(12) UK Patent Application (19) GB (11) 2 062 854 A

(21) Application No **8034225**
(22) Date of filing **23 Oct 1980**
(30) Priority data
(31) **54/139859**
(32) **31 Oct 1979**
(33) **Japan (JP)**
(43) Application published **28 May 1981**
(51) **INT CL[3] G07D 7/00**
(52) Domestic classification **G1A** C10 C12 C1 C3 C8 C9 D2 G13 G1 G2 G6 G7 MH R2 R7 S3 T14 T21 T23 T3 T4 T7 T8 **G4X** 6
(56) Documents cited **GB 2035551A**
(58) Field of search **G1A** **G4X**

(71) Applicant
Tokyo Shibaura Denki Kabushiki Kaisha
72 Horikawa-cho
Saiwai-ku
Kawasaki-shi
Kanagawa-ken
Japan

(72) Inventors
Yasushi Nakamura
Ko Ohtombe
Kouji Izawa

(74) Agents
Batchellor Kirk & Eyles
2 Pear Tree Court
Farringdon Road
London EC1R 0DS

(54) Currency note identification system

(57) An identification system for determining the validity of currency note 15, characterised by memory 28 for storing a series of first electrical signals representing a characteristic of a genuine note. Each of the first signals corresponds to a discrete successive area of the genuine note and represents a component of a first vector. Detector 19 scans note 15 and generates a corresponding series of second electrical signals. Each of said second signals corresponds to a discrete successive area of note 15 and represents a component of a second vector. Calculating means 20–27, 29 are coupled to the detector and memory to calculate a value of similarity corresponding to an angle between the first and second vectors. The similarity value is compared with a predetermined value of permissible authenticity.

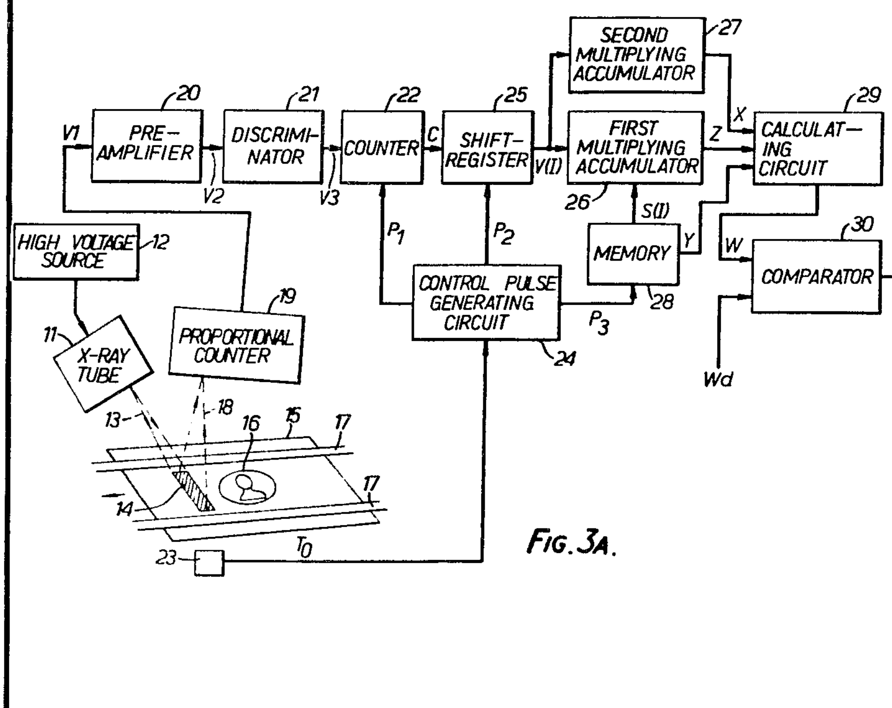

FIG. 3A.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

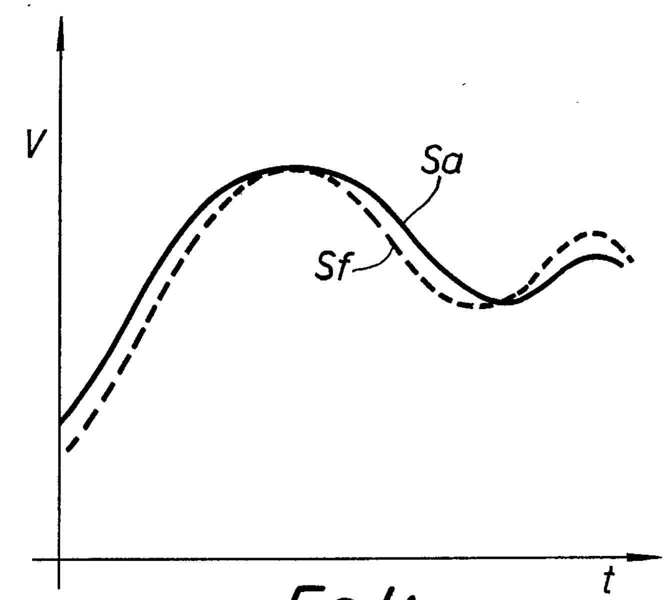

FIG. 1A.

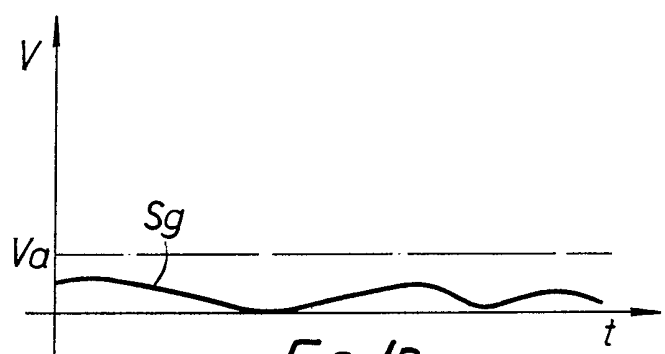

FIG. 1B.

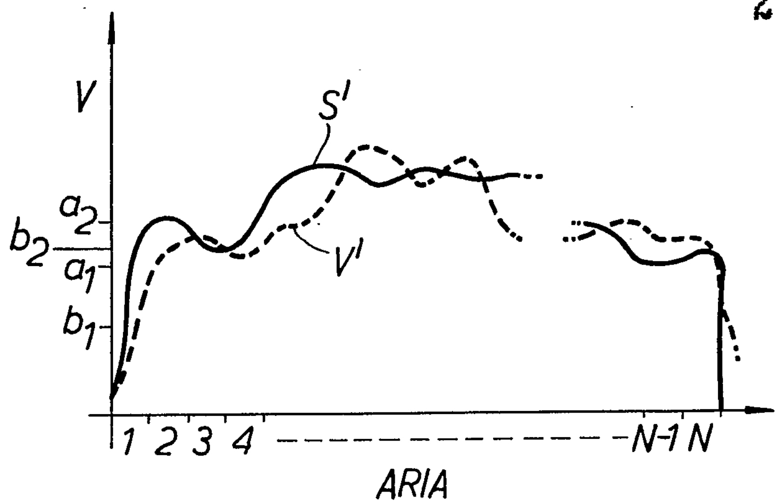

FIG. 2A.

