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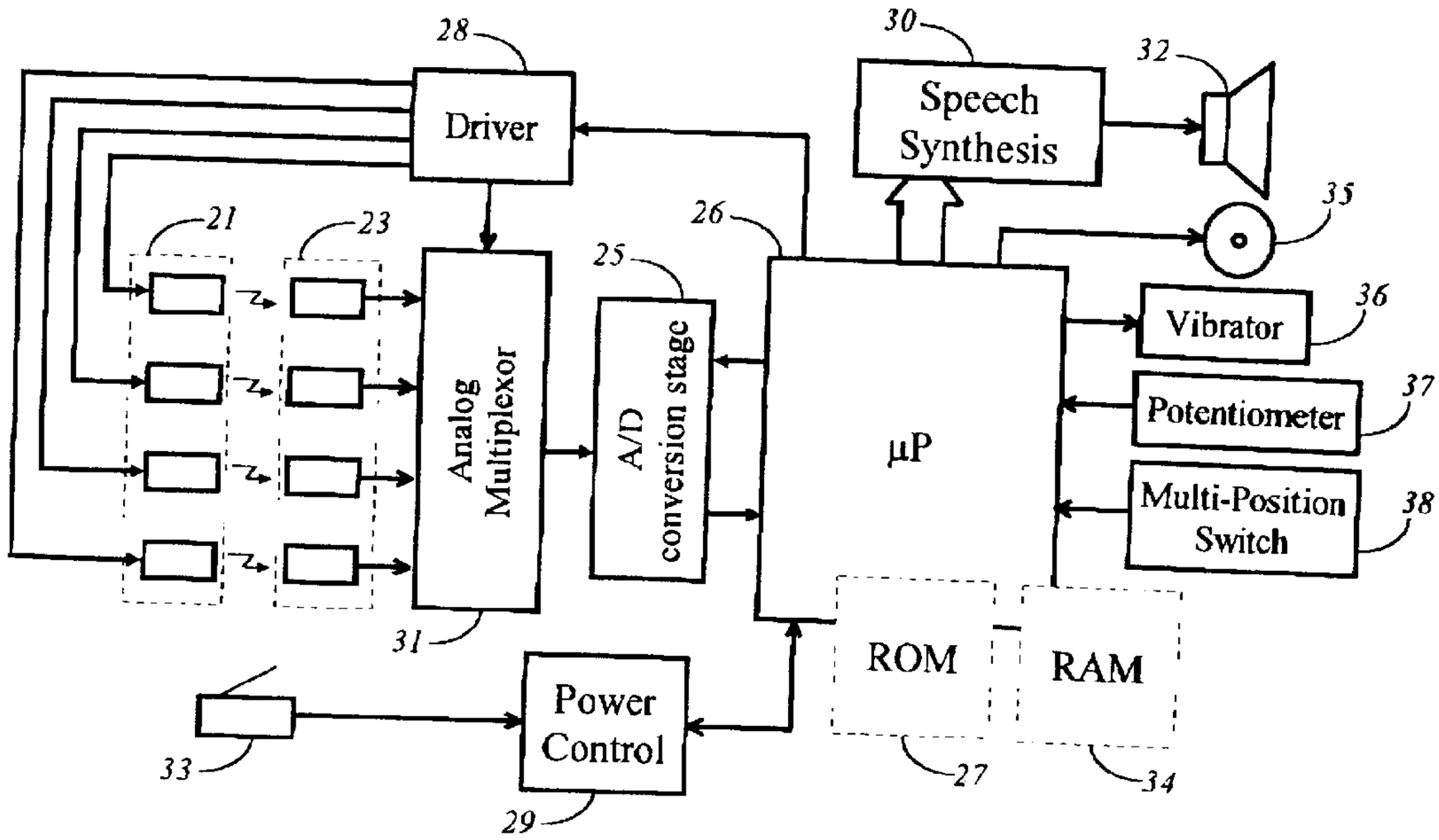
(54) **SYSTEME DE LECTURE DE BILLETS DE BANQUE**

(54) **BANKNOTE READER SYSTEM**



(57) A portable banknote reader for use by blind individuals is adapted to receive a banknote. The reader audibly or by other means announces the denomination of the note. The reader requires currency which is coded with special code markings. In order to read the note, the reader transmits infrared (IR) light through the note from one side and senses the intensity of light passing through the note on the other side. The reader converts intensity readings into a series of signals representative of the presence or absence of codes on the note, compares the series of signals against known codes to determine the denomination of the note and then activates a voice synthesizer or other device to output the denomination. The portable reader is more compact, less expensive and more reliable than current readers, is easy to use by blind people, requires little maintenance and has an expected life of more than 10 years.

ABSTRACT

A portable banknote reader for use by blind individuals is adapted to receive a banknote. The reader audibly or by other means announces the denomination of the note. The reader requires currency which is coded with special code markings. In order to read the note, the reader transmits infrared (IR) light through the note from one side and senses the intensity of light passing through the note on the other side. The reader converts intensity readings into a series of signals representative of the presence or absence of codes on the note, compares the series of signals against known codes to determine the denomination of the note and then activates a voice synthesizer or other device to output the denomination. The portable reader is more compact, less expensive and more reliable than current readers, is easy to use by blind people, requires little maintenance and has an expected life of more than 10 years.

BANKNOTE READER SYSTEM

FIELD OF INVENTION

The present invention relates to a system for recognizing banknote denominations, and particularly a system for indicating the value of specially marked banknotes or currency bills. More particularly still, the system is directed to serving blind individuals by announcing the electronically read denominations of a marked bill after insertion into a hand held, battery operated, device.

BACKGROUND OF THE INVENTION

Visually impaired, blind and deaf- blind persons have to determine the validity and denomination of currency notes by means other than visual.

A solution to this problem, with obvious disadvantages, is to rely on the assistance of a relative or friend.

In the prior art there are readers commonly used for recognition and validation of banknotes, that can be also used to help visually impaired individuals to identify banknotes.

For example, Canadian Patent No. 696,596, Canadian Patent No. 1,177,172, Canadian Patent No. 1,190,651, United States Patent No. 4,349,111, and United States Patent No. 4,127,194 disclose systems for the validation of banknotes, in which the note is propelled past some detectors and various characteristics of the note are compared against reference values. In all these patents, the systems do not require the notes to have a special marking or code, a fact which leads to complex reading procedures and comparisons to be performed among values read from the tested bills and reference values. Hence, the systems performing these operations are necessarily complex.

United States Patent No. 5,692,068 and Canadian Patent No. 1,321,274 disclose bank note readers, in which the reading of notes comprises storing signals in a memory, the signals corresponding to at least a portion of an array of pixels defined by a printed pattern on the face of a banknote. The pattern is raster scanned with an imaging apparatus comprising a light source, a charged coupled device (CCD) and a lens, to obtain a serial signal representing the pattern. The memory is searched for the serial signal by comparing the serial signal with stored reference signals. The presence and denomination of a valid banknote is indicated in the event the comparison correlates to a predetermined degree.

