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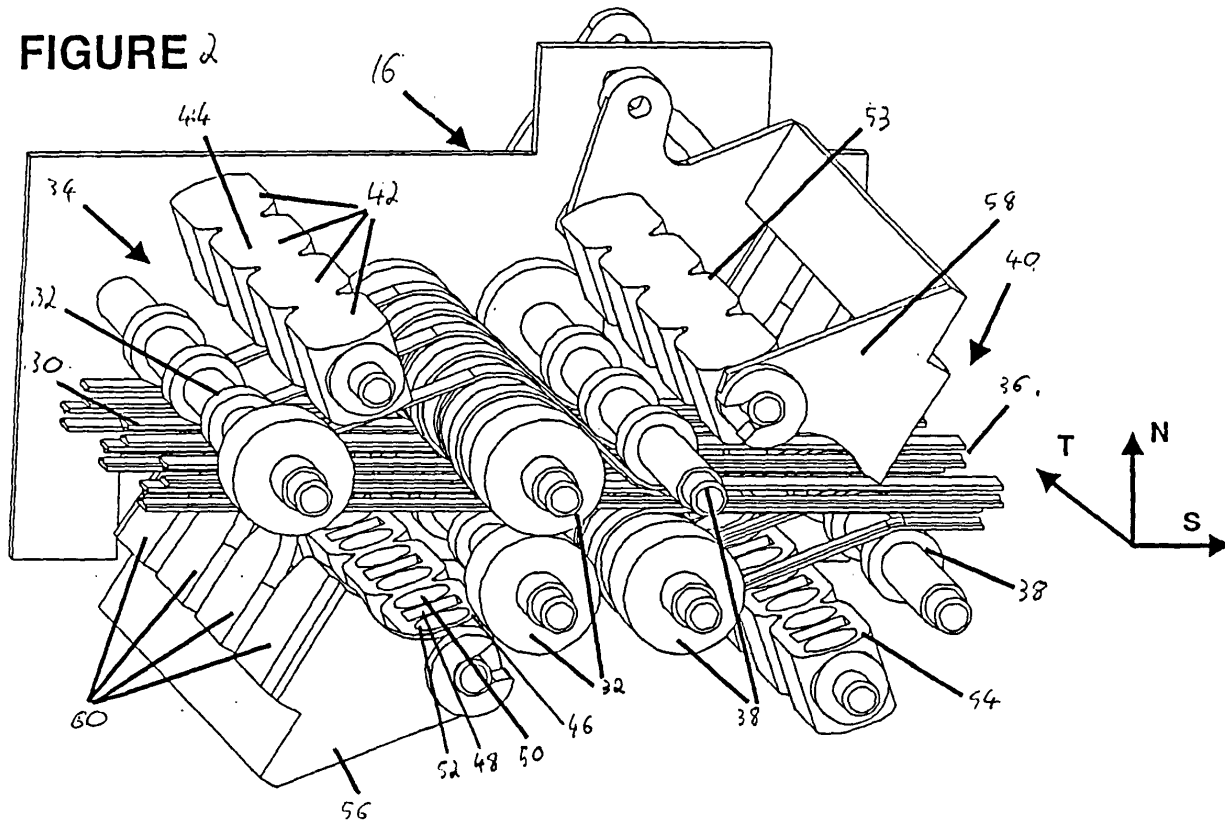
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(54) **Sensor temperature control**

(57) A banknote validator and method of sensing the optical characteristics of a banknote which extends to a

light emitter emitting light, the reflectance and transmission of which by a banknote is sensed, and which involves controlling the temperature of the light emitter.

FIGURE 2



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Description

[0001] This invention relates to an apparatus for sensing optical characteristics of a banknote and other sheets of value such as, for example, cheques and tokens.

