(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 September 2003 (25.09.2003)

PCT

(10) International Publication Number
WO 03/079300 A1

(51) International Patent Classification[7]: G07D 7/00

(21) International Application Number: PCT/US03/06762

(22) International Filing Date: 5 March 2003 (05.03.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/095,164 11 March 2002 (11.03.2002) US
10/095,256 11 March 2002 (11.03.2002) US

(71) Applicant: CUMMINS-ALLISON CORP. [US/US]; 891 Feehanville Drive, Mount Prospect, IL 60056 (US).

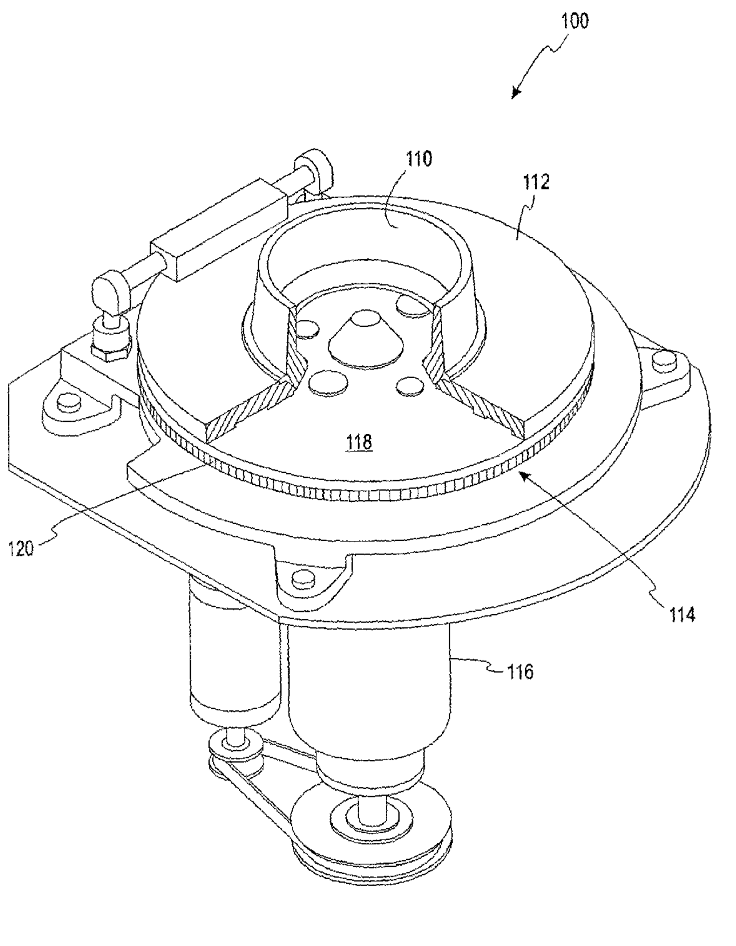
(72) Inventors: **GEIB, Joseph, J.**; 32 Monovar Way, Hot Springs, AR 71909 (US). **BLAKE, John, R.**; 6N715 McKay Drive, St. Charles, IL 60175 (US). **WENDELL, David, J.**; 191 Willow Blvd., Willow Springs, IL 60480 (US). **CASANOVA, Scott, D.**; 205 Rush Street, Roselle, IL 60172 (US). **MECKLENBURG, David, J.**; 102 Oxford Land, Glendale Heights, IL 60139 (US). **STRAUTS, Eric, J.**; 1231 N. Dee Road, Park Ridge, IL 60068 (US).

(74) Agents: **RUDISILL, Stephen, G.** et al.; Jenkens & Gilchrist, 225 West Washington Street, Suite 2600, Chicago, IL 60606 (US).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

[Continued on next page]

(54) Title: COIN PROCESSING SYSTEM



(57) Abstract: A coin processing system (100) for processing a plurality of coins of mixed denominations comprises a rotatable disk (114) for imparting motion to the plurality of coins, a sensor (204) for differentiating between valid and invalid coins, a stationary sorting head (112), and a diverter (300). The stationary sorting head has a lower surface generally parallel to and spaced slightly away from the rotatable disk that forms a queuing channel (166) and exit channels (261-268) for sorting and discharging coins of particular denominations. The queuing channel has a first segment for receiving coins and a second segment for moving the coins past the sensor and is configured to move coins at a faster rate along the second segment for increasing the spacing between adjacent coins. The diverter is disposed along the second segment and is moveable for diverting a coin to a reject region when the sensor detects an invalid coin.