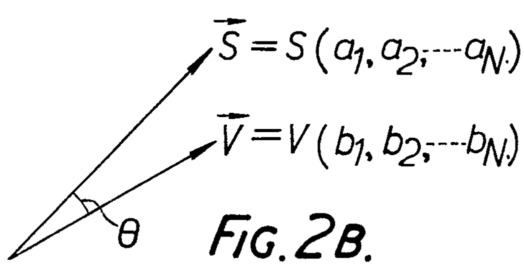

FIG. 2B.

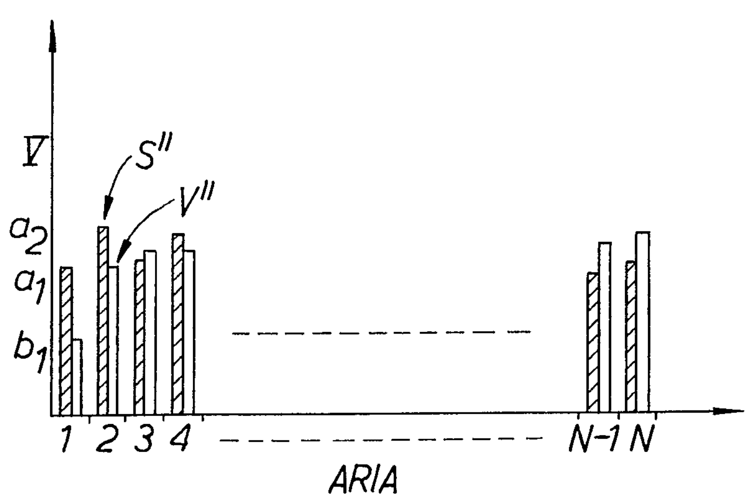

FIG. 2C.

2062854

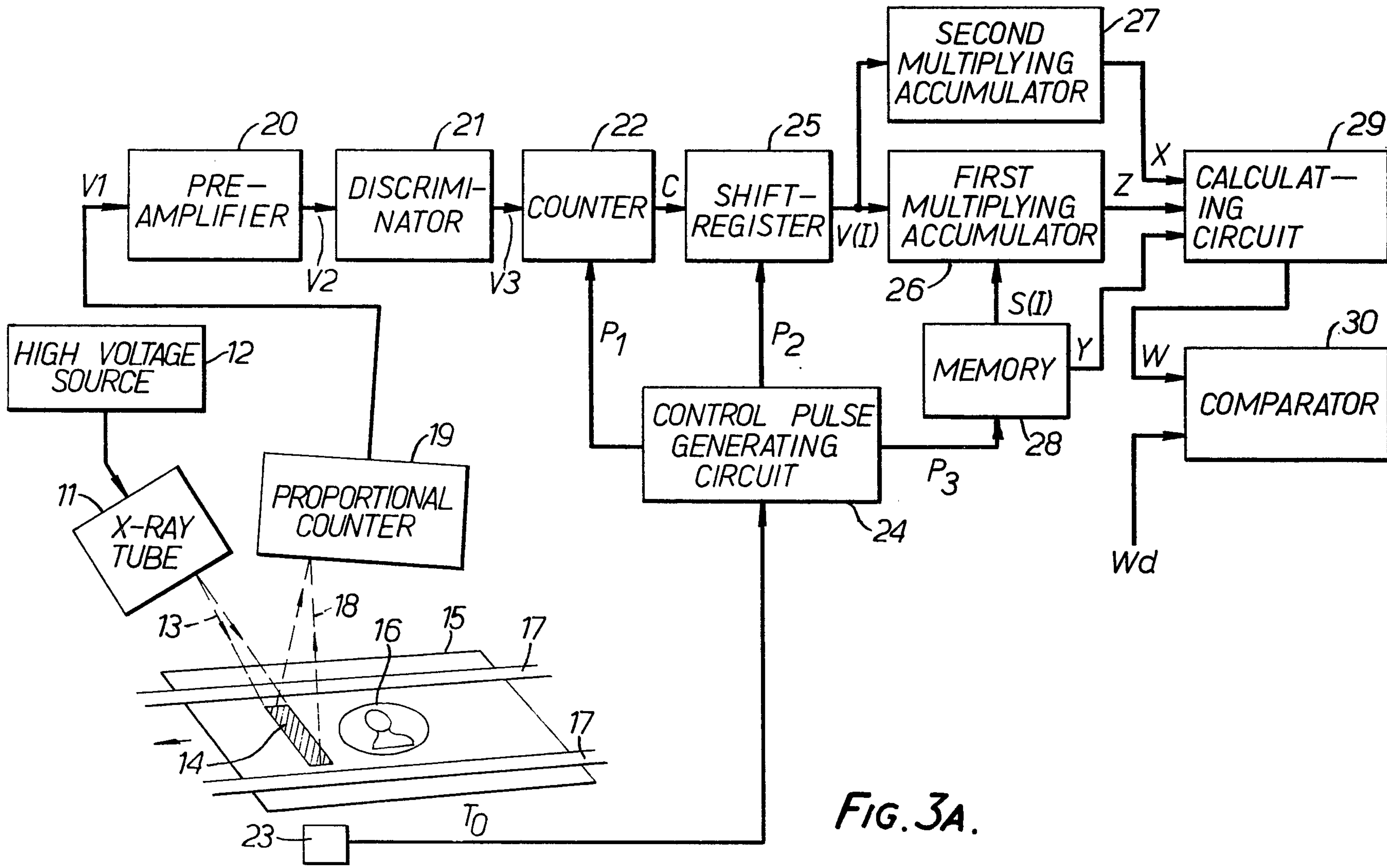

FIG. 3A.