[0002] Such apparatus is commonly used to determine the authenticity and/or denomination of banknotes. Often, a banknote is moved along a path past optical emitters and receivers so that the transmission or reflection characteristics in respective areas of the banknote can be determined by scanning. The apparatus may include emitters (typically LED packages or LED dies) which operate in multiple wavelengths, such as red, green, blue and infra-red. (It is noted that the terms "optical" and "light" are used herein to refer to any electromagnetic wavelength, and not merely visible wavelengths.)

[0003] The measured transmission or reflection characteristics are compared to defined acceptance criteria and a decision is made to accept or reject the banknote based on this comparison. These measurements are also used to determine the denomination of the banknote. There are a number of factors which influence individual measurements and which must be compensated to provide accurate comparison with acceptance criteria. Among these are the quality of the banknote, component drift and component variations from mechanism to mechanism which affects, for example, performance of the emitters and sensors.

[0004] It is known to provide a reference surface within an apparatus for measuring the optical characteristics of banknotes, so as to permit calibration. See, for example, EP-0731737-A and EP-1321904-A (the contents of which are hereby incorporated by reference). It is also known to provide for a manual calibration operation which involves inserting, instead of a banknote, a sheet of calibration paper. This will travel along the banknote path so that the apparatus can be calibrated.

[0005] The measurement from the reference surface or calibration paper can be compared to a predetermined value and the intensity of an emitter and/or the gain of a sensor varied until the measurement matches the predetermined value. Alternatively, the measurement from the reference surface is incorporated into the process used to evaluate the banknote. For example, software incorporated into a validator may compensate measurements derived from a banknote according to stored reference surface measurements. However, software compensations suffer from the disadvantage that the emitters and sensors may not be operating in their optimum range (e.g. the brightness of the emitter may be too low or high for the receiver to be operating in its most sensitive range).

[0006] These calibration methods are intended to deal with variations in measurements attributable to component variations from mechanism to mechanism, ageing of components and component performance changes due to fluctuating temperature.

[0007] However, it has been found that there are fur-

ther variations in measurements. Some of these are attributable to factors which influence the state of the banknote such as dirt and ageing of the banknote. These factors are partially compensated by the use of software algorithms but it has also been necessary to widen the acceptance criteria, which degrades the performance of the apparatus.

[0008] Aspects of the invention are provided in the accompanying claims.

[0009] If the temperature of a light emitter in a banknote validator for validating banknotes by the measurement of transmitted and/or reflected light is regulated, it has been found that acceptance criteria can be narrowed, thereby improving the performance of the validator

[0010] Fluctuations in the operating temperature of the emitters affects the wavelength of the emitted light. For example, the wavelength emitted by infra-red LED's can change by up to 14 nm in the temperature range 0°C to 60°C. Therefore, at different temperatures, reflectance and/or transmittance at different spectral regions is measured. The reflectance and transmittance of a reference surface does not vary significantly with a change in wavelength and therefore the use of the calibration methods described above will have little effect in respect of the change of the wavelength of the emitted light.

[0011] It has been found however, that the reflectance and transmittance of a banknote does vary with changes in the wavelength of incident light, which is attributable to the inks used in the printing of the banknotes. Due to the nature of the reference surfaces referred to above, these variations are not compensated by use of the aforementioned methods of calibration.

[0012] If the change in the reflectance and transmittance of the banknotes were linear or at least regular (monotonic) with changes in temperature, this could be compensated by employing an appropriate algorithm when evaluating the banknote. However, the fluctuation is not regular and therefore the use of such algorithms is not appropriate.

[0013] The temperature of the emitters may be regulated by providing means for regulating the temperature of the environment surrounding the emitter. The temperature regulating means may be self-regulating or may include a heater or refrigerator and means for controlling the heater or refrigerator, such as a thermostat.

[0014] Although it would be desirable to maintain the temperature of the light emitter so that it fluctuates as little as possible, it has been found that if the temperature is maintained within a range of about 20°C, adequate compensation for non-linear variations in the reflectivity of the banknote is provided.