WO 03/079300 A1

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*
— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

COIN PROCESSING SYSTEM

FIELD OF THE INVENTION

The present invention relates generally to coin processing devices and, more particularly, to a coin processing device having a improved coin discrimination system for discriminating between valid and invalid coins and removing the invalid coins, and to a coin discrimination sensor that discriminates among coins of different compositions, thickness, and diameters.

BACKGROUND OF THE INVENTION

Generally, disc-type coin sorters sort coins according to the diameter of each coin. Typically, in a given coin set such as the United States coin set, each coin denomination has a different diameter. Thus, sorting coins by diameter effectively sorts the coins according to denomination.

Disc-type coin sorters typically include a resilient pad (disposed on a rotating disc) that rotates beneath a stationary sorting head having a lower surface positioned parallel to the upper surface of the resilient pad and spaced slightly therefrom. The rotating, resilient pad presses coins upward against the sorting head as the pad rotates. The lower surface of sorting head includes a plurality shaped regions including exit channels for manipulating and controlling the movement of the coins. Each of the exit channels is dimensioned to accommodate coins of a different diameter for sorting the coins based on diameter size. As coins are discharged from the sorting head via the exit channels, the sorted coins follow respective coin paths to sorted coin receptacles where the sorted coins are stored.

It is desirable in the sorting of coins to discriminate between valid coins and invalid coins. Use of the term "valid coin" refers to coins of the type to be sorted. Use of the term "invalid coin" refers to items being circulated on the rotating disc that are not one of the coins to be sorted. For example, it is common that foreign or counterfeit coins (*e.g.*, slugs) enter the coin sorting system. So that such items are not sorted and counted as valid coins, it is helpful to detect and discard these "invalid coins" from the coin processing system. In another application wherein it is desired to process (*e.g.*, count and/or sort) only U.S. quarters, nickels and dimes, all other U.S. coins including dollar coins, half-dollar coins and pennies are considered "invalid." Additionally, coins from all other coins sets including Canadian coins and Euro coins, for example, would be considered "invalid " when processing U.S. coins. Finally, any truly counterfeit coins (*i.e.*, a slug) are always considered "invalid" in any application. In another application it may be desirable to separate Canadian coins from U.S. coins for example. Therefore, in that application all authentic U.S. and Canadian coins are considered invalid, and all non-authentic U.S. and Canadian coins and all coins from other coin sets (*e.g.*, Euro coins) are considered invalid.

Typically, prior-art disc-type coin sorters include a discrimination sensor disposed within each exit channel for discriminating between valid and invalid coins as coins enter the exit channels. In such systems, therefore, coins entered the exit channel and are then discriminated. An invalid coin having a diameter that enables it to pass into an exit channel moves past the discrimination sensor. The discrimination sensor detects the invalid coin and a braking mechanism is triggered to stop the rotating disc before the invalid coin is moved out of the exit channel. A diverter, disposed within the coin path external, or internal, to the sorting head, moves such that a coin entering the coin path is diverted to an invalid coin receptacle. The sorting head is then jogged (electronically pulsed) causing the disc to incrementally rotate until the invalid coin is discharged from the exit channel to the coin path where it is diverted to a invalid coin receptacle. The diverter is moved back to its home position such that coins now entering the coin path are directed to the coin receptacles for valid coins. The coin sorter is then restarted and the disc begins to rotate at the normal sorting rate of speed.

One drawback associated with this type prior art discrimination technique is the downtime consumed by the aforementioned stopping, jogging and restarting of the rotatable disc to remove the invalid coin. This process often takes approximately five seconds per invalid coin. Initially, this may appear to be a relatively insignificant amount of time; however, this time can add up to a significant amount of time in the processing of bulk coins.