The disclosed systems rely on a visual printed pattern, on visual light emitting and detecting hardware. Noise and interference in the visible spectrum increase the chance for incorrect readings or inability to read in these systems. Increased accuracy in reading is achieved at the cost of employing a more complex software method, and hence more complicated logic circuitry. Another disadvantage due to the reliance on a visual pattern on the bill is that an area for the pattern must be reserved on the bill, thus decreasing the graphical design options for the bill. Furthermore, a visual printed pattern on the bill could be photographically reproduced in counterfeit bank notes, and the reader would be deceived in those cases. Visual light detecting and emitting hardware components are fairly large, leading to large, more cumbersome to carry, devices. Such components also tend to consume a considerable amount of battery power.

Canadian Patent No. 1,282,171 discloses a banknote denomination system for use by blind individuals, by providing a hand-held reader in which the user places a banknote, and the reader audibly announces the denomination of the note. The reader requires banknotes coded with special markings. In order to read the note, electro-luminescent panels transmit light through the note from one side and photo sensors sense the intensity of light passing through the note from the other side. The intensity readings are converted to a series of signals representative of the presence or absence of codes on the note and the series of signals are compared against known codes in order to determine the validity and the denomination of the note. A voice synthesizer is activated to output the result of the comparison. The disclosed

system relies on the use of light in the visible spectrum, in terms of the coded markings on the bills and in terms of the light emitting and detecting hardware. Disadvantages associated such systems regarding the accuracy and reliability of the readings, the numerous inefficiencies in terms of hardware design, have been mentioned above.

In addition, the reader system disclosed in Canadian Patent No. 1,282,171, requires the placing of the banknote to be denominated, in a casing having a base with a cover. The note has to be placed into the base and the cover must be closed. Such system, involving moving parts like the cover of the case, are easily breakable, unless very carefully manufactured. Since the bill must be fitted by the user into the base of the case in a more or less exact position, the system may also present handling difficulties to a visually impaired person.

The disclosed system uses only audible means to output the denominations of the bills. However, such means may not be found optimal by all users of such a system.

SUMMARY OF THE INVENTION

The present invention is intended for use by blind individuals to identify the denomination of paper currency or bank notes. This is achieved by providing a portable or hand-held banknote reader in which the user places a banknote in the reader and the reader audibly or by other means, such as tactile, announces the denomination of the note. The reader requires currency which is coded with special code markings. In order to read the note, the reader transmits infrared (IR) light through the note from one side and senses the intensity of light passing through the note from the other side. It converts intensity readings to a series of signals representative of the presence or absence of codes on the note, compares the series of signals against known codes to determine the denomination of the note and then activates a voice synthesizer or other device to output the denomination.

According to the invention, there is provided a portable banknote reader for determining the denomination of currency notes having an array of opaque IR markings, indicative of the denomination of said notes, at some or all of predetermined code locations on said notes, said reader comprising: a housing for receiving a banknote in a predetermined position therein; IR light source means in said housing for transmitting IR light through at least said predetermined code locations of a banknote disposed in said housing; means disposed in said housing in opposed relation to said IR light source means for receiving IR light transmitted thereby and responsive thereto for producing a series of signals representative of the array of markings on a banknote disposed in said housing; means for comparing said series of signals against each of a plurality of predetermined signals indicative of denominations of banknotes and producing an output signal indicative of the actual denomination of a note in said housing when said series of representative signals matches one of said plurality of predetermined signals; and means responsive to said comparing means output signal for producing an announcing signal indicative of the denomination of a note in said housing.

Other advantages, objects and features of the present invention will be readily apparent to those skilled in the art from a review of the following detailed description of preferred embodiments in conjunction with the accompanying drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows an example Canadian $20 banknote in outline, with special code markings in infrared ink, according to the present invention;

Figure 2 is a perspective depicting the hand-held device according to the present invention;

Figure 3 is a block schematic of the circuit in the hand-held device for reading and interpreting the code markings of Figure 1 according to the present invention;

Figures 4A, 4B, 4C and 4D are flow charts for the program operating the device of Figure 2; and

Figure 5 is a flow chart for the denomination output subroutine, in terms of the output means selected by the user of the device.

Similar references are used in different figures to denote similar components.

DETAILED DESCRIPTION OF THE INVENTION

For simplicity the invention will be described in accordance with a preferred embodiment, specifically in accordance with a reader for Canadian bank notes.

Figure 1 of the drawings shows in outline a paper bank note 10 for the denomination Canadian $20, having adjacent its narrow edges code markings in the form of two sets of black squares 11/12 and 13/14 made by printing the currency note 10 with invisible IR ink. The marking code actually consists of four binary positions corresponding to four squares on either end of the note 10. The code for the denomination 20 is that the outer two most squares 11, 12, 13 and 14 are inked. The position of the remaining squares is shown in dotted outline as squares 15, 16, 17 and 18. Out of sixteen possible combinations of a four-binary code, the all-zero and all-one cases cannot be used as they contain no contrast and the remaining fourteen combinations must have the same definition regardless of the orientation of the note with respect to the reader. This permits up to seven denominations to be differentiated, hence is sufficient to identify six denominations, ranging from $2 to $1000, of Canadian bank notes.

A blind person who wishes to know the denomination of the note 10 inserts the same in a hand-held reader 19, shown in Figure 2, in perspective. The note 10 is inserted in the

reader 19 through slot 20. Once fully inserted, IR light emitting diodes (LEDs) 21 face the code squares 11, 12, 15 and 16 . Infrared light emanating from IR LED *'s* 21 is transmitted through the note 10 and received by four IR photo diodes 23, one opposite each of the squares 11, 12, 15 and 16. The banknotes 10 have the four square binary codes printed in infrared opaque located at the same corresponding positions on both ends of all banknotes 10 to permit the reading of the banknote denomination regardless of which end of the banknote 10 is first inserted into the reader 19.

In one embodiment of the invention, the LED's 21 and the LED photodiodes 23 are enclosed in a plastic housing of the reader 19.

It will be understood by those skilled in the art that the number of the coded markings on the notes to be denominated, their shape and arrangement, the intensity of the ink printing, as well as the number of the LED's 21 and of the detecting photo diodes 23, are not limited to the above description and they depend on the specific application of the invention, on the cost and complexity desired for that application.