[0015] It is possible, by controlling the temperature regulator, to control the temperature of the emitter in a range defined by any reasonable minimum and maximum values. However, it has been found that during operation, the temperature of the banknote validator and its components does not fluctuate above about 70°C. Therefore, the temperature regulator preferably maintains the tem-

perature of the emitter in the range of between about 50°C and about 70°C. By choosing the maximum operating temperature of the validator as the maximum of the range, it is only necessary to provide a heater; cooling will occur through radiation.

[0016] Preferably, the heater is self-regulating such as a positive temperature coefficient heater although Peltier elements also provide suitable heaters.

[0017] Preferably, the validator includes a plurality of emitters and a plurality of temperature regulators so that each emitter is associated with a temperature regulator.

[0018] Preferably, the validator also includes means for calibrating which may include a reference surface which is illuminated by the light emitters or may include a calibration sheet of reflectance or transmittance characteristics which do not vary substantially with changes in the operating environment which is fed through the validator in the same manner as a banknote. In such an arrangement, the accuracy of the validator is improved over those known in the prior art as the calibration means compensates for device-to-device variations and those which vary regularly with changes in the operating environment, whereas regulating the temperature compensates for changes in the wavelength of the emitted light due to temperature fluctuations.

[0019] An arrangement embodying the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a diagram of a banknote validator;

Figure 2 is a perspective view of an apparatus for measuring transmittance and reflectance characteristics of a banknote for use in the validator of Figure 1;

Figure 3 is a side view of a printed circuit board for use with the apparatus of Figure 2; and

Figure 4 is a view of the reverse side of the printed circuit board illustrated in Figure 3.

[0020] Figure 1 illustrates a banknote validator. The validator has an inlet 12 arranged to receive banknotes which travel along a path 14 to an apparatus 16 which is arranged to test the optical transmission and reflectance characteristics of the banknote. It is to be realised that although the invention is described with reference to an apparatus which measures the reflected and transmitted light from a banknote, it is equally applicable to any validation means which uses light to validate banknotes or other sheets of value.

[0021] A control means 18 is arranged to send signals to and receive signals from the apparatus 16 and to use the received signals to determine the authenticity and the denomination of the banknote. The control means 18 is also arranged to send control signals to the apparatus 16 to perform a calibration operation, as will be described below. The banknote travels from the apparatus 16 to a gate 20 which is controlled by the control means 18 in dependence upon the type of banknote received. The gate can direct the banknote either to a path 22 leading

to an outlet 24, or to a path 26 leading to a banknote store 28.

[0022] The apparatus 16 for sensing the optical characteristics of banknotes is shown in more detail in the perspective view of Figure 2. Banknotes are conveyed in the scanning direction S by means of endless belts 30 and sets of rollers 32 at the inlet side 34 of the apparatus and endless belts 36 and sets of rollers 38 at the outlet side 40 of the apparatus. The belts 30 and rollers 32 at the inlet side 34 of the apparatus are disposed laterally between the belts 36 and rollers 38 at the outlet side 40 of the apparatus.

[0023] Optical devices 42 are arranged in modules, or units. A first unit 44 is disposed above the banknote path at the inlet side 34, and faces a second unit 46 below the banknote path. Each unit comprises four optical devices 42 arranged in a line extending in the transverse direction T, each device comprising an emitter 48 and a pair of receivers 50, 52 arranged as shown to sense the reflectance and transmission characteristics in a banknote. The units 44 and 46 are arranged for sensing the reflectance and transmittance characteristics of banknotes in scanned areas which extend between the inlet belts 30.

[0024] Two further units, 53 and 54, are disposed respectively above and below the banknote path at the outlet side 40. These are of similar structure and orientation to the modules 44 and 46, except that they are arranged to scan the areas between the outlet belts 36.

