between fingers. With this limited amount of information, "false accept" and "false reject" error rates were on the order of 2%-5%.

Also, because of the methods of the previous inventions, it was relatively simple to produce an artificial hand from a simple cardboard cutout. This made the previous inventions unsuitable for use in high security areas.

In accordance with the present invention, an improved apparatus of the finger or hand identification type is provided wherein the entire apparatus is included within a member on which a hand can be placed. In accordance with a preferred embodiment, a flat plate which occupies little counter space and which has a relatively low power consumption is employed. Further, all significant optical features along the length of the finger and the webbing between fingers can be measured and some or all used in the determination of valid identity. Also because of the optical geometry of the measuring device, the measurement is free from artifact due to fingernails.

Likewise, the system is very difficult to defeat with an artificial hand since to do so would require the adequate replication of the many features which are measured.

Accordingly, it is an object of the present invention to provide an identification apparatus of the type wherein one determines the characteristics of one or more fingers which does not require an overhead light source and which measures a plurality of characteristics of the hand or fingers.

Other objects and features of the invention will be brought out in the balance of the specification.

In order that the present invention may more readily be understood the following description is given, merely by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a perspective view of an apparatus embodying the present invention.

Fig. 2 is a plan view of the apparatus.

Fig. 3 is a diagrammatic view illustrating the scanning action which is employed in accordance with the present invention.

Fig. 4 is a exploded view of an apparatus suitable for carrying out the present invention.

Fig. 5 is a plan view of the apparatus with the hand plate removed.

Fig. 6 is an enlarged section on the line 6-6 of Fig. 5.

Fig. 7 is an enlarged perspective view, partly in section, illustrating the motion of the scanning elements.

Fig. 8 is a simplified schematic diagram of the logic circuitry.

Fig. 9 is an enlarged partial view of a finger being scanned and the response curve.

Fig. 10 is an enlarged partial view showing an alternate scheme for illuminating a finger

Fig. 11 is a typical voltage response curve by a finger scan.

Fig. 12 is another scan curve.

Fig. 13 is still another scan curve.

Fig. 14 is another scan curve.

Fig. 15 is a first derivative curve, i.e. $\frac{dV}{dt}$ of the curve of Fig. 14.

Fig. 16 is a second derivative $\frac{(d^2V)}{(dt^2)}$ of the same curve.

Referring now to the drawings by reference characters, there is shown an identification system which includes a hand plate 10 mounted on a base 12. A card reader 14 is connected by a suitable cable 16 to the identification device. The hand plate 10 has a plurality of slots therein and, in the embodiment illustrated, has slots for four fingers designated 18, 20, 22 and 24 which are splayed as in a normal hand. In addition, two slots are provided designated 26 and 28, the purpose of which is to identify the crotch positions between the fingers placed between slots on 18 and 20 as well as between slots 22 and 24, respectively. The hand plate also has a locating pin 30 to insure that one places the hand in the proper position on the identification device. Normally, the hand plate is hollowed around each of the finger slots as is shown at 32; ordinarily the crotch slots are not so hollowed. This hollowing of the finger slots makes it simpler to place the hand in the proper position and also secures better contact between the finger and the hand plate.

In accordance with a preferred embodiment of the present invention, both the light source and the light sensing device are incorporated in a cell located under the hand plate 10. The cells move up and down on the finger slots and the crotch slots to measure the desired characteristics of the fingers. One of the cells is shown enlarged in Fig. 7. The cell is generally designated 34 and has a round body portion 36 with opposed flat sides 38. The flat sides 38 form a sliding fit in one of the longitudinal slots. The cell also has flat sides 39 at right angles to the flat sides 38 which fit into a transverse slot as at 20B in figures 6 and 7. Each of the cells contains a light source such as a LED 40 and a photoelectric pick up cell 42. Thus each of the units 34 is self contained with its light source and pick up so that if there is light colored object, such as a finger in the slot, light will be reflected back from the light source to the pick up cell 42.

As can best be seen in Fig. 3, the path of travel of the cells 34 is up and down the path of the extended fingers. Since the fingers are spread out in a normal hand it is necessary that the path of the cells have both a longitudinal and a transverse component.

The method of achieving the combination of the longitudinal and the transverse travel will now be described. Mounted under the hand plate 10 is a longitudinal guide plate 44 which has a plurality of slots therein corresponding to the slots in the hand plate. Thus slot 18A in the longitudinal guide plate corresponds to slot 18 in the hand plate and so on.

Mounted under the longitudinal guide plate is the movable transverse guide plate 46 which is mounted for longitudinal movement on the rods 48 and 50. This plate has a series of short slots corresponding with the slots in the longitudinal guide plate except that these slots are at right angles to the slots in the longitudinal guide plate. Thus, slot 18B is lo cated at a right angle to slot 18A and so on. In addition, plate 46 has a transverse slot 52 extending for almost the complete width of the plate.

Mounted under the transverse drive plate 46 is a motor 54 with a gear box 56 mounted thereon with an output shaft 58. Shaft 58 is coupled to a crank arm 60 provided with a roller 62 which fits into slot 52. The motion imparted can best be appreciated with reference to Fig's. 3 and 5. As shaft 58 revolves, the drive plate 46 moves up and down on rods 48 and 50 in the direction shown by the double arrow 64. This will cause cells 34 to move in a transverse direction and at the same time in a longitudinal direction; the interaction of the two sets of slots produces a vector upon each of the cells so that as the shaft 58 makes one revolution, each of the cells will follow an angling path up and down one of the finger slots.