Figure 3 shows the optoelectronic circuitry housed in the device 19, which comprises in addition to four IR emitters 21 and four IR photo diodes 23, an analog-to-digital converter 25 for converting the voltage developed at each of the photo detectors into a digital representation. The analog-to-digital converter 25 delivers the digitized voltage values to a microprocessor 26, which controls the operation of the device by means of a program stored in read-only memory (ROM) 27. A driver 28, in response to the microprocessor 26, controls the emitters 21 and analog multiplexor 31. An activation switch 33 triggers the power control block 29, which develops and holds the necessary voltage level from the battery until instructed to shut down by the microprocessor 26. A user control interface comprises a potentiometer 37 and multi-position switch 38 which defines the type of output, its volume or intensity and if applicable, the language and pitch. If voice output is selected, a speech synthesis block 30 generates the speech in the selected language at the selected volume and announces it with a speaker 32. If coded tones are selected, the microprocessor 26 generates

the signal at the selected volume and pitch and drives the buzzer 35. If a tactile output is selected, the microprocessor 26 generates the signal at the selected intensity and pitch and drives the vibrator 36. The announcement depends on the actions performed by the microprocessor 26 to determine the denomination of the bank note. These actions are described with reference to the flow charts shown in Figures 4A, 4B, 4C and 4D.

In the circuit shown in Figure 3, a suitable microprocessor 26 is an 80C31BH with a crystal frequency of 14.7456 MHz, and a digital to analog converter such as an AD7224KR performing speech synthesis 30. A single channel analog to digital conversion 25 can be performed using a ratiometric method consisting of comparing, by means of a comparator, a reference generated by charging a capacitor with pulses from the microprocessor. The size of the pulses and number of charge/discharge cycles used dictate the accuracy obtained. The emitters 21 radiate IR light with a wavelength in the range 800 to 900 nm. A suitable device as an emitter is an HSDL-44XX.

The read-only memory 27, in addition to storing the program for the microprocessor 26, also stores the data for the output signal be it speech, tone or tactile vibration. The program executed by the microprocessor 26 implements the logic illustrated in the flow charts 4A, 4B, 4C and 4D. The speech, tone or tactile outputs indicate the bank note's denomination and conditions where the note cannot be read or the battery voltage is weak.

In order to initiate a note-reading operation, the user inserts a bank note into reader 10. The insertion of the banknote closes the activation switch 33, thus triggering the power control block 29. Power is asserted to the microprocessor 26 and code execution commences. The first operation after system initialization instructs the power control block 29 to maintain power until code execution is complete whereupon the microprocessor 26 issues a power-off command to the power control block 29. The functions between power-on and power-off are described with reference to the flow charts 4A, 4B, 4C and 4D.

Figure 4A shows the activation and power-on stage. After system initialization, a lock power-on signal is issued. The battery-low input is tested and if present, a battery-low code is stored in a random- access memory (RAM) 34. The microprocessor 26 then signals to the driver 28, via two TTL states, which emitter/detector pair to activate. An emitter/detector pair is made by an emitter 21 and a detector 23 placed directly opposite to each other. In a preferred embodiment, the emitter/detector pairs are activated sequentially. The purpose of activating the emitter/ detector pairs sequentially is twofold. Firstly, light interference from one emitter to a detector other than the one directly opposite it is eliminated. Secondly, a single channel A/D stage can be employed, reducing cost, providing future extendibility and using fewer microprocessor I/O resources. Each A/D operation uses 768 charge/discharge cycles, taking 7.6 ms. This provides 7-bit accuracy for input voltages between 0.5v and 2.5v. At the end of this stage, the microprocessor 26 has four values corresponding to the four analog levels generated by the detectors. The four values now held into the RAM 34 are range checked against calibrated levels received during production from paper samples with IR material outside of the working specification. If any of the values are outside of the valid range, the program jumps to Figure 4D, point C, otherwise continues to Figure 4B, point B.

The steps in Figure 4B analyze the values expecting them to fall roughly into two categories, "coded" and "not coded". Every valid bank note has at least one value in each category. The categories are defined by the largest gap in the numeric values of the four analog levels detected, as follows: the values below the gap are categorized as "coded" and those above are categorized as "not coded". The minimum and maximum in each category are compared to determine the spreads. The spreads are checked against predetermined values and if excessive, the program jumps to Figure 4D, point C, as all regions categorized as either "coded" and "not coded" must be closely matched for any single valid bank note. The average of both categories are compared and checked against a predetermined range. If the difference is outside of this range, the program jumps to Figure 4D, point C as "coded" and "not coded" regions on a single valid bank note must differ by a predetermined amount. If these tests pass, the program continues to Figure 4C.

The resolved populations of the two categories are then combined with reference to the detector they were received from to create a 4-bit binary map. The map is compared with maps of the known bank notes. If a match is found, a corresponding matching- denomination code is recorded in the internal memory 34 and the program continues to Figure 5, point E. If no match is found, the program jumps to Figure 4D, point C.

Figure 4D shows the common steps executed when a reading has failed. A data file for a "cannot read" code is stored in the internal memory 34 and the program jumps to Figure 5, point E. The storage of a pointer or array index is used to select various codes in the RAM 34. The conversion from this software reference to data files occurs conditionally in Figure 5. Figure 5 is common to all program sequences (low battery, cannot read and all matching-denominations). If speech is selected as output mean, the stored code/pointer/array index is used to select the appropriate data file used to synthesize speech.

Figure 5 shows the logic followed to announce the denomination. The selection for speech is checked and if valid, the language is determined. If a battery low code was stored in RAM 34, the data file from a primary or secondary language is selected. Next, the data file corresponding to the primary or secondary language is chosen based on the matched-denomination or error code stored in RAM 34. The speech synthesis process is activated and passed the selected data file. If speech is not the selected output, the low-battery code, if present, and the denomination or error code are converted into the output code format. This code is then passed to the selected output device driver. There are drivers for the buzzer 35 or the vibrator 36. Once an announcement has been completed by either an audio, a tactile or any other non-visual distinguishable output, the microprocessor 26 causes the power to be turned off.

The main advantages of the present invention are drawn from the use of light in the IR spectrum for the identification of currency notes having special coded markings, as opposed to the prior art use of light in the visible spectrum.

The identification by means of IR light permits the use of more accurate and more compact hardware components. Prior art electro-luminescent light panels used in the light emitting hardware are larger, and more expensive than IR LEDs. Additionally, electro-luminescent light panels consume more power than IR LEDs.

The same advantages in terms of size, cost and power consumption apply when comparing prior art photo sensors, such as cadmium sulfide light sensors, with photodiodes, used as light detecting elements.

In terms of power, the use of IR LEDs and of photodiodes, instead of electro-luminescent light panels and cadmium sulfide light sensors, almost doubles the battery life and hence the expected life of the device.

The smaller size of the IR LEDs and of photodiodes compared to prior art hardware components, allows for a smaller housing and hence a more compact, easier to handle reader.

Furthermore, the LEDs are less subject to change with environmental conditions such as temperature and humidity, than photoconductive cells. Therefore, the present invention allows for more uniformity from component to components, compared to prior art systems.