[0025] Figure 2 also shows a pair of calibration units 56, 58. Each unit carries four reference bodies 60 and is mounted for pivotal movement about an axis parallel to the transverse direction T so that the body can be pivoted from a non-operational position, as shown in Figure 2, to an operational position in which each reference body 60 is located between an optical device 42 of one of the units (44 or 46) and the corresponding optical device 42 in another of the units (53 or 54). In this position, the reference body is located in or near the banknote path, and is operable to transmit light from the emitter 48 of one of the devices to the receivers of the opposed device, and to reflect light from the emitter 48 of each device to its adjacent receivers 50, 52. Each reference body has reflection and transmission characteristics which do not vary significantly with changes in the operating environment or over time, so that calibration of the apparatus can be performed by taking reflectance and transmission measurements while the calibration units 56, 58 are in their operational positions.

[0026] The operation of the validator 10 of Figure 1 is as follows. A received banknote is delivered to the inlet side 34 of the apparatus 16. The reference members 56, 58 are in their non-operational positions at this time. The control means 18 continuously checks the light transmitted between the optical units 44, 46 in the inlet section 34 until it detects the significant change caused by the leading edge of the banknote.

[0027] When the banknote enters the apparatus 16, the control means 18 moves the reference members 56,

58 to their operational positions and takes both transmission and reflection calibration measurements which are used to adjust the power supply to the LED's of respective wavelengths so that the intensities of the outputs as measured by the receivers comply with a predetermined level, adjust the sensitivities of the receivers and/or alter the processing of the receiver outputs to achieve calibration of the apparatus.

[0028] Instead of performing the calibration each time a banknote has passed through the apparatus 16, the calibration operation may be performed only at the beginning of the transaction which may involve the measurement of one or more banknotes.

[0029] As the banknote continues to travel between the units 44, 46, various transmission and reflectance measurements are taken in sequence under the control of the control means 18 which activates the respective LED's of different wavelengths (see below, Fig. 3), and enables the respective receivers, according to a stored programme.

[0030] The measurements are initially carried out using the units 44, 46, but similar measurements are also carried out by the units 53, 54 when the leading edge of the banknote has reached these units.

[0031] Various modifications of the described arrangements are possible. For example, the reference members 56, 58 could be replaced by a sheet, made of for example plastics material, with reflection and/or transmission characteristics which do not vary substantially with changes in the operating environment or over time. This sheet could be fed along the banknote path, using the normal banknote feeding mechanism, and stored within the banknote apparatus, for example using a dedicated sheet store, so that the reference sheet can be discharged from the store to perform a calibration operation and then returned to the store.

[0032] As illustrated in Figure 3, within each of the devices 42, the emitter 48 and the receivers 50 and 52 are mounted on a common circuit board 70. As illustrated, a single circuit board is used for all the devices 42 within a single module. Each emitter comprises an LED assembly which includes one LED die each of a respective wavelength red, green and blue and three different wavelength infra-red LED dies. As illustrated, the circuit board includes a number of further emitters 72, 74 and 76 comprising respective LED dies and respective receivers 78, 80; 82, 84 and 86, 88.

[0033] Figure 4 illustrates the reverse side of the circuit board 70 illustrated in Figure 3. A plurality of heaters 90, 92, 94 and 96 are mounted on the circuit board at opposed positions to respective emitters 48, 72, 74 and 76. Suitable heaters are known in the art but in a preferable embodiment, the heaters are positive temperature coefficient (PTC) heaters which have the advantage of regulating the temperature without the need for a separate thermostat.

[0034] The heaters heat the surrounding area which includes the portion of the circuit board 70 to which the

emitters are attached and therefore regulate the temperature of the emitters to maintain it in a predetermined range of between about 50°C and about 70°C. A suitable PTC heater which operates in this range is sold by Advanced Thermal Products, Inc. under the part number PS425C050S102H. This ensures that there are no substantial variations in the wavelength of the light emitted by the emitters due to temperature variations.