It is preferred that the device work on infrared light to reduce the effect of ambient light on the operation. Accordingly, the strips 66 which are transparent to infrared light and opaque to visible light would normally be placed under each of the slots of the hand plate 10.

The drive plate 46 also carries a transparent grid blade 68 which has a series of dark lines 70 thereon. The grid plate 68 passes between the arms 71 and 72 of an optical sensor which can be of substantially the same structure as the device 34 so that as the grid 68 passes over the pick up 72, a series of pulses will be produced to serve as a clock to indicate the position of the drive plate.

Optically significant features are determined by a measurement of optical reflectance along the finger. Such features include: the position of maximum reflectance points, minimum reflectance points, and points half-way in reflectance between maximum and minimum points. The position of the maximum, minimum and mid-points of the spacial 1st, 2nd, 3rd---Nth derivatives of the reflectance signal can serve as reference points.

Since fingers differ in albedo it is preferable not to look for some absolute value of reflectivity but it is better to employ a circuit which has a floating reference point and which adjusts for differences in the reflectivity of fingers. Strangely enough, it has been found that the refectivity reaches a peak near the tip of the finger where the tip of the finger is not in contact with the plate. Advantage is taken of this in one practical embodiment of the invention and the cut off point is the 50% fall off in light pick up after the circuit reaches a peak value. This is illustrated in Fig. 9 where the sensor 34 is shown moving along a finger 75. The amount of light pick up is shown on the curve below. It will be seen that there as the sensor moves along the finger, various peaks in reflectivity such as those designated 77A, 77B and 77C are noted. Just as the pick up reaches a point just short of the fingertip a peak 79 is reached. Now as the sensor moves farther out, the light pick up gradually falls off and the half value point 81 can be employed as a trigger. Similarly, the position of the crotch can be measured, and in one embodiment of the invention, identification is made based solely on the length of the fingers as determined by the position of the tip and crotch. However, in other embodiments, other features such as the points 77A-C can be measured and compared with stored data as is described later.

Figs. 11, 12, 13 and 14 show scans of typical fingers. It will be seen that the maximum value of reflected light does not reach a sharp peak so that the maximum value is not a suitable reference point. However by measuring the minimum reflectance point as well as the maximum and taking a value half-way between these points, one obtains a valid and reproducible reference point.

Another method of securing significant measurements is illustrated in Figs. 14, 15 and 16. In Fig. 15 the first derivative $\frac{(dV)}{(dt)}$ of the curve of Fig. 14 is plotted so that one obtains a plurality of peaks such as those designated 43A, 43B and 43C which can be compared with stored data. One can now take the second derivative $\frac{(d^2V)}{(dt^2)}$ of this curve, as is shown in Fig. 16, and obtain a series of flip-flops from a positive to a negative value at the cross-over points 45A, 45B...45X which are easy to detect. Higher derivations provide even more sharply defined points. Thus, by taking the first, second or higher derivatives of the response curves, one can convert subtle, almost imperceptible changes into sharply defined points.

In Fig. 8 there is shown a highly simplified diagram of the detection system and it will be seen that the light falling on the sensors 42A, 42B, 42C, 42D, 42E and 42F (representing four fingers and two crotches of a hand) is fed to an analog signal multiplexer 83 whose inputs are connected to each of the photo detector circuits; this signal is fed to an analog to digital converter 84 connected to the output of the analog multiplexer, and then to a microprocessor 85 which controls the multiplexer and receives the output of the analog to digital converter. A grid clock 87 develops a position signal which is fed to the microprocessor 85. A magnetic card reader 14 which is connected to the microprocessor stores and provides the reference hand geometry data. In this manner, one or more characteristics such as the length of the finger are determined and is compared with data included on the card, or supplied from a separate source.

Normally it is preferred that the light source and photosensor be mounted as a unit in a cell which scans a portion of the hand. However, it is also possible to use a fixed light source as is shown in Fig. 10. Here a fixed light source 95 is employed which illuminates the end and a portion of the under surface of a finger and the moving cell 97 contains only the photosensor.

It will be obvious to those skilled in the art that many variations can be made in the exact structure shown without departing from the spirit of this invention. For instance, instead of the flat plate illustrated, the sensor could be enclosed in a cylindrical or round object which the subject would grasp.

CLAIMS:

1. Personnel identification apparatus comprising:
   a. means having a surface for supporting a hand,
   b. slot means in said surface whereby a finger can cover at least a portion of said slot means,
   c. a light source illuminating at least a portion of the under surface of a finger,
   d. a light detecting means movable under said slot means,
   e. means to determine the amount of reflected light from said light source and,
   f. electronic means to determine a desired characteristic of a finger based on said reflected light and to compare the same with stored data.

2. The apparatus of claim 1 wherein said surface is planar.

3. The apparatus of claim 1 having a plurality of slots corresponding with a plurality of fingers.

4. The apparatus of claim 2 having additionally a slot between finger slots to determine the position of the crotch between fingers.

5. The apparatus of claim 2 wherein said slots extend at an acute angle to each other, approximating the normal spread of fingers on a hand.