In addition, the provision of special coded markings on the bills combined with the high accuracy in readings favoured by the use of IR light, leads to the possibility of performing only few comparisons between the codes indicated by infrared markings of a currency note to be identified, and stored reference codes. Therefore simple identification algorithms and hence, simple logic circuitry, can be used.

The flexibility in selecting from a variety of output means is also a advantageous, novel feature of embodiments in accordance with the present invention.

From the discussion in the background section, an additional advantage of the present invention in one of its aspects versus prior art systems, will be seen to reside in the particular design of the casing of the reader. This particular design involves the insertion of the currency bill through a slot of the case, rather than having to open a cover of the case and to place the note in an exact required position.

Furthermore, as previously discussed, the accuracy of readings conferred by the use of IR light allows only few comparisons to be performed before a conclusion regarding the identity of a banknote is reached. Given a symmetric coding of both ends of the currency note to be denominated, the note can be inserted with either one of its ends first, into the reader, thus leading to a faster identification process.

It will be apparent to one skilled in the art that although the present invention has been described as being intended for the purpose of identification of currency notes by visually impaired individuals, its applications could easily extend to other systems, such as intended for the authentication and validation of various documents.

Numerous modifications, variations and adaptations may be made to the particular embodiments of the invention described above without departing from the scope of the invention, which is defined in the claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A portable bank note reader for determining the denomination of currency notes having an array of opaque IR markings, indicative of the denomination of said notes, at some or all of predetermined code locations on said notes, said reader comprising:

a housing for receiving a bank note in a predetermined position therein;

IR light source means in said housing for transmitting IR light through at least said predetermined code locations of a bank note disposed in said housing;

means disposed in said housing in opposed relation to said light source means for receiving IR light transmitted thereby and responsive thereto for producing a series of signals representative of the array of markings on a bank note disposed in said housing;

means for comparing said series of signals against each of a plurality of predetermined signals indicative of denominations of bank notes and producing an output signal indicative of the actual denomination of a note in said housing when said series of signals matches one of said plurality of predetermined signals; and

means responsive to said comparing means output signal for producing an announcing signal indicative of the denomination of a note in said housing.

2. A portable bank note reader as defined in claim 1, said housing having a slot for accepting currency notes and comprising means responsive to said notes being accepted into said slot for activating said light source .

3. A portable bank note reader as defined in claim 1, said light responsive means including a plurality of IR light sensitive elements, each said element being responsive to IR light passing through one of said predetermined code locations by producing a signal indicative of the presence or absence of a marking at said location.

4. A portable bank note reader as defined in claim 3, said IR light responsive means further comprising means responsive to said marking indicative signals from said plurality of

IR light sensitive elements for producing said series of signals, said series of signals being a series of digital signals.

5. A portable bank note reader as defined in claim 4, said means responsive to said marking indicative signals being an analogue-to-digital converter.

6. A portable bank note reader as defined in claim 3, said IR light source means further comprising IR light emitting diodes (LEDs).

7. A portable bank note reader as defined in claim 3, each said IR light sensitive elements being an IR photodiode.

8. A portable bank note reader as defined in claim 1, said comparing means including a microprocessor electrically connected to said IR light sensing means for receiving said series of signals in digital format and memory means for storing said plurality predetermined signals in digital format.

9. A portable bank note reader as defined in claim 8, further comprising means responsive to said microprocessor for energizing said IR light source means.

10. A portable bank note reader as defined in claim 9, said means responsive to said microprocessor being a driver.

11. A portable bank note reader as defined in claim 8, 9 or 10, said IR light responsive means including a plurality of IR light sensitive elements, each said element being responsive to IR light passing through one of said predetermined code locations by producing a signal indicative of the presence or absence of a marking at said location.

12. A portable bank note reader as defined in claim 11, said IR light responsive means further including means responsive to said marking indicative signals from said plurality of

IR light sensitive elements for producing said series of signals, said series of signals being a series of digital signals.

13. A portable bank note reader as defined in claim 12, said means responsive to said marking indicative signals being an analogue-to-digital converter.

14. A portable bank note reader as defined in claim 1, 8, 9 or 10, said means responsive to said comparing means output signal including voice synthesis means and a speaker.

15. A portable bank note reader as defined in claim 1, 8, 9 or 10, said means responsive to said comparing means output signal including a tactile output device.

16. A portable bank note reader as defined in claim 1, 8, 9 or 10, said means responsive to said comparing means output signal including a vibrator.

17. A portable bank note reader as defined in any one of claims 3 to 10 and 11 to 16, said housing having a slot for accepting currency notes and comprising means responsive to said notes being accepted into said slot for activating said IR light source means.

18. A portable bank note reader for determining the denomination of currency notes having an array of IR opaque markings, indicative of the denomination of said notes, at some or all of predetermined code locations on said notes, said reader comprising:

a housing for receiving a bank note in a predetermined position thereon whereat a bank note may be inserted in said predetermined position in said housing ;

IR light source means in said housing for transmitting IR light, when said note is inserted into said housing through at least said predetermined code locations;

an array of IR photodetectors disposed in said housing for sensing IR light transmitted by said IR light source means, each said photodetector being operable to produce a signal indicative of the presence or absence of a marking at one of said predetermined code locations

of a bank note whereby said array of photodetectors produce a series of signals representative of the array of markings on a bank note disposed on said housing;

means for decoding said array of representative signals based on predetermined threshold values, to a series of decoded signals;

means for converting said decoded signals to a series of digital signals;

memory means for storing a plurality of coded digital signals representative of predetermined denominations;

microprocessor means for comparing said series of digital signals against each said coded digital signals in said memory means and producing an output signal indicative of the actual denomination of a note in said housing when said series of digital signals matches one of said coded digital signals; and

means for producing an announcing signal indicative of the denomination of a note in said housing.

19. A portable bank note reader as defined in claim 18, said announcing means comprising voice synthesis means and a speaker.

20. A portable bank note reader as defined in claim 18, said announcing means comprising a tactile output device.

21. A portable bank note reader as defined in claim 18, said announcing means comprising a vibrator.

22. A portable bank note reader as defined in claim 18, said microprocessor means further comprising driver means responsive to said microprocessor means for energizing said IR light source means.

23. A portable bank note reader as defined in claim 18, said means for converting being an analogue-to-digital converter.