Claims

1. A banknote validator which validates banknotes by measuring transmitted and/or reflected light which includes a light emitter and a temperature regulator for controlling the temperature of the light emitter.
2. The banknote validator of claim 1 wherein the temperature regulator maintains the temperature of the light emitter within a range of about 20°C.
3. The banknote validator of claim 2 wherein the temperature regulator maintains the temperature of the light emitter between about 50°C and about 70°C.
4. The banknote validator of any preceding claim wherein the temperature regulator is a heater.
5. The banknote validator of any preceding claim wherein the temperature regulator is self-regulating.
6. The banknote validator of claim 5 wherein the temperature regulator is a positive temperature coefficient heater.
7. The banknote validator of any preceding claim which includes calibrating means.
8. The banknote validator of claim 7 wherein the calibrating means includes at least one reference surface to permit calibration by measuring its optical characteristics.
9. The banknote validator of any preceding claim wherein the light emitter is mounted on a circuit board.
10. The banknote validator of claim 9 wherein the temperature regulator is mounted on the circuit board on an opposite side to the light emitter at a position substantially corresponding to the position of the light emitter.
11. The banknote validator of any preceding claim wherein said light emitter is a light emitting diode.
12. The banknote validator of any preceding claim which includes a plurality of light emitters and a plurality of

temperature regulators so that each light emitter has a temperature regulator associated therewith.

13. A method of sensing the optical characteristics of a banknote which includes the steps of providing a light emitter to emit light to be reflected or transmitted by a banknote; measuring the reflected or transmitted light and applying acceptance criteria to the measured values to validate the banknote; and controlling the temperature of the light emitter. 5 10
14. The method of claim 13 wherein the temperature of the light emitter is maintained within a range of about 20°C. 15
15. The method of claim 14 wherein the temperature of the light emitter is maintained between about 50°C and about 70°C.
16. The method of any one of claims 13 to 15 which includes the additional step of performing a calibration operation. 20
17. The method of claim 16 which includes the step of measuring the optical characteristics of a reference surface to perform said calibration. 25