6. The apparatus of claim 1 having a holder movable beneath said slot means, said holder having a light source and a light detecting means therein.

7. Apparatus according to claim 1 having a plurality of slots, said slots being set at an acute angle to each other, and holder means corresponding to said slots, each holder means including a light source and a light detecting means and means for moving said holders along the undersides of said slots.

8. Apparatus in accordance with claim 1 having a fixed light source directed toward the finger.

9. The apparatus of claim 1 wherein said electronic means includes a plurality of photodetector circuits and means for determining maximum reflectance points, minimum reflectance points and half-way points and comparing at least one of said points with stored data.

10. The apparatus of claim 1 including means to derive the first, second or higher derivatives from said reflectance points and means to compare significant points on one or more derivatives with stored data.

11. The apparatus of claim 1 wherein said electronic means comprises the following:

a. a plurality of photodetector means,

b. an analog signal multiplexer having inputs connected to each of said photodetector means,

c. an analog to digital converter connected to the output of said analog signal multiplexer,

d. a microprocessor which controls the multiplexer and receives the output of the analog to digital converter,

e. a grid clock connected to said microprocessor, said grid clock indicating the position of said photodetector means, and

f. means to compare stored data with data generated by said photodetector means.

12. The apparatus of claim 10 having in addition a magnetic card reader to receive stored data from a magnetic card.

13. The method of identification which includes illuminating at least a portion of the under surface of at least one finger and scanning the reflected light from said finger for optically significant features and comparing the results of said scanning with stored data.

14. The method of claim 12 wherein the maximum reflectance from the finger is determined as well as the minimum reflectance and the value half-way between the maximum and minimum is taken as a reference point.

15. The method of claim 12 wherein singular points of a derivative of the reflectance are taken as reference points.

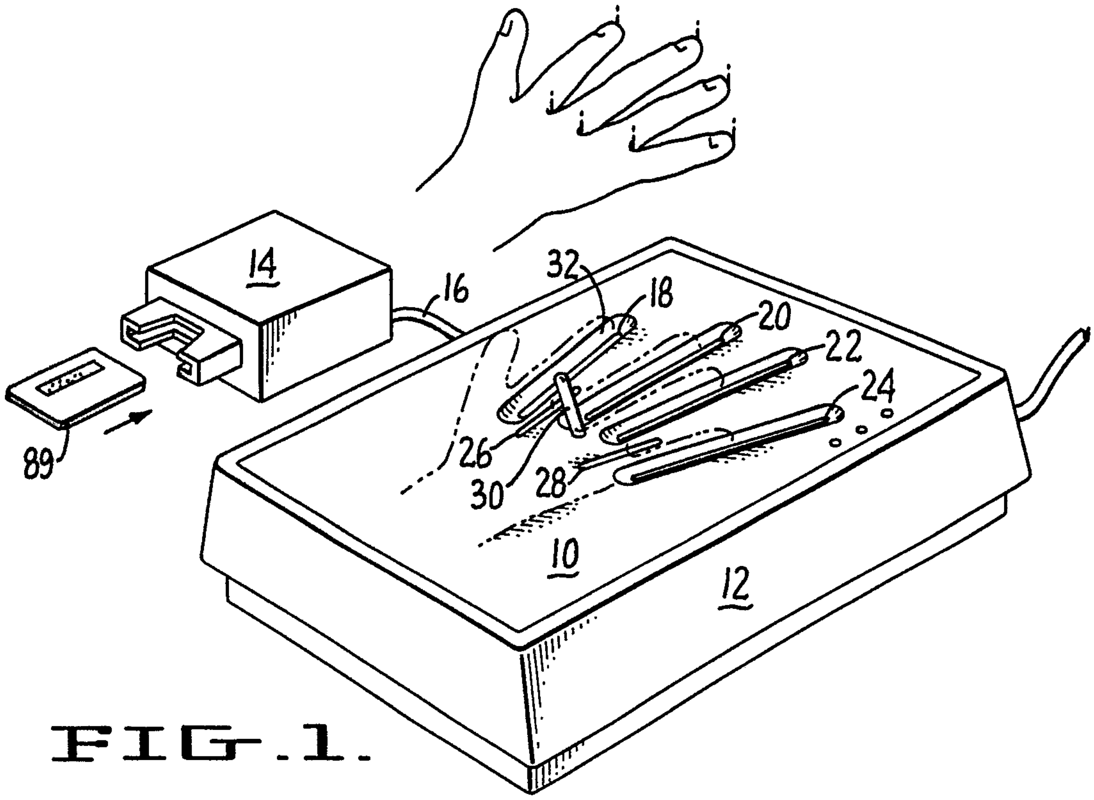


FIG.1.