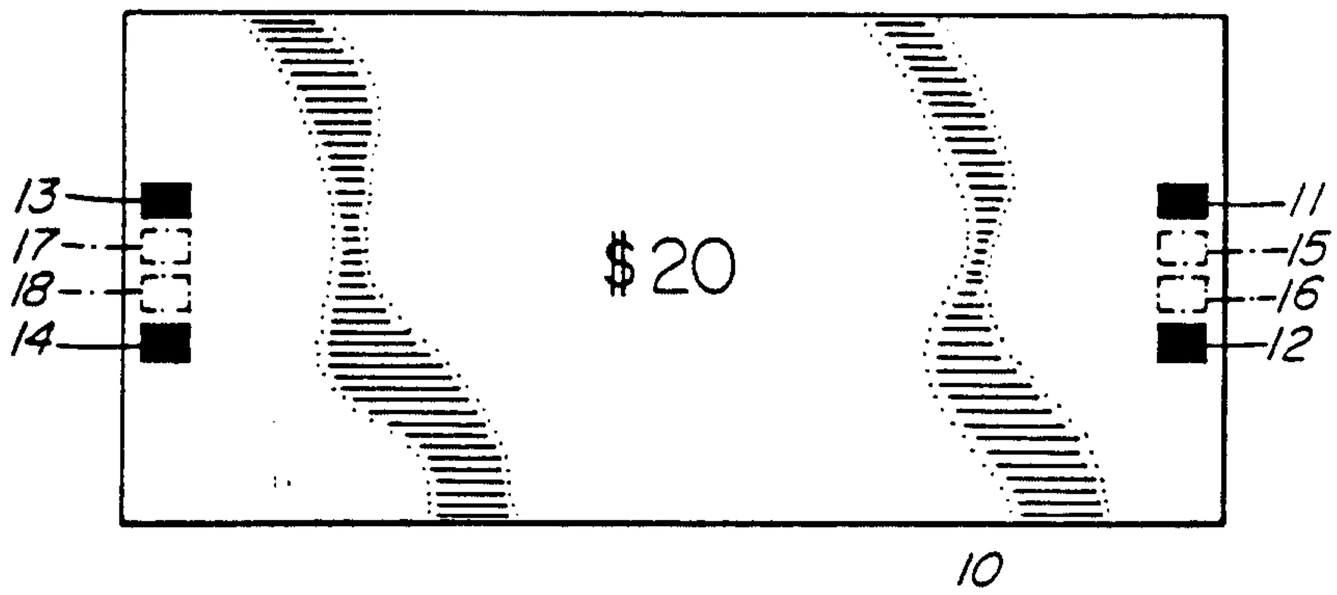


FIG. 1

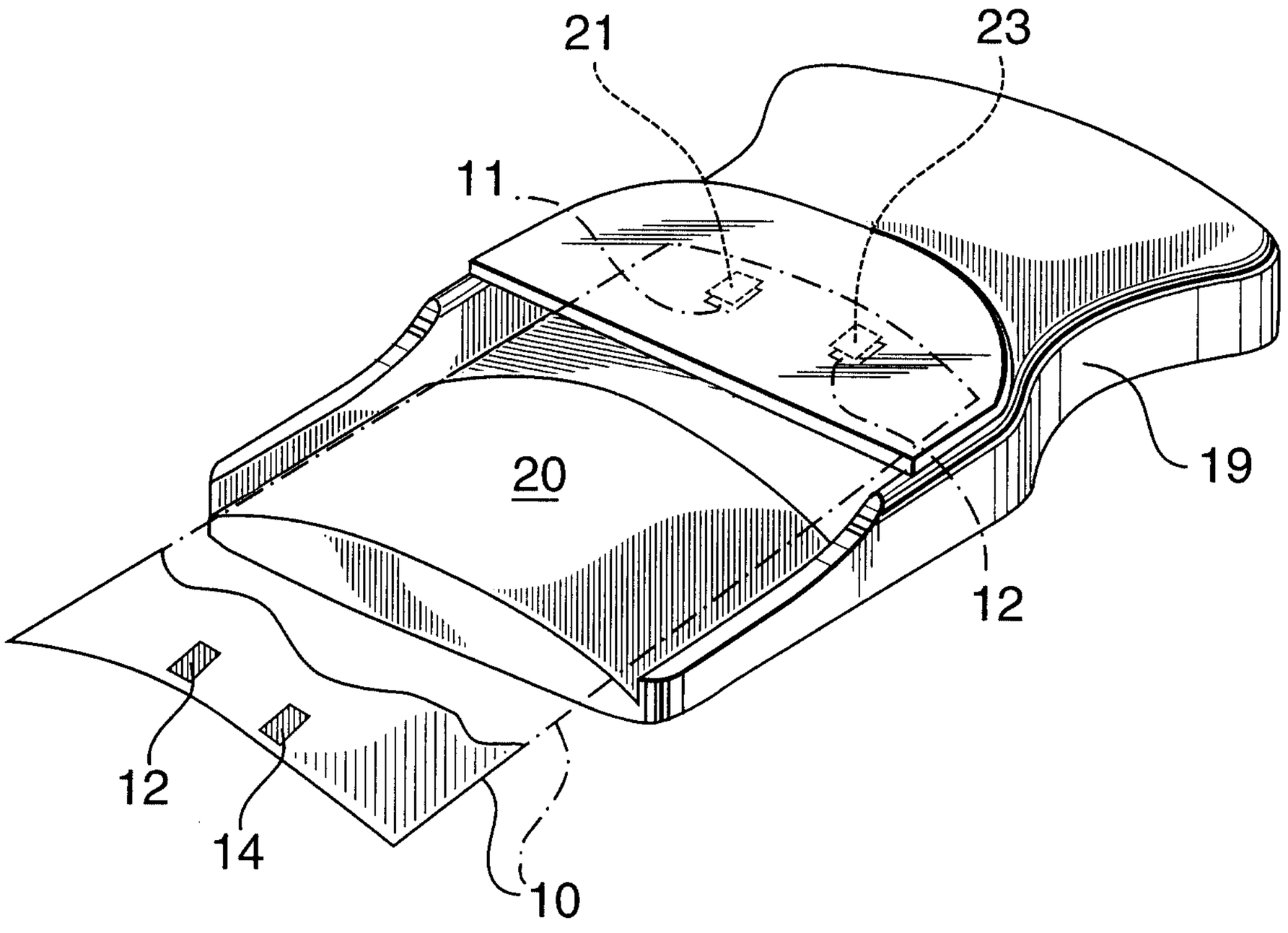


FIG. 2

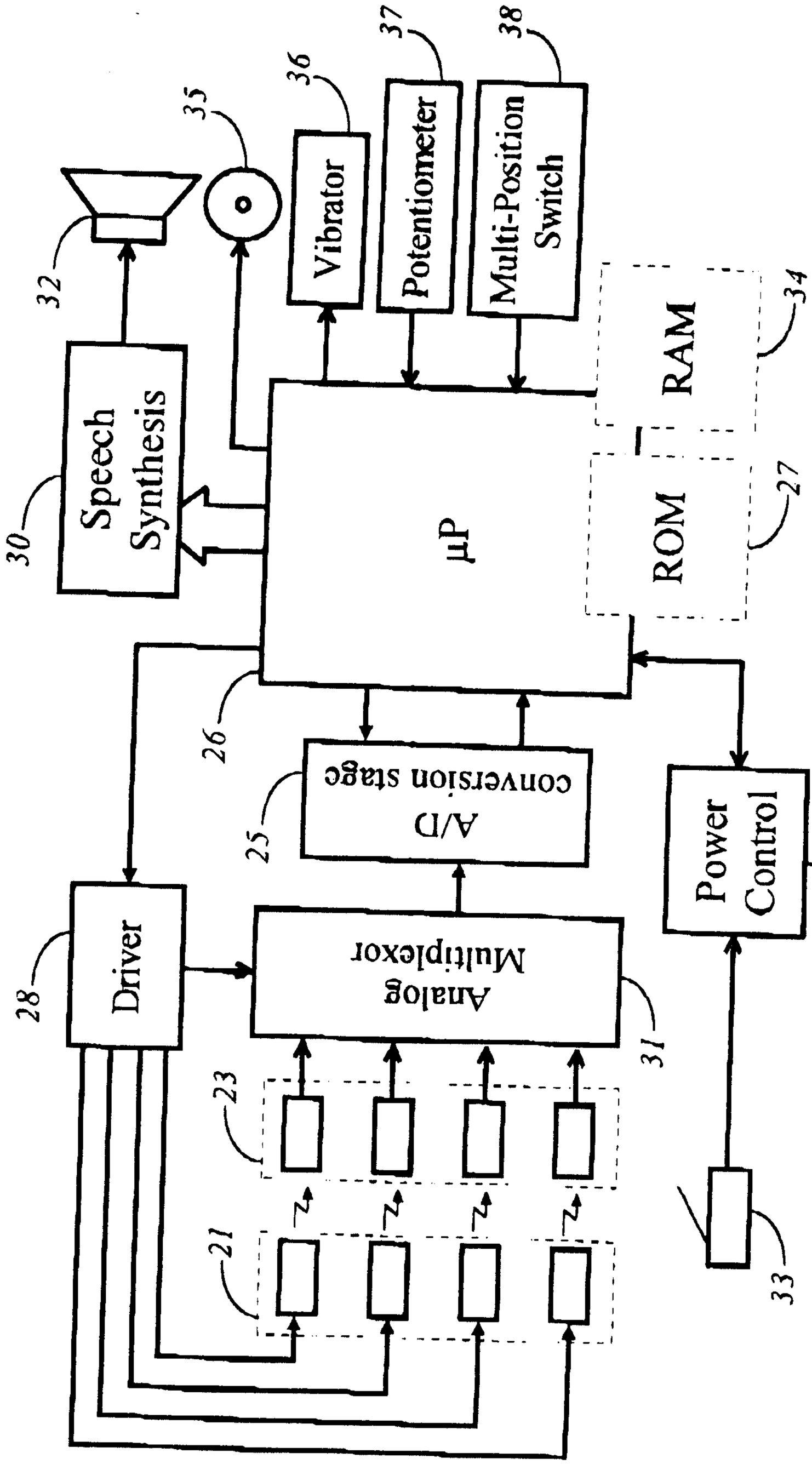

Speech Synthesis
30
32
35
Vibrator
36
Potentiometer
37
Multi-Position Switch
38
RAM
34
ROM
27
µP
26
A/D conversion stage
25
Analog Multiplexor
31