Furthermore, because the rotatable disc rapidity breaks and stops so that an invalid coin is not ejected from a coin exit channel before the diverter is moved to route invalid coins to a reject receptacle, the overall speed (*i.e.*, the number of rotations of the rotatable disc per minute) is limited. Additionally, this type prior art discrimination technique results in more "wear and tear" on the breaking system and motor. Accordingly, a need exists for a coin processing machine that can discriminate invalid coins at a high-rate of speed.

Coin discrimination sensors have been employed to discriminate among various coins. A typical coin discrimination sensor includes at least one primary coil for inducing eddy currents in the coin to be analyzed. The primary coil receives an alternating voltage which correspondingly produces an alternating current in the coil. The alternating current flowing in the primary coil produces an alternating magnetic field through and around the coil as is well known in the art.

Characteristics of the alternating magnetic field depend upon a variety of factors including the frequency and amplitude of the voltage applied to the primary coil. The primary coil, also known as the excitation coil, inductively couples with a coin brought into proximity with the coil, thereby producing eddy currents in the coin being analyzed. Because the magnetic field from the primary coil is alternating, the corresponding eddy currents are alternating as well. The induced eddy currents are influenced by the characteristics of the coin being analyzed.

The magnitude of the eddy currents produced is influenced by the frequency of the alternating magnetic fields applied. High frequencies tend to create magnetic fields that penetrate near the surface of the coin, giving a better indication of a coin's surface area. Low frequencies tend to penetrate further into the coin, giving a better indication of a coin's volume. Coin discrimination sensors which employ eddy currents to discriminate among different coins typically use an excitation signal that is oscillating at a single frequency. Thus, coin discrimination sensors having a high-frequency excitation signal distinguish better among coins of different diameter. Conversely, coin discrimination sensors having a low-frequency excitation signal distinguish better among coins of different thickness. What is needed, therefore, is a coin discrimination sensor that uses a composite excitation signal so as to distinguish among coins having different compositions, thicknesses, and diameters.

SUMMARY OF THE INVENTION

According to one embodiment of the present invention, a coin processing system for processing a plurality of coins of mixed denominations comprises a rotatable disc for imparting motion to the plurality of coins, a sensor for differentiating between valid and invalid coins, a stationary sorting head, a diverter and a controller. The stationary sorting head has a lower surface generally parallel to and spaced slightly away from the rotatable disc. The lower surface forms a queuing channel and a plurality of exit channels for sorting and discharging coins of particular denominations. The queuing channel has a first segment for receiving coins and a second segment for moving the coins past the sensor and is configured to move coins at a faster rate along the second segment for increasing the spacing between adjacent coins. The diverter is disposed along the second segment beyond the sensor and is moveable between a first position for permitting coins to proceed to the plurality of exit channels and a second position for diverting coins to a reject region. The controller moves the diverter from the first position to the second position when the sensor detects an invalid coin.

According to another embodiment of the present invention, a discrimination sensor includes a transmission coil and two reception coils. The transmission coil produces a magnetic field over a section of a coin path along which coins pass. The reception coils are configured to detect signals that are indicative of characteristics of each coin passing along the coin path. The characteristics include at least a coin composition, such as metal content, a coin thickness, and a coin diameter.

According to yet another embodiment of the present invention, a discrimination sensor includes a first coil coupled to a second coil. The first coil and the second coil produce a magnetic field over a coin path along which coins pass. The magnetic field couples to the coins to induce eddy currents within a passing coin. The first coil and the second coil also detect signals corresponding to the eddy currents, which signals are indicative of at least a coin composition, a coin thickness, and a coin diameter.

A method according to yet another embodiment of the present invention includes moving a coin along a coin path, inducing eddy currents in the coin by subjecting the coin to a magnetic field of a high frequency and a low frequency, detecting signals corresponding to the eddy currents that are indicative of a coin composition, a coin thickness, and a coin diameter, and processing the signals to determine an identity of the coin.

The above summary of the present invention is not intended to represent each embodiment, or every aspect, of the present invention. Additional features and benefits of the present invention are apparent from the detailed description, figures, and claims set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a coin processing system, according to one embodiment of the present invention, with portions thereof broken away to show the internal structure.

FIG. 2 is an enlarged bottom view of a sorting head for use with the system of FIG. 1.

FIG. 3 is a cross-sectional view of the sorting head shown in FIG. 2 taken along line 3-3.