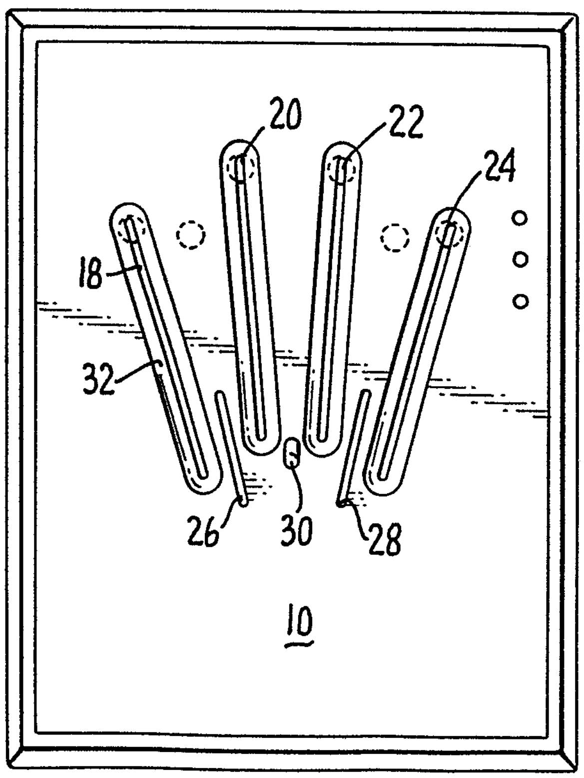


FIG.2.

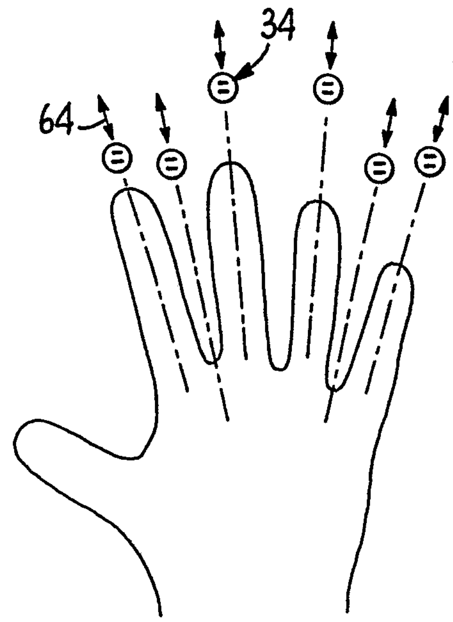
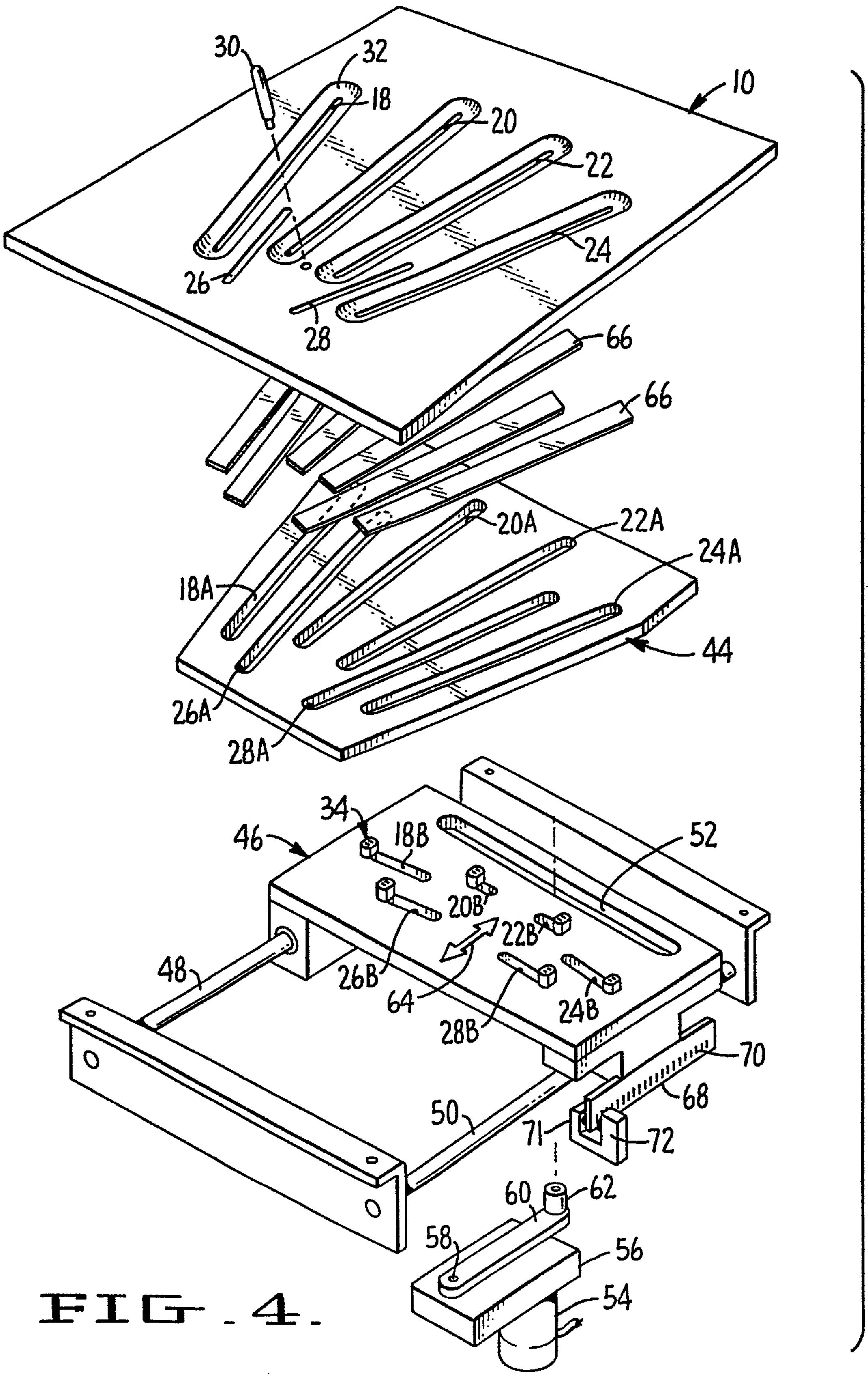


FIG.3.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20B
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FIG. 4.