Driver
28
23
21
Power Control
29
33

Fig. 3

Fig. 4A

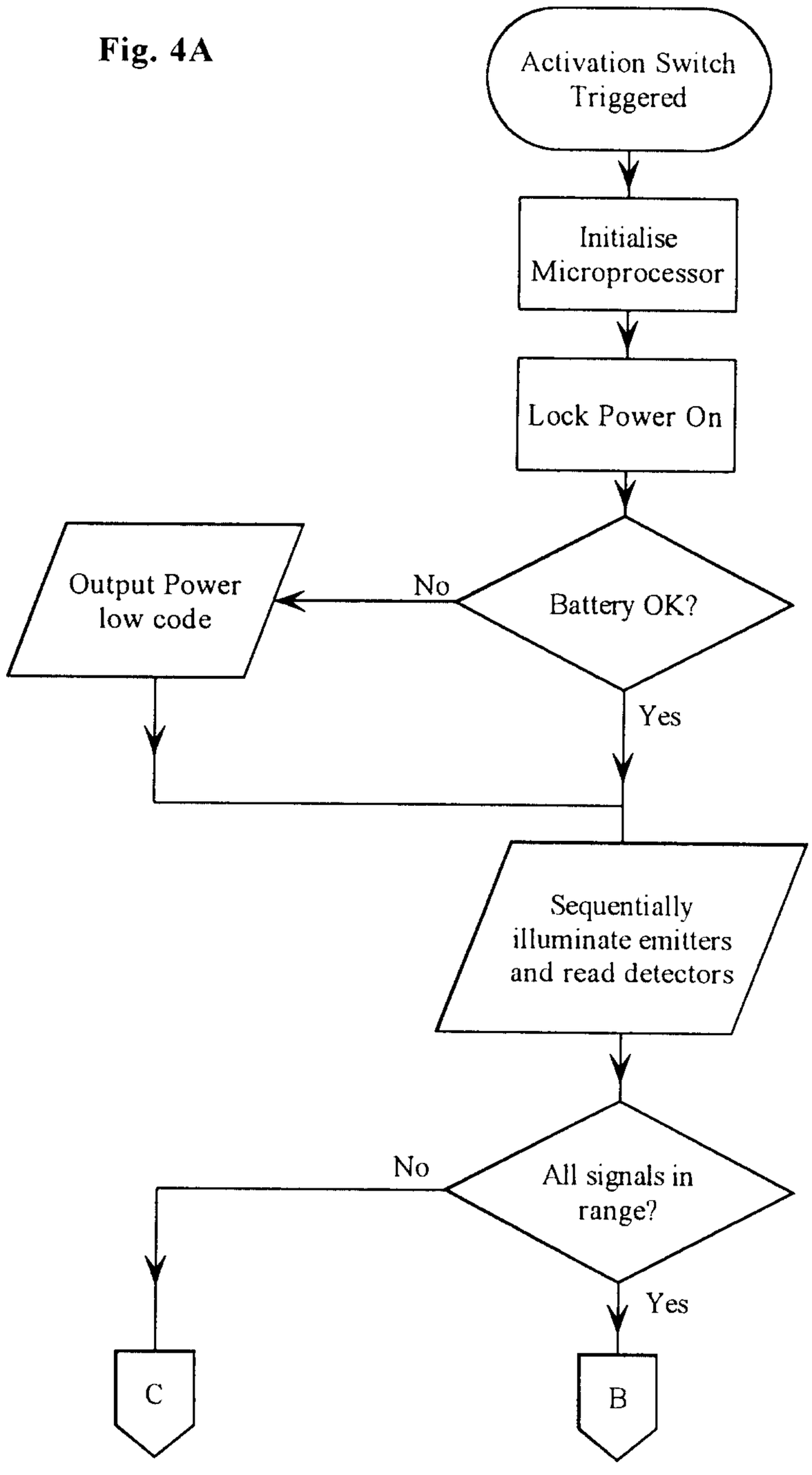

Activation Switch Triggered
Initialise Microprocessor
Lock Power On
Battery OK?
No
Output Power low code
Yes
Sequentially illuminate emitters and read detectors
All signals in range?
No
Yes
C
B