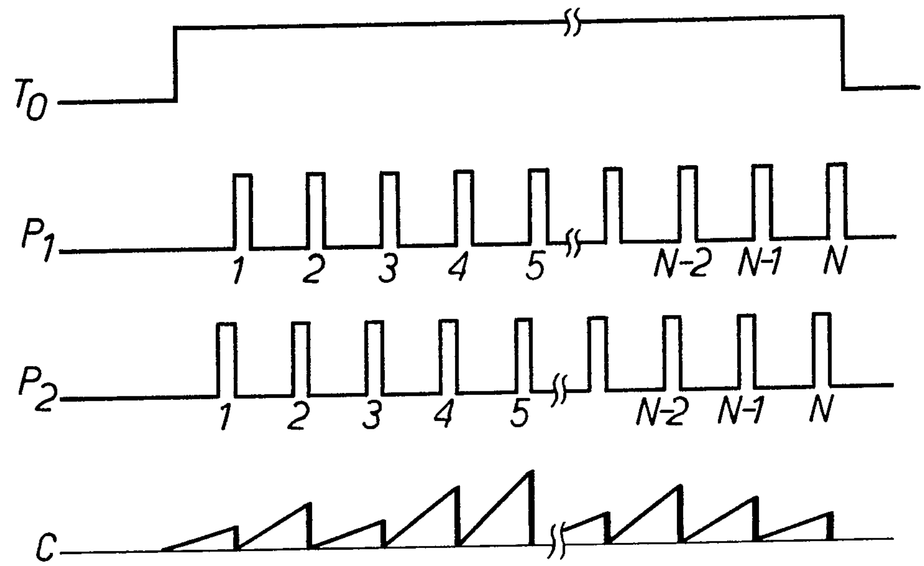

FIG. 3B.

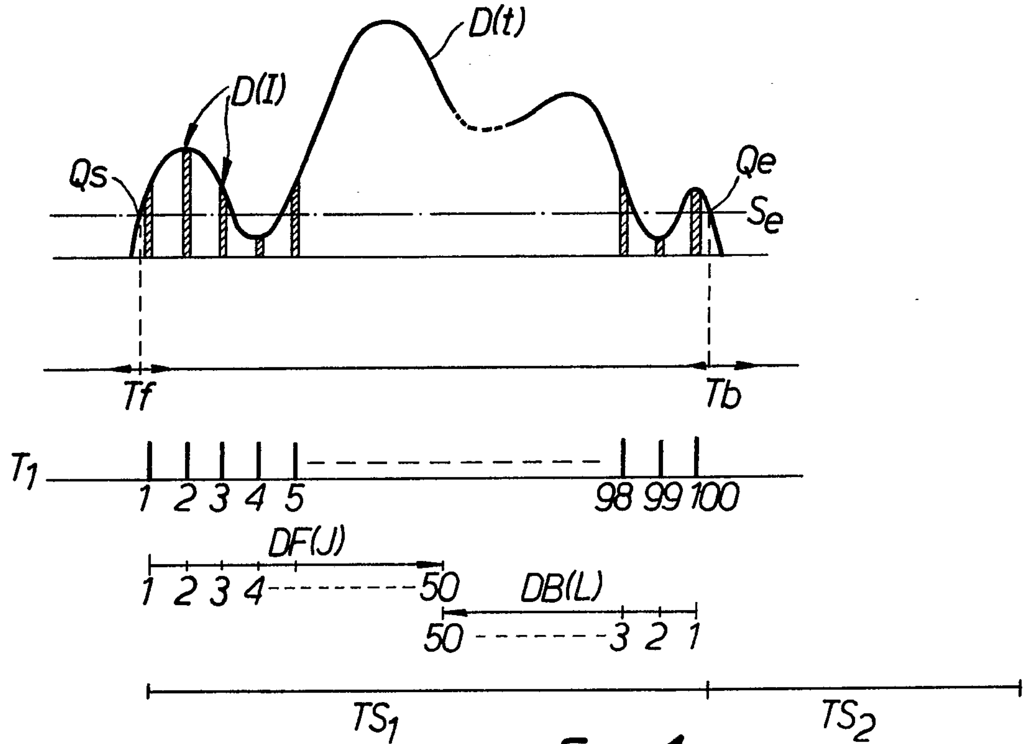
D(t)
D(I)
Qs
Qe
S_e
Tf
Tb
T_1
1 2 3 4 5
98 99 100
DF(J)
1 2 3 4
50
DB(L)
50
3 2 1
TS_1
TS_2

FIG.4.

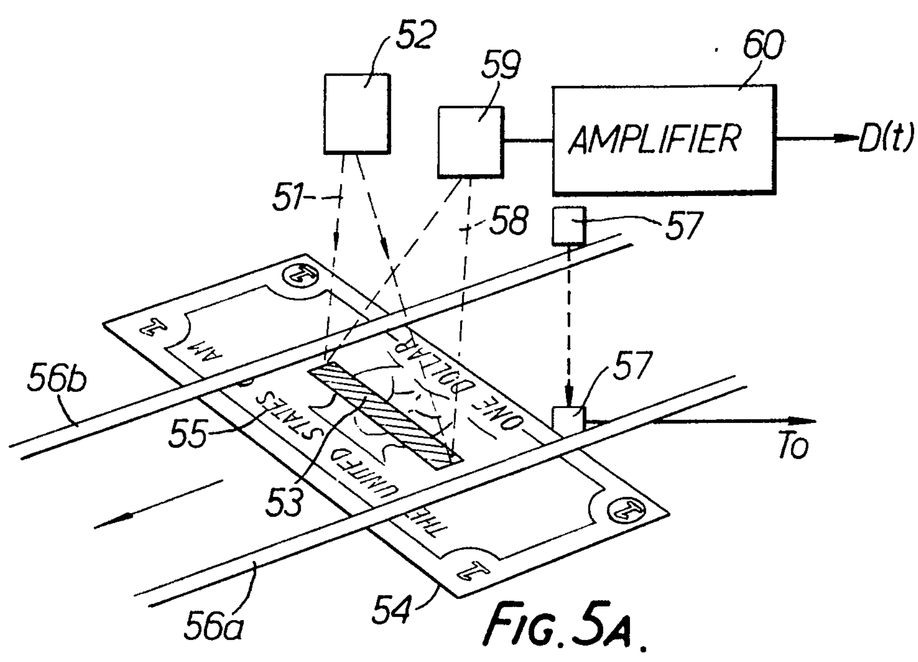
52
59
60
AMPLIFIER
D(t)
51
58
57
57
56b
55
53
To
56a
54
ONE DOLLAR
THE UNITED STATES

FIG.5A.