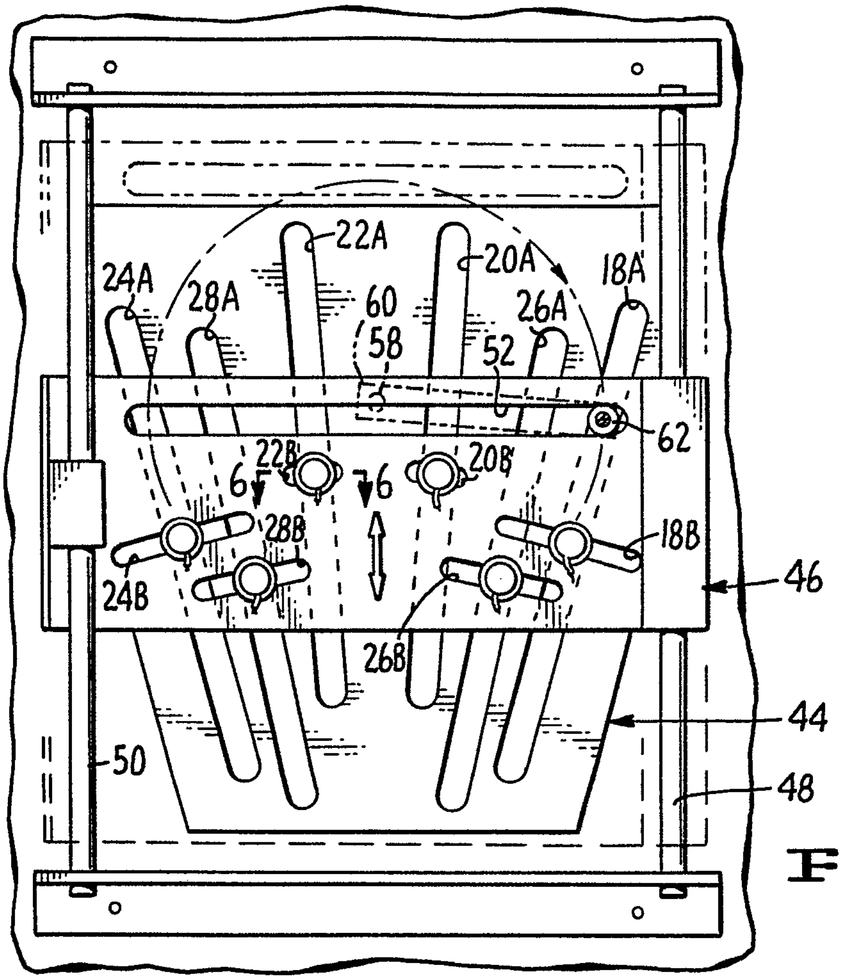

FIG. 5.

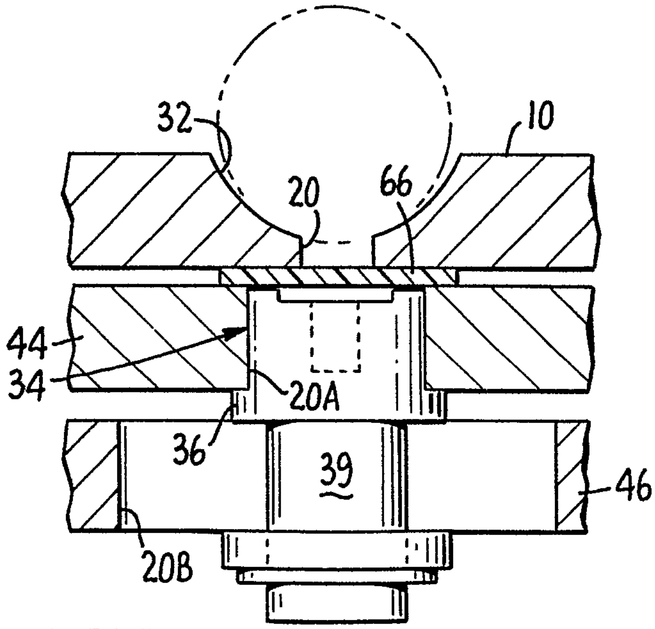

FIG. 6.

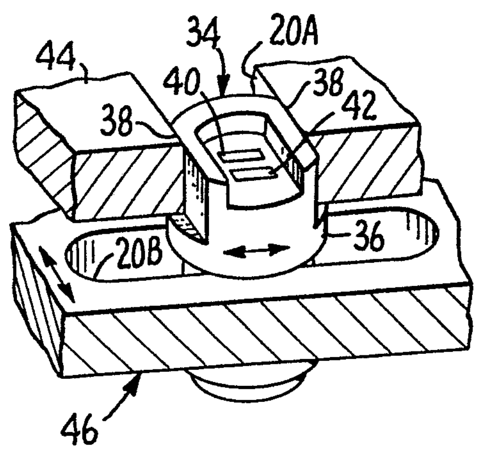

FIG. 7.