Fig. 4B

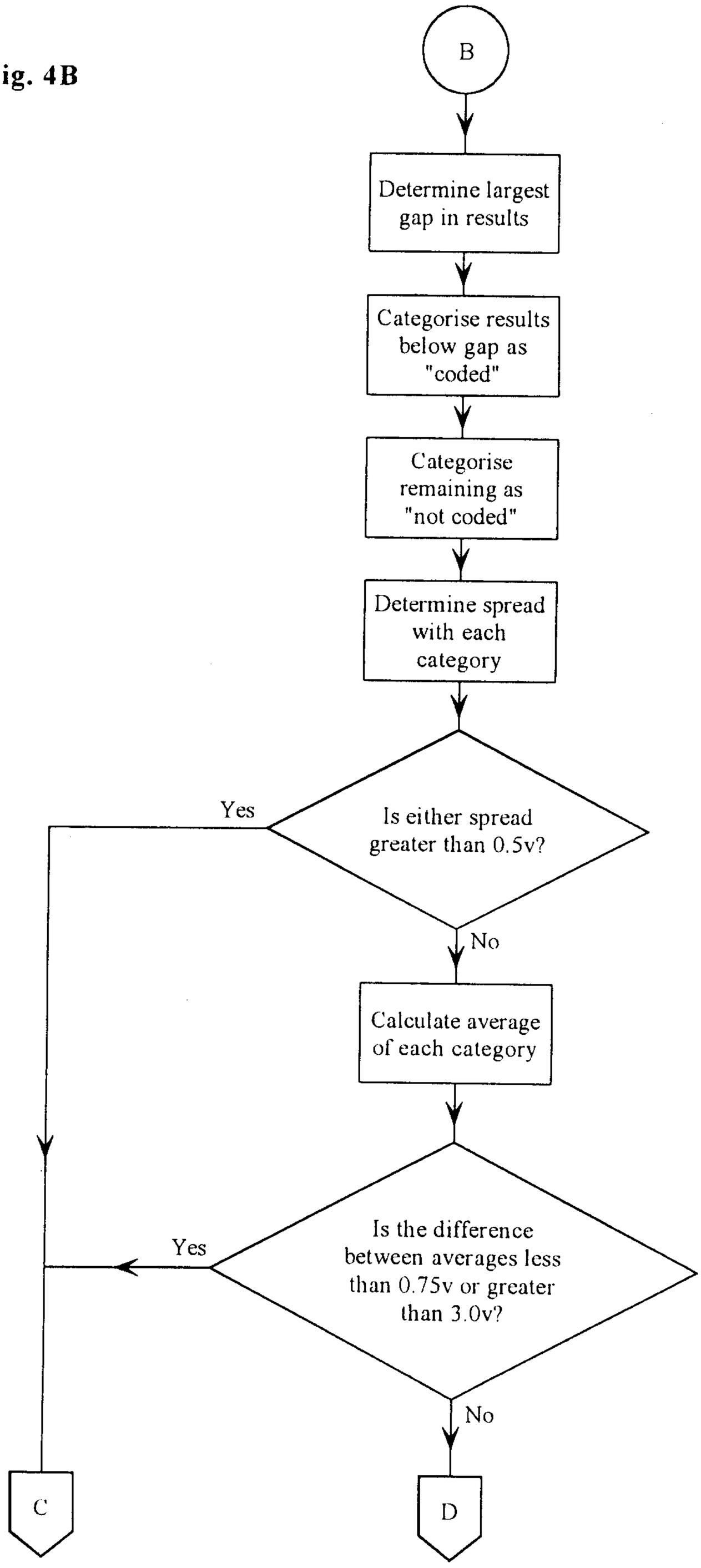

B
Determine largest gap in results
Categorise results below gap as "coded"
Categorise remaining as "not coded"
Determine spread with each category
Is either spread greater than 0.5v?
Yes
No
Calculate average of each category
Is the difference between averages less than 0.75v or greater than 3.0v?
Yes
No
C
D