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FIGURE 1

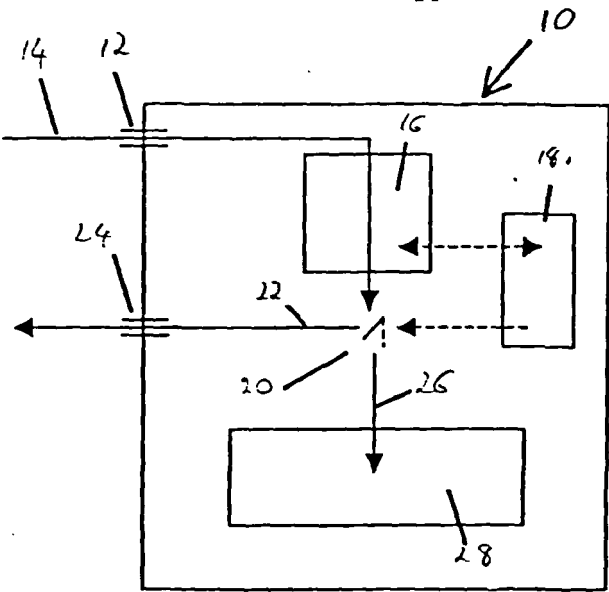
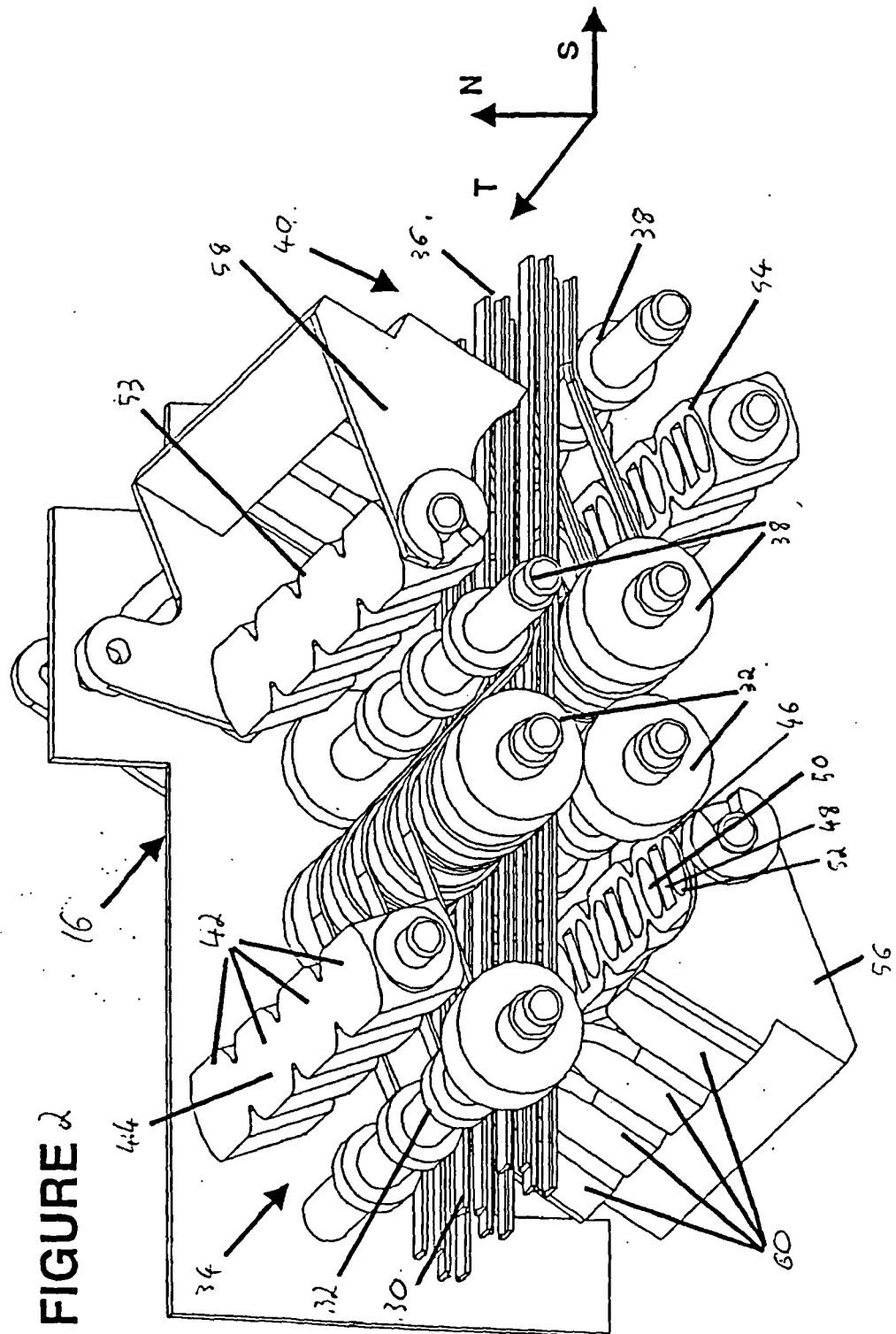