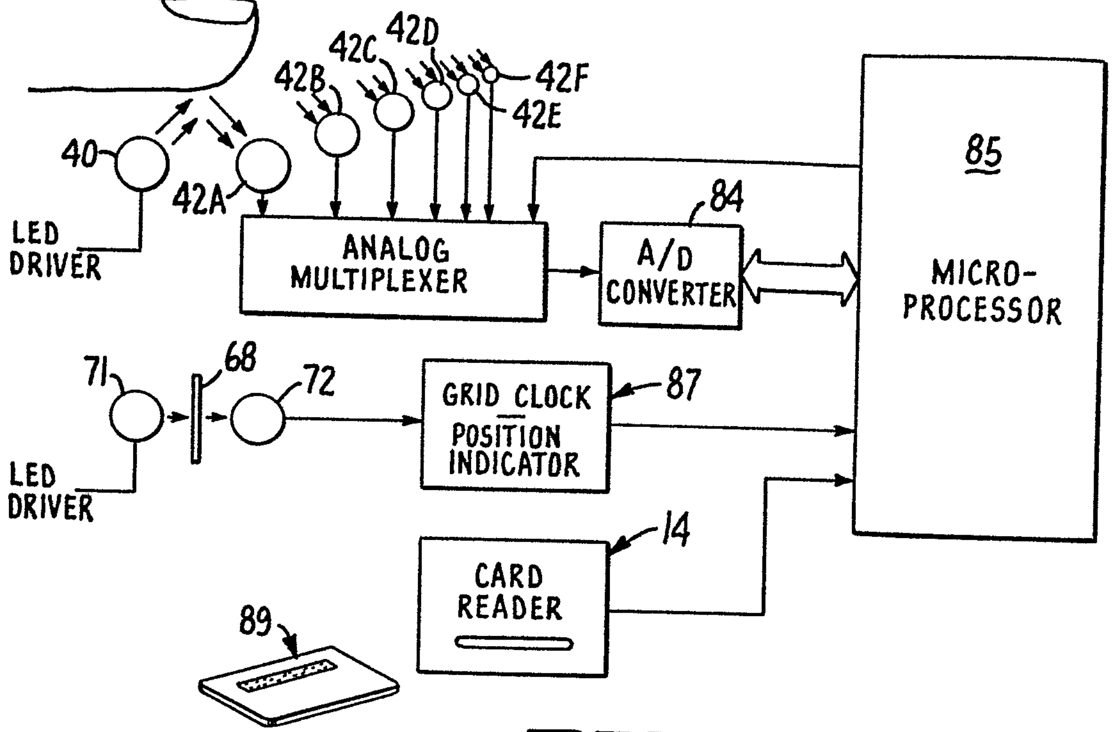

FIG. 8.

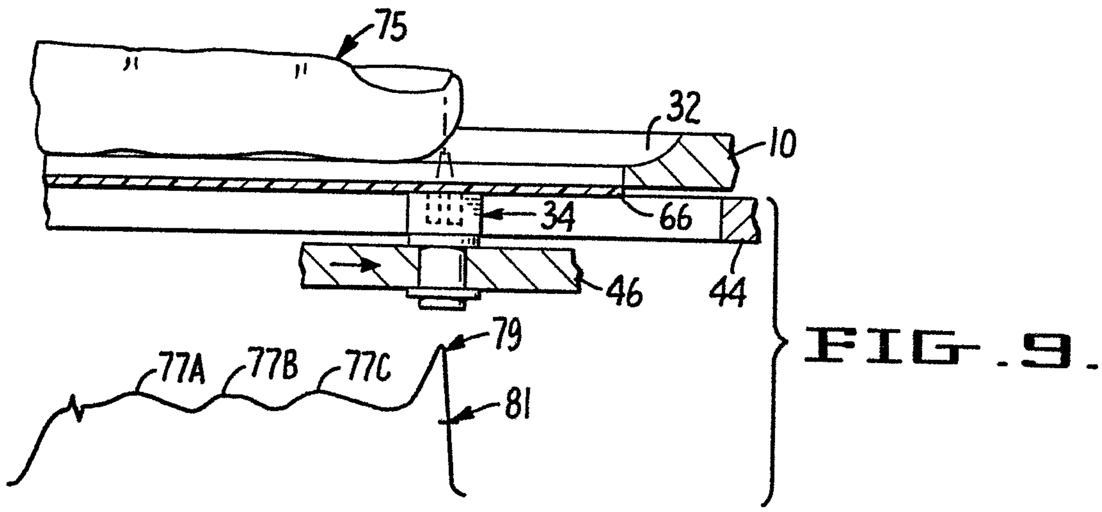

FIG. 9.