Fig. 4C

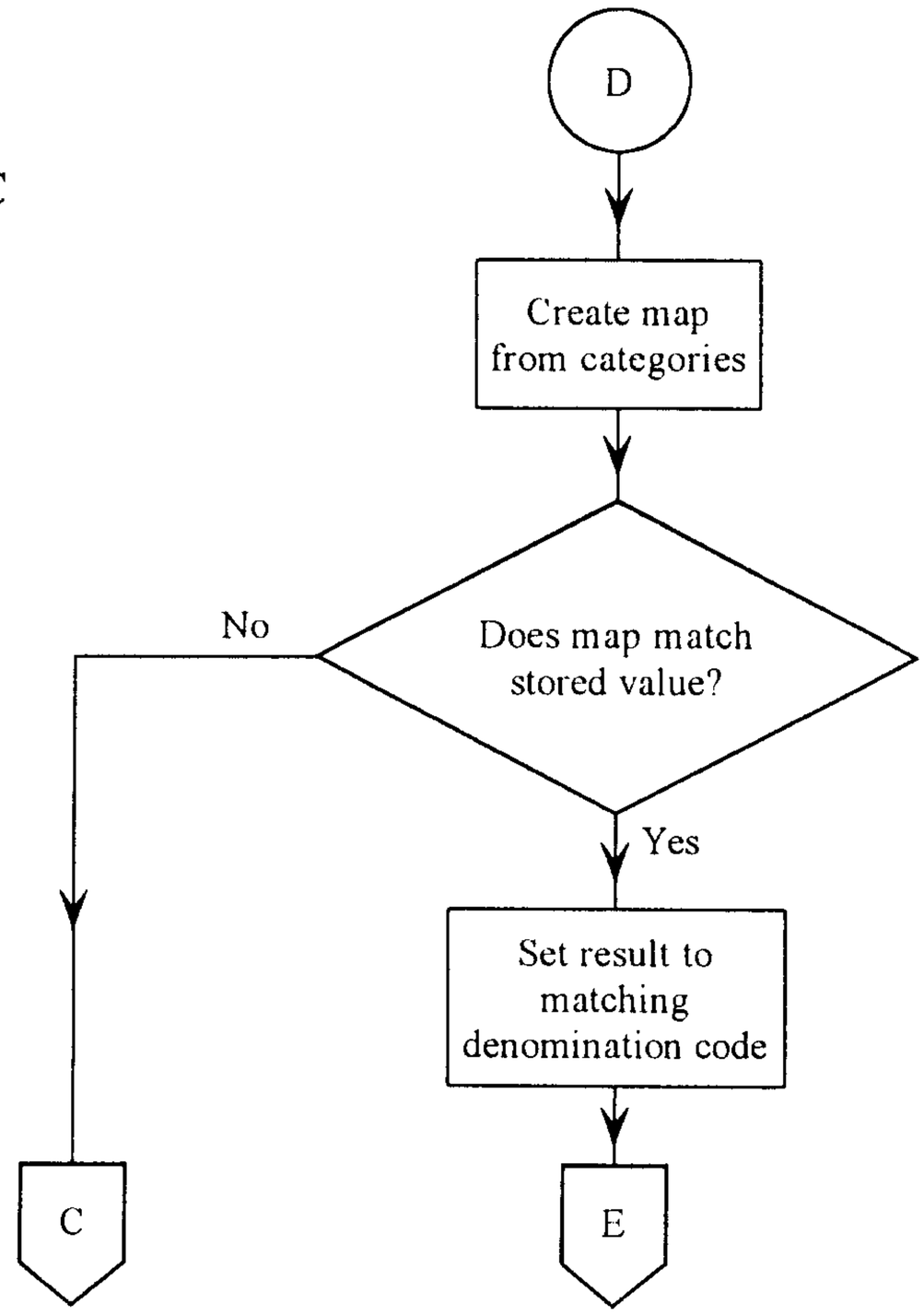

D
Create map from categories
Does map match stored value?
No
Yes
Set result to matching denomination code
C
E

Fig. 4D

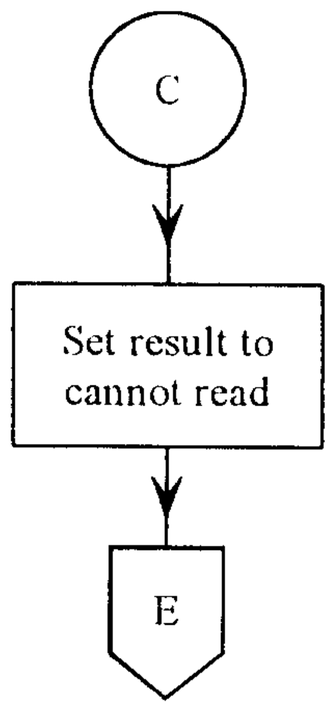
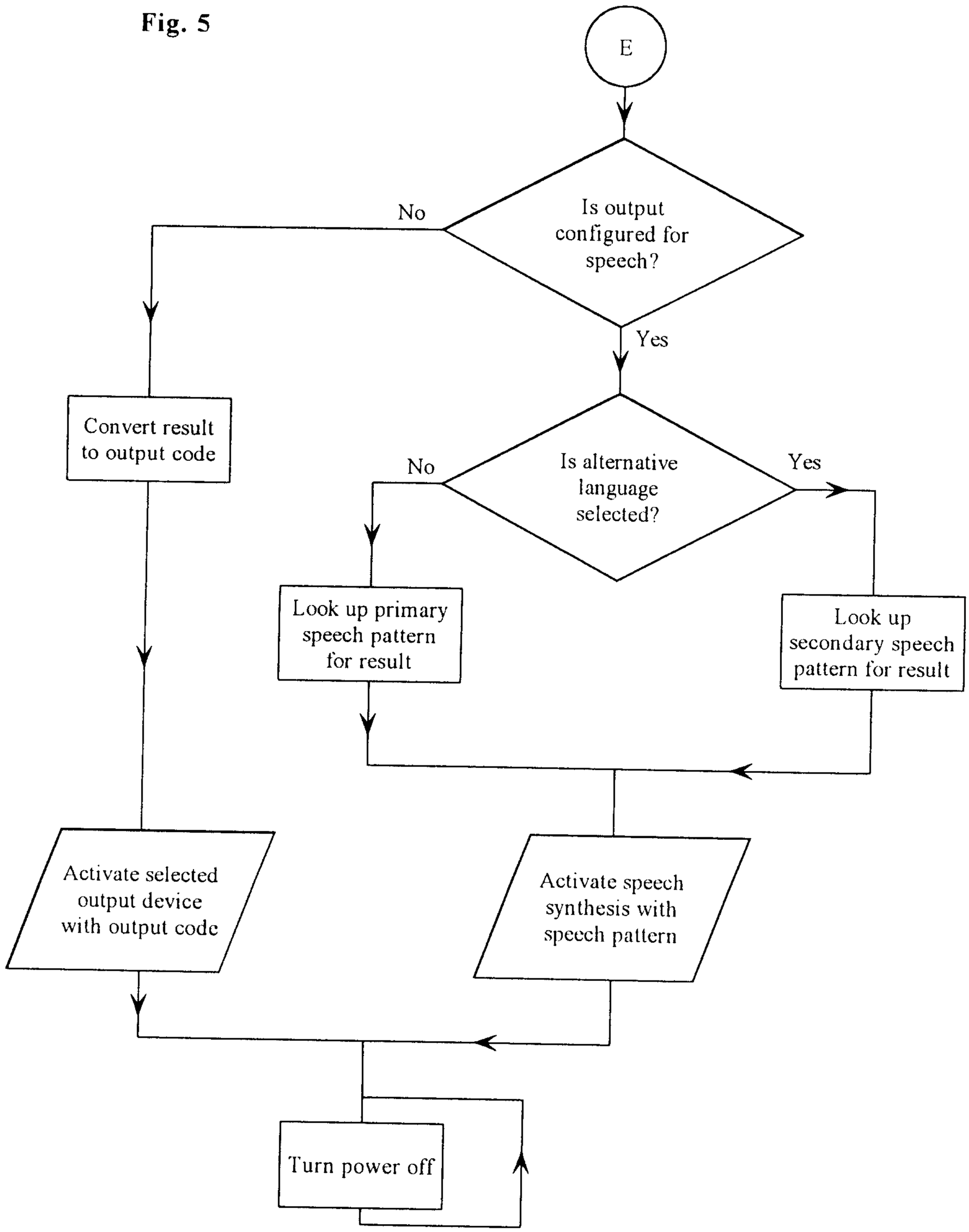

C
Set result to cannot read
E

Fig. 5


E
Is output configured for speech?
No
Yes
Convert result to output code
Is alternative language selected?
No
Yes
Look up primary speech pattern for result
Look up secondary speech pattern for result
Activate selected output device with output code
Activate speech synthesis with speech pattern
Turn power off