FIGURE 2



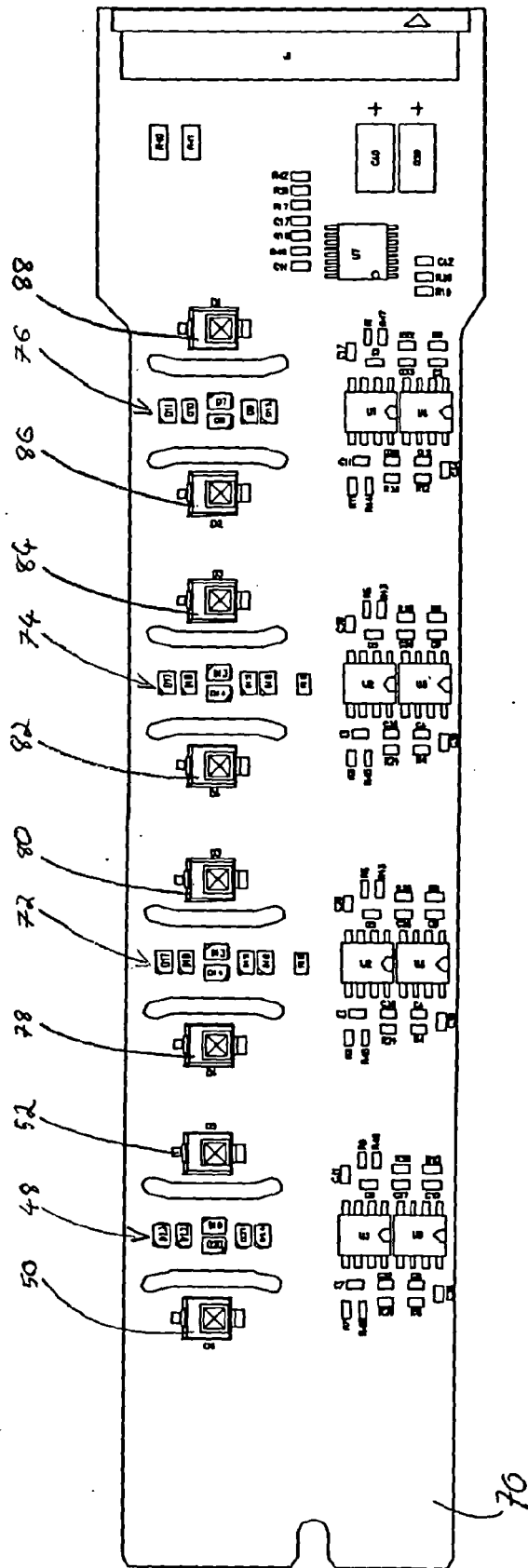


FIGURE 3

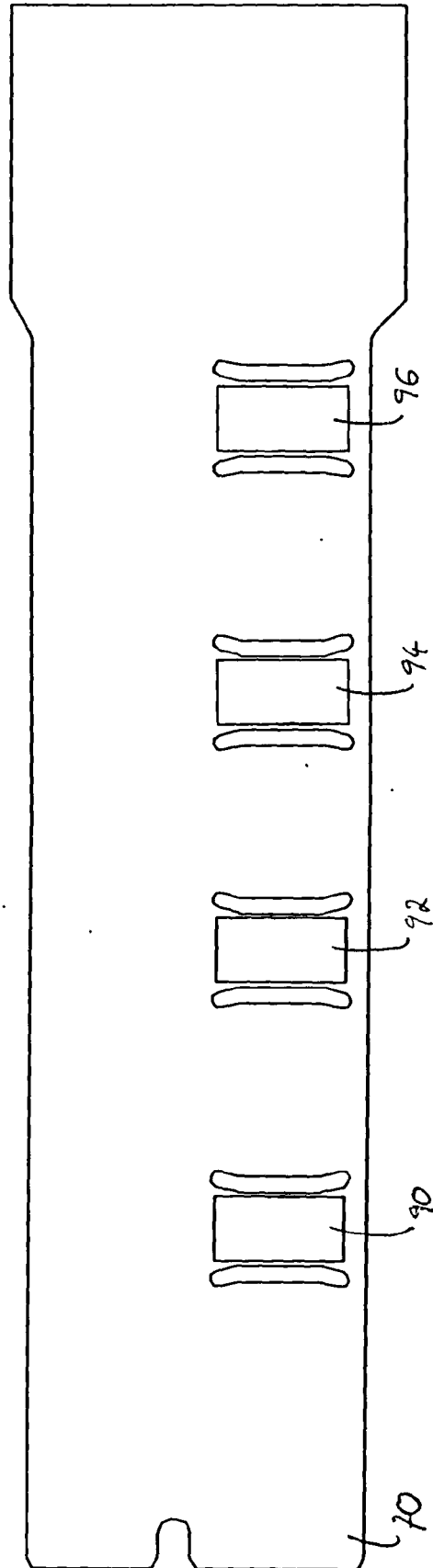


FIGURE 4



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EUROPEAN SEARCH REPORT

Application Number
EP 04 25 8013

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Place of search Munich		Date of completion of the search 18 April 2005	Examiner Paraf, E
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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