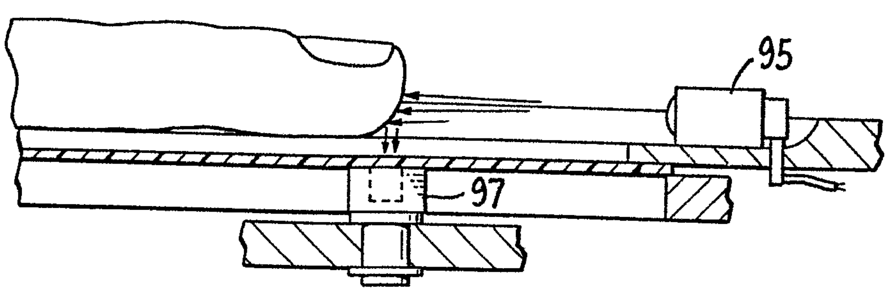

FIG. 10.

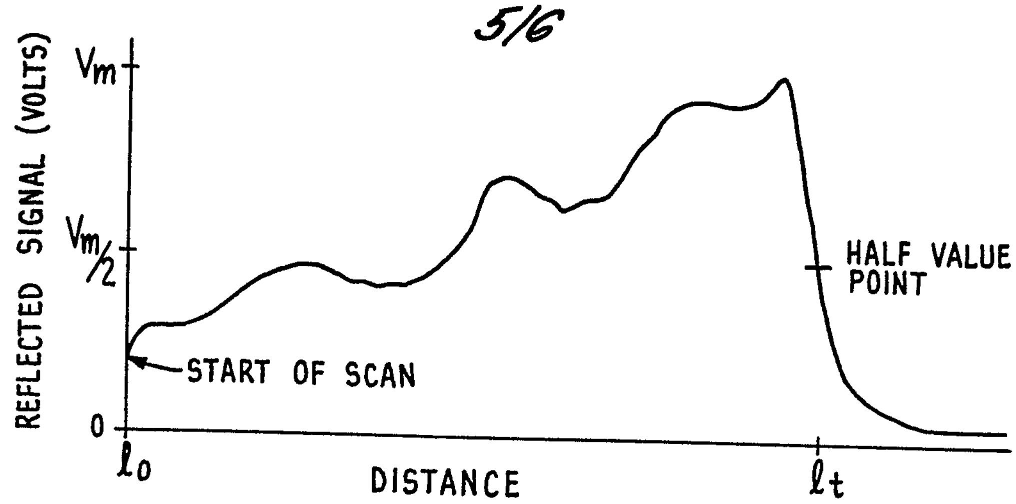

FIG.11.

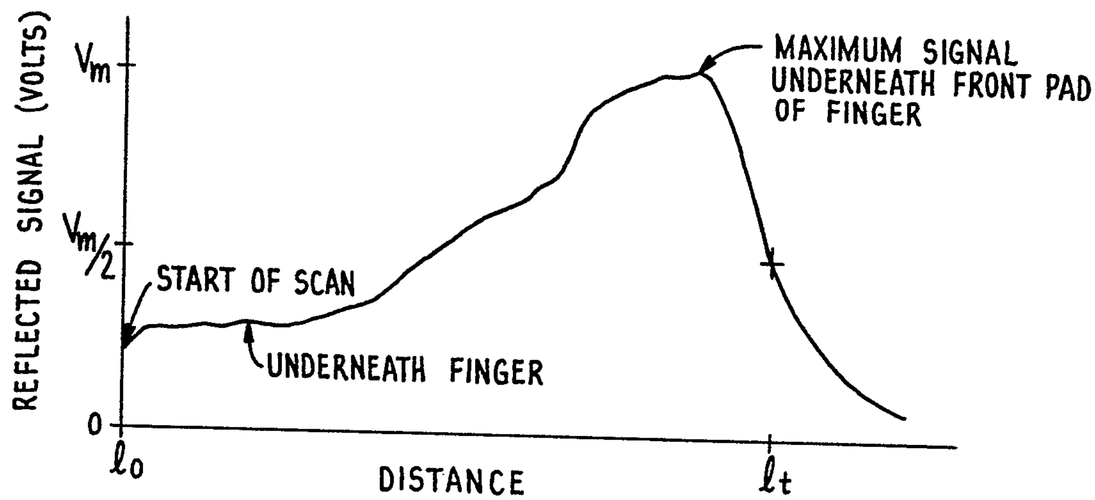

FIG.12.

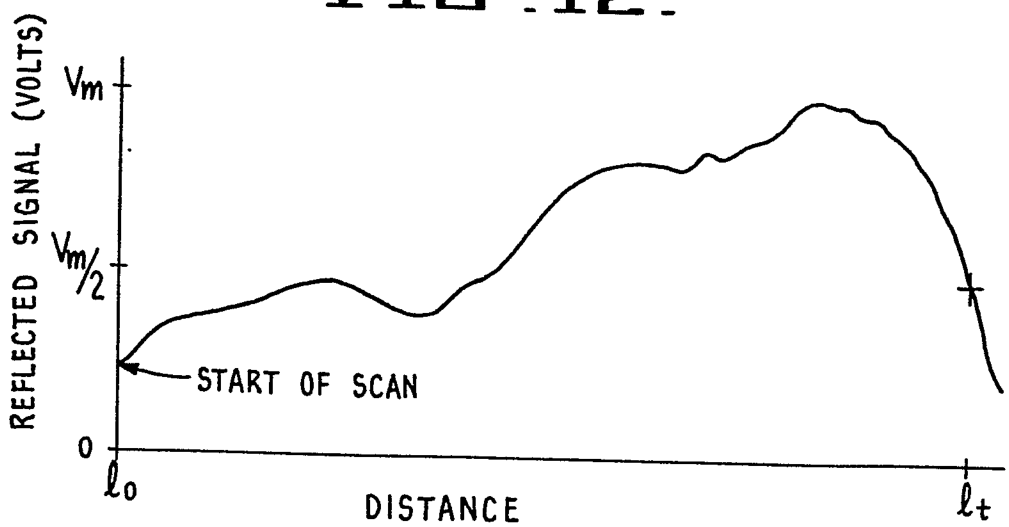

FIG.13.