2062854

6/6

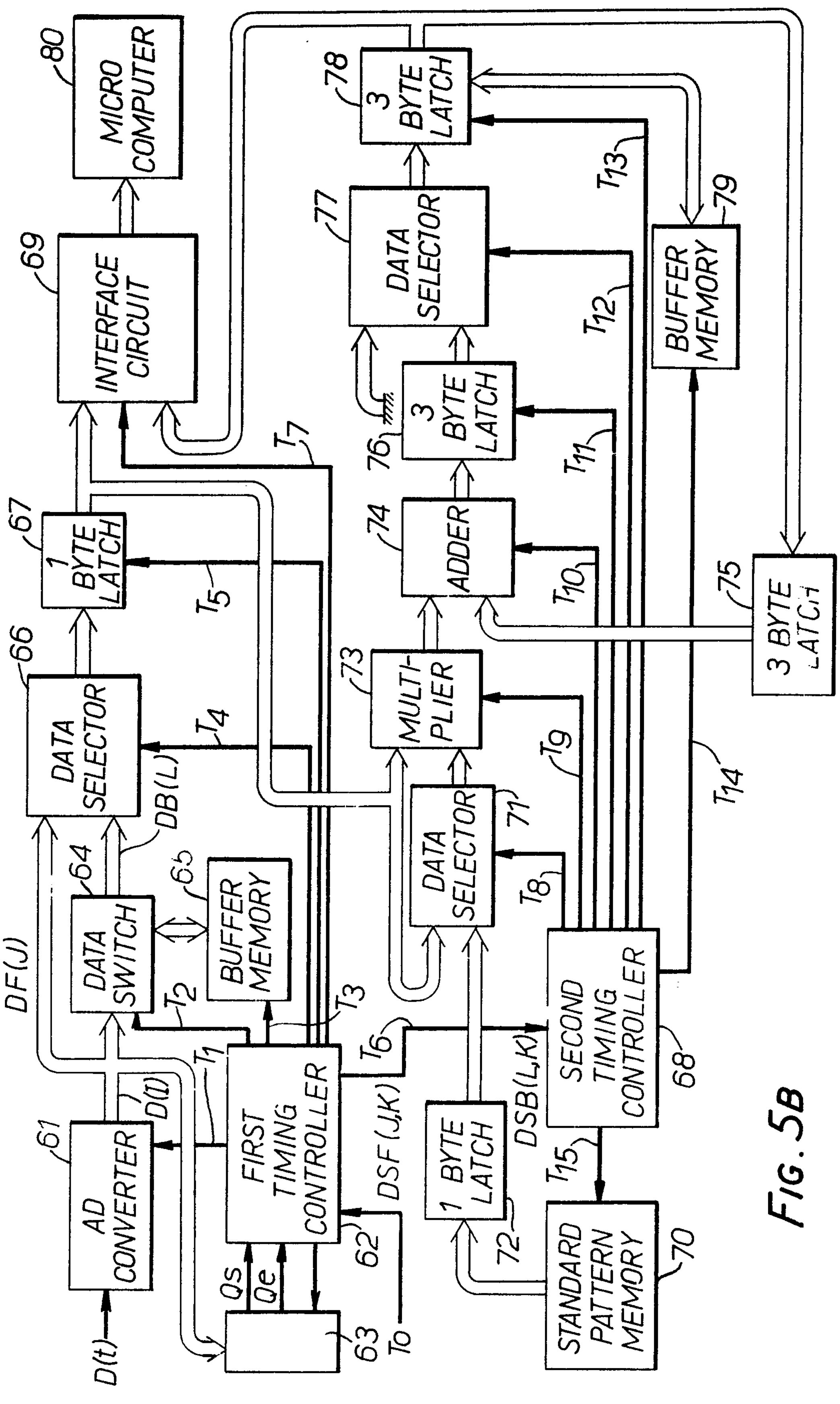

FIG. 5B

SPECIFICATION

Currency note identification system

This invention relates generally relates to systems for identifying currency, and more particularly to an improved process for identifying a genuine currency note. The increased usage of vending machines, money changers, bank terminal machines etc in recent years has made it necessary to automatically and correctly identify the authenticity of currency notes, and especially bank notes.

The identification of the currency notes is generally done by detecting light reflected from the notes, as described in U.S. patent no. 4,179,685. Merely detecting reflected light, however, does not necessarily verify the authenticity of the detected note to prevent the acceptance of forged notes. One method which has been developed to verify authenticity by detecting magnetic material, metallic element, or color which is contained in the currency or its printing ink is disclosed in Japanese patent disclosures nos. 54-4199 and 53-146698 corresponding to U.S. patent application serial no. 969,379, filed December 14th 1978. In these disclosures, the detection of colour, magnetic material, or metallic elements is performed by substantially the same process.

For example, in the Japanese patent disclosure no. 54-4199 the analogue detecting signal S_a, as shown in Fig. 1A, is obtained by scanning a detected bank note and compared with an anologue standard signal S_f, corresponding to a genuine note, to obtain an absolute difference signal S_g (see Fig. 1B). If difference signal S_g remains less during its entire time interval, than a predetermined level V_a, when the detected bank note is considered to be genuine.

If at any instant the difference signal exceeds level V_a, the note will be rejected. This method therefore has disadvantages in that a note having a minor disfigurement due to its handling (i.e. wrinkles) and daily processing will be rejected which otherwise should not occur. These minor disfigurements can be caused by handling which stretch, shrink, and/or fade printing patterns or which decrease the quantity of magnetic material or metallic elements.

In the field of currency identification systems, the printing patterns of the detected objects (i.e. currency notes) are in fixed and standard forms; as a result, the measured difference between the detected note and signals corresponding to a genuine note are generally small. On the other hand, in the field of pattern recognition systems the printing patterns are generally not in fixed and standard forms; variations in the figures or patterns exist which must be recognised and checked for comparision. As a result, the system circuity must be sensitive to greater differences between the detected pattern and the known pattern, than is the case with currency note identification systems where greater differences are not tolerated. In the field of pattern recognition, methods are utilised which calculate numerous values of similarity between areas of a detected object and corresponding areas of known object to determine if the detected pattern should be accepted (see U.S. patent nos. 3,688,267 and 3,906,446). The present invention incorporates some features of pattern recognition into a currency note identification system whereby a novel method and apparatus is employed to calculate a value of similarity between a detected note and a genuine note to determine authenticity.

According to the present invention there is provided a currency identification system for examining an authenticity characteristic of a detected currency note and comparing it to an authenticity characteristic of a genuine currency note to determine if the detected currency note is genuine characterised by; memory means for storing a series of first electrical signal representing the authenticity characteristic of said genuine currency note, each of said first signals corresponding to a discrete successive area of said genuine currency note and representing a component of a first authenticity vector; detecting means for scanning said detected currency note and generating a series of second electrical signal representing the authenticity characteristic of said detected currency note, each of said second signals corresponding to a discrete successive area of said detected currency note and representing a component of a second authenticity vector; calculating means coupled to said detecting means and said memory means to calculate a value of similarity corresponding to an angle between said first authenticity vector and said second authenticity vector; and comparing means for comparing the value of similarity with a predetermined value which represents a permissible authenticity value for the detected currency corresponding to a genuine currency.

The disadvantage resulting from utilising the prior art method of comparing an absolute value difference signal to a predetermined level V_a may thus be avoided. Moreover, in the preferred system of the invention, the time consuming disadvantage of prior art pattern recognition systems of calculating a large number of values of similarity between numerous area of a detected pattern and corresponding areas of a known pattern is eliminated by utilising pattern recognition techniques in which a single value of similarity between the detected note and the genuine note is preferably employed, rather than numerous values.

Some embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1A, 1B shows the waveforms of an analogue detecting signal S_a, an analogue standard signal S_f, and the difference signal S_g employed in an identification method of the prior art;

Figures 2A, 2C shows waveforms of electrical analogue signals S', V' and S'', V'';

Figure 2B shows vectors $\vec{S}$, $\vec{V}$ where employed in explaining the principles of the instant invention;

Figure 3A shows a block diagram of one embodiment of the invention;

Figure 3B shows a series of waveforms for explaining the embodiment of Fig. 3A;

Figure 4 shows a schematic view for explaining a further embodiment of the invention;

Figure 5A shows a perspective view of the characteristic detecting part of the embodiment of the invention shown in Fig. 4;

Figure 5B shows a block diagram of the embodiment of the invention shown in Figs. 4 and 5A.

The principles of this invention are explained with reference to Figs. 2A and 2B. The electrical signal curves S' and V' are shown in Fig. 2A for a genuine note and a note (which is to be authenticated) respectively. In addition to time, the X-axis indicates that each section of the printing pattern range is divided into N areas and the Y-axis indicates the value of the electrical signal (e.g. $a_1, a_2 \ldots ; b_1, b_2 \ldots$) along any point on the area. The electrical signals S' and V' may be electrical analogue signals (as shown in Fig. 2A) generated from light being reflected from a currency note or electrical discrete signals corresponding to a quantity of metallic elements at each area (not shown). In Fig. 2A, the solid line S' shows an electrical analogue signal generated by scanning a genuine currency note and the dotted line V' shows an electrical analogue signal generated by scanning a detected currency note. The electrical analogue signal S' is first sampled at N points along the genuine currency note resulting in an electrical signal S'' (see Fig. 2C) consisting of components $a_1, a_2, \ldots, a_N$ which are stored in memory. In practice, these components are obtained and stored in memory before the detected currency is examined. The electrical analogue signal V' is then supplied at N points along the detected currency resulting in an electrical signal series V'', (see Fig. 2C) consisting of components $b_1, b_2, \ldots b_N$. Clearly, if electrical discrete signals are employed, rather than analogue signals, then there is no need to use sampling to obtain the components.

As shown in Fig. 2B, a first authenticity vector $\vec{S}$ is defined as a vector composed of N components in a N dimensional coordinate system, each component corresponding to a respective one of the successive N area signals of S'' shown in Fig. 2C of the genuine currency note. The second authenticity vector $\vec{V}$ is defined as a vector composed of N components in a N dimensional coordinate system, each component corresponding to a respective one of the successive N area signals of V'' shown in Fig. 2C of the detected currency.

In this invention, the angle θ between the first authenticity vector $\vec{S}$ and the second authenticity vector $\vec{V}$ is examined to obtain a single value of similarity (W) between the signals. One of the following values of similarity can be used: $\cos\theta$, $\sin\theta$, $\cos^2\theta$ $\sin^2\theta$ etc. in general, $\cos\theta$ can be used to represent the value of similarity (W) as shown by the following expression:

$$W = \cos\theta = \frac{\vec{S}\cdot\vec{V}}{|\vec{S}|\cdot|\vec{V}|} = \frac{\sum_{I=1}^{N} S(I)\cdot V^{(I)}}{\sqrt{\sum_{I=1}^{N} \{S(I)\}^2}\cdot\sqrt{\sum_{I=1}^{N} \{V(I)\}^2}}$$

Where S(I) is each component of the sampled genuine currency signal (i.e. S'') and V(I) is each component of the sampled detected currency signal (i.e. V''). When W (i.e. $\cos\theta$) is larger than a predetermined permitted value W_d, the examined currency note is genuine, where W_d is larger than 0.5 and less than 1.

Fig. 3A shows a block diagram of one embodiment of the invention for calculating a single value of similarity W to determine authenticity. A X-ray tube 11 receiving electrical power from a high voltage source 12 generates x-rays 13 in a predetermined area 14 for irradiating a detected currency note 15. The printing ink used in forming printing pattern 16 on the note contains one metallic element such as Z_n, this element is distributed on the currency note 15 corresponding to the printed pattern. The currency note 15 is conveyed at a uniform speed, in the direction shown, by the conveying belts 17. When the printed pattern 16 passes through area 14, a fluorescent emission 18 is generated by the action of x-rays 13 on the metallic element. The fluorescent emission 18 has the characteristic, $E = hc$ (where E = Energy, h = Plank's constant, λ = wavelenth, c = electromagnetic wave speed). The wavelength λ of fluorescent emission 18 depends upon the type of metallic elements contained in the printing ink, and the intensity of emission 18 is proportional to the quantity of the metallic elements.

By detecting the emission 18 and converting it to electrical pulses, the quantity and type of the metallic elements can be obtained. The wave amplitude of the detected pulses is made to correspond to the wavelength of the emission and thus to the type of metallic element and the number of od detected pulses is made proportional to the intensity and thus to the quantity of element present. Therefore, by measuring the pulse wave amplitude the type of elements contained in the currency note can be detected; by counting the number of pulses, the quantity of the elements can be detected.

As shown in Fig. 3A, the fluorescent emission 18 is detected by a proportional counter 19. Proportional counter 19 converts emission 18 to electrical pulse signals V_1, and supplies these signals to a pre-amplifier 20. Pre-amplifier 20 amplifies the electrical pulse signals V to V_2 and then supplies these amplified signals to an amplitude discriminator 21. Discriminator 21 has a preset upper and lower limit wherein only pulses V_3 having an amplitude between the upper and lower limit are permitted to pass. The upper and lower limit are set to permit passage of signals which have element (e.g. Zn). The electrical pulse signals V_3 are supplied to a counter 22 (e.g. an 8 bit counter) to count the number of pulses per area.

As the detected note passes through the x-ray detection system, its leading edge and its trailing edge are detected by an opto-electric switch 23. The edge detection signal T_0 is supplied to a control pulse generating circuit 24. As shown in Figs. 3A and 3B, circuit 24 generates a counter clear pulse P_1, a shift register timing pulse P_2 and a timing control signal P_3 based on edge detection signal T_0. The counter clear pulses P_1 comprises N pulses at regular intervals for clearing counter 22 N times during the time interval when the currency note 15 is being scanned. Each P_1 pulse corresponds to a discrete successive area of the detected note. As a result, a count number C corresponding to the quantity of element Zn (for example) at each of N areas is obtained in counter 22. Shift register timing pulses P_2 are supplied to a shift register 25 immediately before counter clear pulse P_1 is supplied to counter 22; consequently, the counted value C is set in shift register 25. A quantity of element Zn at each of N areas, of the detected currency note 15, namely each component V(I) of second authenticity vector $\vec{V}$ (i.e. V(1), V(2) . . . V (N)), is successively supplied from shift register 25 to a first multiplying accumulator 26 and a second multiplying accumulator 27.