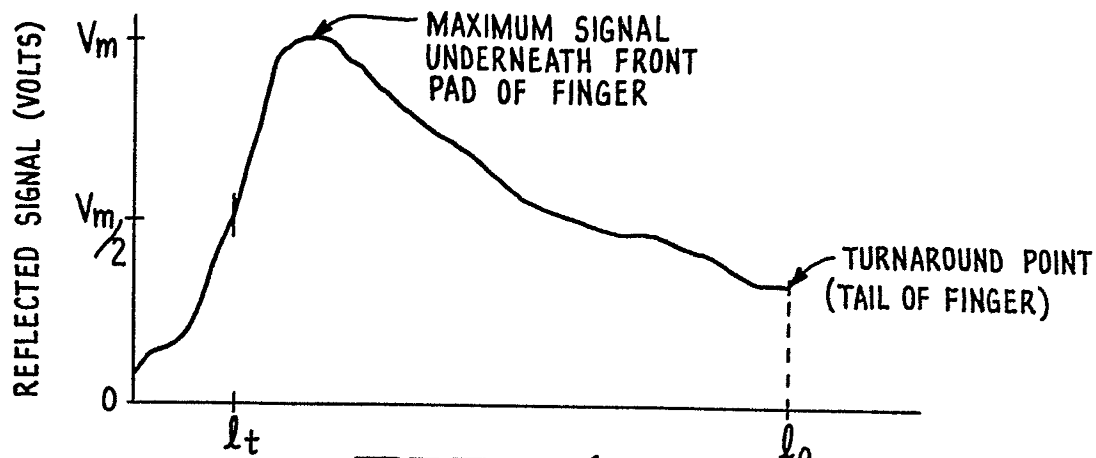

FIG.14.

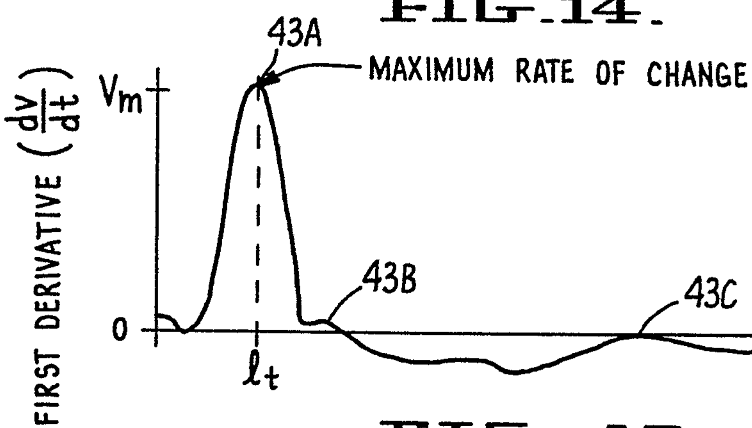

FIG.15.

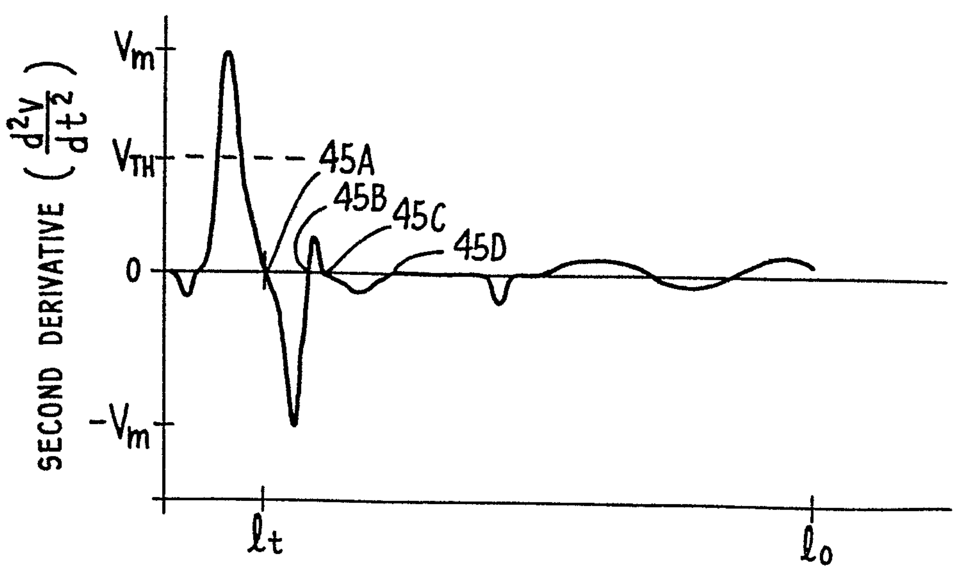

FIG.16.