A read only memory (ROM) 28 is programmed to store values representing the particular quantity of elements Zn at each of the N areas of a genuine currency note, namely each component S(I) of first authenticity vector $\vec{S}$ (i.e. S(1), S(2), . . . S(N − 1), S(N)). The memory also contains the value Y, where;

$$Y = \sum_{I-I}^{N} \{S(I)\}^2$$

a necessary value in calculating the value of similarity. In response to a timing control signal P_3, memory 28 successively supplies each component S(I) of first authenticity vector $\vec{S}$ to first multiplying accumulator 26. First multiplying accumulator 26 calculates Z, where

$$Z = \sum_{I-I}^{N} V(I) \cdot S(I).$$

In particular, first multiplying accumulator 26 calculates Z = N(I),S(I) when V(1) is supplied from shift register 25 and S(I) is supplied from member 28 and calculates $Z(2) = V(2) \cdot S(2) + V(1) \cdot S(1)$ when V(2) is supplied from shift register 25 and S(2) is supplied from memory 28. Circuit 26 continues this series of operations until all N values for V(I) and V(N) are received, multiplied together, and summed to calculate Z. Second multiplying accumulator 27 calculates X, where

$$X = \sum_{I-I}^{N} \{V(I)\}^2.$$

In particular, second multiplying accumulator 27 calculates $X_1 = \{V(1)\}^2$ when V(1) is supplied from shift register 25 and calculates $X_2 = \{V(2)\}^2 + \{V(1)\}^2$ when V(2) is supplied from shift register 25. Circuit 27 continues this series of operations until all N values for V(I) are received, squared and summed to calculate X.

The values X, Z, and Y are supplied to a calculating circuit 29 which functions to extract square roots, multiply, and divide to calculate the value of similarity W, where

$$W = \frac{}{\sqrt{X} \cdot \sqrt{Y}}.$$

As discussed previously regarding Fig. 2B, the angle θ between vectors V and S is examined to calculate the value of similarity (i.e. cos θ). This value, calculated by circuit 29, is supplied to a comparator 30. Comparator 30 compares the value of similarity W with the predetermined permitted value W_d, wherein $0.5 < Wd < 1$. If W is larger than W_d, the output level of comparator 30 is high, indicating that the detected currency note 15 is genuine.

This embodiment of the invention eliminates the adverse readings caused by minor disfigurements due to handling and daily processing since numerous components are not compared to obtain numerous values of similarity. Rather two vectors are compared which are formed of the various components. As previously discussed, the value of similarity depends on the angle θ between first authenticity vector $\vec{S}$ and second authenticity vector $\vec{V}$, and is independent of each vector's length. Therefore, even if some components V(I) of second authenticity vector $\vec{V}$ are substantially greater or less than corresponding components S(I) of first authenticity vector $\vec{S}$, rejection of a genuine note can be prevented.

In the embodiment shown Fig. 3A, the quantitative distribution of Zn is detected, but it is possible to detect other metallic elements such as Fe, Cu, Pb, Cr. Also, it is possible to identify by detecting a plurality of metallic elements which may be contained in the detected currency note.

In the embodiment of Fig. 3A, an angle between first authenticity vector $\vec{S}$ and second authenticity vector $\vec{V}$ is examined. Alternatively, however, if

$$V(I) - \sum_{I=1}^{V} \frac{V(I)}{N}$$

is substituted for V(I) in the previous expression and

$$S(I) - \sum_{I=1}^{N} \frac{S(I)}{N}$$

is substituted for S(I), a better method for examining authenticity is possible. Moreover, rather than using a single detector as shown in Fig. 3A, several arrayed detectors can be positioned along the currency notes. In this case, a signal obtained from each detector would correspond to each component of vector $\vec{V}$.

Fig. 4 discloses the principle of a further embodiment which detects the printing pattern as the authenticity characteristic. Moreover, rather than calculating a single value of similarity as disclosed in the previous embodiment, two values of similarity are calculated. D(t) corresponds to a photo-electric analogue signal produced by scanning a detected currency not Q_s corresponds to the beginning of the printing pattern while Q_e corresponds to the end of the printing pattern. Q and Q_e are the points at which D(t) crosses a predetermined level S_1 at times T_f, T_b. Various methods can be used in order to detect Q_s and Q_e. For example, it is possible to use the beginning of the currency note and the terminal end of the currency note, respectively. The area between Q_s and Q_e is divided into N area (e.g. 100 areas), and analogue signal D(t) is sampled by a sampling signal T_1, shown in Fig. 4 to give amplitude values D(I). Sampled signal D(I) at each sampling point is then divided into a first and second series DF(J) and DB(L). Each of these signal series are used to calculate a value of similarity. Series DF(J) begins with the first area and the other series DB(L) begins with the last Nth area. Each of these series terminates with the mean value of N (e.g. 50, where N = 100). Series DB(L) is obtained by successively storing all the amplitude values of series D(I) and then reading out these values in reverse order. Namely, during a time interval TS_1, a first value of similarity W_f is calculated from first series DG(J) (F = 1, . . . , 50) while second series DB(L) is stored into a memory. During a interval TS_2, second series DB(L) (L = 1, . . . , 50) is read out in reverse order from the memory and a second value of similarity W_b is then calculated. In this embodiment, a detected currency note is scanned once and the resultant electrical signal is divided into two signal series DF(J), DB(L). Alternatively, the two signal series can be obtained by scanning the note twice; scanning first to contain the first series and then varying the orientation of the note and then scanning it again to obtain the second series.

Assume two series SF(J) (J = 1, . . . , 50), SB(L) (L = 1, . . . , 50) have been obtained by scanning a genuine currency note in a manner similar to obtaining series DF(J) and DB(L), as discussed above, and then storing these signals in memory. A first value of similarity W_f beginning with the first area of a detected note and a second value of similarity W_b beginning with the last Nth area of the detected note can then be obtained as follows;

$$W_f = \frac{\sum_{I=1}^{50} DF(J)\cdot SF(J)}{\sqrt{\sum_{J=1}^{50}\{DF(J)\}^2}\cdot\sqrt{\sum_{J=1}^{50}\{SF(J)\}^2}}$$

$$W_b = \frac{\sum_{L=1}^{50} DB(L)\cdot SB(L)}{\sqrt{\sum_{L=1}^{50}\{DB(L)\}^2}\cdot\sqrt{\sum_{L=1}^{50}\{SB(L)\}^2}}$$

Upon obtaining the two values of similarity there are various methods to identify a genuine currency by comparing these values with a predetermined value representing a permissible authenticity value. In one method, when both W_f and W_b are larger than the predetermined permitted value (e.g. 0.6) it is thereby determined that the detected currency note is genuine. With the other method, when the mean value $W = (W_f + W_b)/2$ is larger than the predetermined permitted value, it is thereby determined that the detected currency note is genuine.

The embodiment shown in Fig. 5A and 5B incorporates the methods discussed above regarding Fig. 4. In this embodiment five types of currency notes (e.g, one dollar bills, five dollar bills, ten dollar bills, twenty dollar bills and fifty dollar bills) are acceptable in which first and second values of similarity are obtained for each note (e.g. $W_1 \ldots W_f^5$ and $Wb_1 \ldots Wb_5$). Fig. 5A shows a schematic view of the mechanism for detecting an authenticity characteristic of a printing pattern on the currency note. A light 51 from light source 52 illuminates a predetermined area 53 on the detected note currency 54. Detected note 54 had a printing pattern 55 and is conveyed with uniform speed in the direction shown by conveying belts 56a, 56b. A photo-electric switch 57 detects the leading edge and trailing edge of the detected currency note 54 and generates an edge detectiong signal T_0. The light 58 reflected by currency note 54 is converted into a electrical signal in a photo detector 59 and are then amplified by an amplifier 60 to produce analogue electrical signal D(t).

As shown in Fig. 5B, electrical signal D(t) is supplied to an A-D converter 61 and the edge detection signal T_0 is supplied to a first timing controller 62. A-D converter 61 receives sampling signals T_1 from a first timing controller 62 to produce sampled amplitude value series D(I). A pattern range detecting circuit 63 (e.g., Schmitt-Trigger) supplies signals Q_s and Q_e to first timing controller 62. A data switch 64 supplies signal D(I) to a 128 byte buffer memory 65 and a data selector 66 under the condition of a control signal T_2. That is, during time interval TS_1 (See Fig. 4), data signal D(I) is stored in buffer memory 65 under the condition of a control signal T_3; during time interval TS_2 data signal D(I) stored in buffer memory 65 is supplied, as electrical signal series DB(L), to a data selector 66 through data switch 64. Data selector 66 receives signal series DF(J) from AD converter 61 supplies this signal series during time interval TS_1 to a 1 byte latch 67 for temporarily storing DF(J). Selector 66 also supplies electrical signal series DB(L) during time interval TS_2 to 1 byte latch 67. Data selector 66 and 1 byte latch 67 are controlled by control signals T_4, T_5 from first timing controller 62. First t 62 also supplies control signals T_6, T_7 to a second timing controller 68 and to an interface circuit 69.

Calculation of the first value of similarity W_f is performed during time interval TS_1. The types of standard pattern data DSF(J,K) and DSB(L.K) (where $K = 1, \ldots, 5$) corresponding to printing patterns of the various genuine currency notes (e.g. five types) are stored in a standard pattern memory 70 and the signal series

$$\sum_{J=1}^{50}\{D,SF(J,K)\}^1$$

and

$$\sum_{L=1}^{50} \{D,SB(L,K)\}^2$$

are stored in microcomputer 80. When the electrical signal series DF(J) (J = 1, . . . , 50) is supplied to a data selector 71 from 1 byte latch 67, the five types of standard pattern signals DSF(J,K) (J = 1, . . . , 50) (K = 1, . . . , 5) are supplied from pattern memory 70 to the data selector 71 through a 1 byte latch 72. The data selector 71 alternatively supplies electrical signal series DF(J) and standard pattern signals DSF (J,K) to a multiplier 73 under the condition of a control signal T_8 from second timing controller 68. Multiplier 73 calculates $(DF(J))^2$ and DF(J) DSF(J,K) under the condition of a control signal T_9 from second timing controller 68. The output of multiplier 73 is supplied to an adder 74. Adder 74 adds the output of multiplier 73 to the output of a 3 byte latch 75; the resultant output is supplied to a 3 byte latch 76. Latch 75 contains the results of a previous calculation which was stored in buffer memory 79, as will be discussed. The output of 3 byte latch 76 is supplied to a data selector 77. Data selector 77 selects the output of 3 byte 76 or a clear signal; the output signal is then supplied to a 3 byte latch 78. The output of 3 byte latch 78 is stored in a buffer memory 79.

When multiplier 73 produces a new output, based upon the receipt of new data, which is supplied to adder 74, the previous data stored in buffer memory 79 is supplied to 3 byte latch 75 through 3 byte latch 78. This previous data is then summed in adder 74 with the new data output from multiplier 73. A clear signal is then supplied to buffer memory 79 through 3 byte latch 78. Next, the new data received from 3 byte latch 75 and multiplier 73 which is summed by adder 74 is then stored in buffer memory 79 throughlatch 76, selector 77 and latch 78, as discussed previously. Namely, adder 74 calculates the sum of

$$\sum_{J=1}^{j-1} \{DF(J)\}^2.$$

and $\{DF(j)\}^2$, and the sum of

$$\sum_{J=1}^{J-1} \{DF(J)\cdot D,SF(J,K)\}$$

and $\{DF(j)\cdot DSF(j,K)\}$,

$$\sum_{J-1}^{j-1} \{DF(J)\}^2$$

and

$$\sum_{J=1}^{j-1} \{DF(j)\cdot DSF(J,K)\},$$

represents the previous data, while $\{DF(j)\}^2$ and $\{DF(j)DSF(j,k)\}$ represents the new data. Then

$$\sum_{J=150}^{j} \{DF(J)\}^2$$

and

$$\sum_{J=1}^{j} \{DF(J)DSF(J,K)\}$$

are stored in buffer memory 79. Finally,

$$\sum_{J=1}^{50} \{DF(J)\}^2$$

and

$$\sum_{J=1}^{50} \{DF(J) \cdot DSF(J,K)\}$$

are supplied to microcomputer 80 through interface circuit 69. Microcomputer 80 calculates the first value of similarity relating to one dollar bills W_f1 etc at follows:

$$W_{f1} = \frac{\sum_{J=1}^{50}\{DF(J) \cdot DSF(J,1)\}}{\sqrt{\sum_{J=1}^{50} \{DF(J)\}^2} \cdot \sqrt{\sum_{J=1}^{50} \{D,SF(J,1)\}^2}}$$

Likewise, the values of similarity relating the remaining bills are calculated. That is, W_{f2}, W_{f3}, W_{f4}, W_{f5} are calculated.

Calculating the second value of similarity occurs as follows. During time interval TS_2, the second series DB(L) read out from buffer memory 65 is supplied to 1 byte latch 67 through data switch 64 and data selector 66. Second series DB(L) (L = 1., , , , 50) is supplied to data selector 71, multiplier 73, and interface circuit 69 from 1 byte latch 67. Multiplier 73 calculates $\{DB(L)\}^2$ and $\{DB(L)\ DSB(L,K)\}$ under the condition of a control signal T_9 from second timing controller 68. Adder 74 calculates the sum of

$$\sum_{L=1}^{I-1} \{DB(L)\}^2$$

and $\{DB(I)\}^2$ and the sum of

$$\sum_{L=1}^{I-1} \{DB(L) \cdot DSB(L,K)\}$$

and $\{DSB(I) \cdot DSB(I,K)\}$ in a manner disclosed previous regarding DF(J). Finally,

$$\sum_{L=1}^{50} \{DB(L)\}^2$$

and

$$\sum_{L=1}^{50} \{DB(L) \cdot DSB(L,K)\}$$

are supplied to microcomputer 80 through interface circuit 69. Microcomputer 80 calculates the second value of similarity relating to the one dollar bills, five dollar bills, ten dollar bills, twenty dollar bills and fifty dollar bills. That is, similarity values W_{b1}, W_{b2}, W_{b3}, W_{b4}, W_{b5} are calculated in microcomputer 80. For example, the second value of similarity relating to a fifty dollar bill (i.e. W_{b5}) is as follows:

$$W_{b5} = \frac{\sum_{L=1}^{50}\{DB(L)\cdot DSB(L,5)\}}{\sqrt{\sum_{L=1}^{50}\{DB(L)\}^2}\cdot\sqrt{\sum_{L=1}^{50}\{D,SB(L,5)\}^2}}$$

Finally, microcomputer 80 calculates $W_k = (W_{fk} + W_{bk})/2$, where $k = 1, \ldots, 5$. The computer then determines whether each value of W_k is larger than the predetermined permitted value (e.g., 0.6). If each value is larger than 0.6, the W_k nearest to 1.0 is selected. For example, if the W_k value nearest to 1.0 is W_2, it is conculuded that the detected currency note is a genuine five dollar bill. If each value of W_k is less than 0.6, it is then determined that the detected currency note is a false currency note.

In the embodiment shown in Fig. 5A detection is performed by detecting the authenticity characteristic of a printing pattern by reflected light. It should be clear that other methods can be used, such as detecting by fluorescent X-ray, or by magnetic lines of force.

CLAIMS

1. A currency identification system for examining an authenticity characteristic of a detected currency note and comparing it to an authenticity characteristic of a genuine currency note to determine if the detected currency note is genuine characterised by memory means for storing a series of first electrical signals representing the authenticity characteristic of said genuine currency note, each of said first signals corresponding to a discrete successive area of said genuine currency note and representing a component of a first authenticity vector; detecting means for scanning said detected currency note and generating a series of second electrical signals representing the authenticity characteristic of said detected currency note, each of said second signals corresponding to a discrete successive area of said detected currency note and representing a component of a second authenticity vector; calculating means coupled to said detecting means and said memory means to calculate a value of similarity corresponding to an angle between said first authenticity vector and said second authenticity vector; and comparing means for comparing the value of similarity with a predetermined value which represents a permissible authenticity value for the detected currency corresponding to a genuine currency.

2. A system as in claim 1 for authenticating currency notes containing at least one metallic element, the said system including means for irradiating said detected currency note with X-rays, means for detecting fluorescent emissions generated by the irradiated currency and producing a series of pulses; pulse height detecting means for detecting the type of said metallic element by measuring the pulse height of said pulses; and, pulse counting means for detecting the quantity of said metallic element at each said successive area and producing said second electrical signals in accordance with said count.

3. A system according to claim 1, wherein said memory means is arranged to store a signal Y where

$$Y = \sum_{I=1}^{N}\{S(I)\}^2$$

said calculating means comprising a first multiplying accumulator for calculating

$$Z = \sum_{I=1}^{N}\{V(I)\cdot S(I)\}$$

and a second multiplying accumulator for calculating

$$X = \sum_{I=1}^{N}\{V(I)\}^2$$

where S(1) represents each of said first signals and V(1) represents each of said second signals; and said calculating means further comprising a similarity calculating circuit means for calculating the value of similarity W wherein

$W = Z / \{\sqrt{X} \cdot \sqrt{Y}\}$.

4. A currency identification system for examining an authenticity characteristic of a detected currency note and comparing it to an authenticity characteristic of a genuine currency note to determine if the detected currency is genuine comprising: memory means for storing a first and second series of first electrical signals representing the authenticity characteristic of said genuine currency note, each of said first electrical signals corresponding to a discrete successive area of said genuine currency, the electrical signals of said first series representing a component of a first genuine authenticity vector and the electrical signals of said second series representing a component of a second genuine authenticity vector; detecting means for scanning said detected currency note and generating a first and second series of second electrical signals representing the authenticity characteristic of said detected currency note, each of said second electrical signals corresponding to a discrete successive area of said detected currency note, the electrical signals of said first series representing a component of a first detected authenticity vector and the electrical signals of said second series representing a component of a second detected authenticity vector; calculating means coupled to said detecting means and said memory means to calculate a first and second value of similarity, said first value of similarity corresponding to a first angle between said first genuine authenticity vector and said first detected authenticity vector, said second value of similarity corresponding to a second angle between said second genuine authenticity vector and said second detected authenticity vector; and comparing means for comparing the first and second values of similarity with a predetermined value which represents a permissible value for the detected currency corresponding to a genuine currency.

5. A system of claim 4, wherein said detecting means comprises scanning means for scanning the detected currency note in a predetermined direction to produce reflected light corresponding to the authenticity characteristic of said detected currency note; authenticity detecting means for detecting the reflected light and producing an analogue detected signal; sampling means, receiving said analogue detected signal, for producing said second electrical signals corresponding to said discrete successive areas from a first area to a Nth area, of said detected currency, said sampling means containing means to produce said first and second series wherein said first series begins with said first area and the second series begins with said Nth area.

6. A system of claim 5, wherein each of said first series and second series terminates with the main value of the Nth area.

7. A currency identification method for examining an authenticity characteristic of a detected currency note and comparing it to an authenticity characteristic of a genuine currency note to determine if the detected currency is genuine comprising the steps of; storing a series of first electrical signals representing the authenticity characteristic of said genuine currency note, each of said first signals corresponding to a discrete successive area of said genuine currency note and representing a component of a first authenticity vector; scanning said detected currency note and generating a series of second electrical signals representing the authenticity characteristic of said detected currency note, each of said second signals corresponding to a discrete successive area of said detected currency note and representing a component of a second authenticity vector; calculating a value of similarity corresponding to an angle between said first authenticity vector and said second authenticity vector; and comparing the value of similarity with a predetermined value which represents a permissible authenticity value for the detected currency corresponding to a genuine currency.

8. A currency note identification system substantially as herein described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon) Ltd.—1981.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.