FIG. 4a is a cross-sectional view of the sorting head shown in FIG. 2 taken along 4-4.

FIG. 4b is a cross-sectional view of an alternative embodiment of that which is shown in FIG. 4a.

FIG. 5 is an oversize view of a queuing channel of the sorting head shown in FIG. 2.

FIG. 6 is a functional block diagram of the control system for the a coin processing system shown in FIG. 1.

FIG. 7a is a perspective view of an external diverter according to one alternative embodiment of the present invention.

FIG. 7b is a front end view of the external diverter shown in FIG. 7a taken along line 7b-7b.

FIG. 8 is an enlarged bottom view of a programmable sorting head that can be used with the coin processing system of FIG. 1 instead of the sorting head shown in FIG. 2.

FIG. 9 is an enlarged bottom view of a sorting head and an external optical sensor that can be used with the coin processing system of FIG. 1 instead of the sorting head shown in FIG. 2.

FIG. 10 is a top view of a programmable power rail coin processing system according to one alternative embodiment of the present invention.

FIG. 11 is a perspective view of a rail and an endless belt for use with the programmable power rail coin processing system of FIG. 10.

FIG. 12 is a perspective view of the programmable power rail coin processing system of FIG. 10 disposed within a cabinet according to one an alternative embodiment of the present invention.

FIG. 13 is a enlarged bottom view of a sorting head having a single coin exit station that can be used with the coin processing system of FIG. 1 instead of the sorting head shown in FIG. 2.

FIG. 14 is a functional block diagram of a coin discrimination system according to an embodiment of the present invention.

FIG. 15 is a functional block diagram of a coin discrimination system according to another embodiment of the present invention.

FIG. 16a is a top view of a bobbin which is employed in a coin discrimination sensor according to the present invention.

FIG. 16b is a side view of the bobbin shown in FIG. 16a.

FIG. 16c is an end view of the bobbin shown in FIG. 16b.

FIG. 17 is a diagrammatic cross-sectional view of a coin discrimination sensor according to an embodiment of the present invention.

FIG. 18 is a schematic circuit diagram of the coin discrimination sensor of FIG. 17.

FIG. 19 is a diagrammatic perspective view of the coils in the coin discrimination sensor of FIG. 17.

FIG. 20 is a graphical illustration of a waveform of an excitation signal which is provided to the coin discrimination sensor of FIG. 14.

FIG. 21 is a graphical illustration of a waveform of a detection signal from the coin discrimination sensor of FIG. 14 when no coin is present.

FIG. 22 is a graphical illustration of a waveform of a detection signal from the coin discrimination sensor of FIG. 14 when a 5 cent coin is present.

FIG. 23 is a graphical illustration of the two waveforms shown in FIGS. 21 and 22.

FIG. 24 is a scatter chart of the 30 KHz sine and cosine amplitude values for a coin set associated with the coin discrimination sensor of FIG. 14.

FIG. 25 is a scatter chart of the 480 KHz sine and cosine amplitude values for the coin set of FIG. 24.

FIG. 26 is a functional block diagram of a coin discrimination system according to yet another embodiment of the present invention.

FIG. 27 is a diagrammatic cross-sectional view of the coin discrimination sensor shown in FIG. 26.

While the invention is susceptible to various modifications and alternative forms, specific embodiments are shown by way of example in the drawings and will be desired in detail herein. It should be understood, however, that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Turning now to the drawings and referring first to FIG. 1, a disc-type coin processing system 100 according to one embodiment of the present invention is shown. The coin processing system 100 includes a hopper 110 for receiving coins of mixed denominations that feeds the coins through a central opening in an annular sorting head 112. As the coins pass through this opening, they are deposited on the top surface of a rotatable disc 114. This rotatable disc 114 is mounted for rotation on a shaft (not shown) and driven by an electric motor 116. The disc 114 typically comprises a resilient pad 118, preferably made of a resilient rubber or polymeric material, bonded to the top surface of a solid disc 120. While the solid disc 120 is often made of metal, it can also be made of a rigid polymeric material.

According to one embodiment, coins are initially deposited by a user in a coin tray (not shown) disposed above the coin processing system 100 shown in FIG. 1. The user lifts the coin tray which funnels the coins into the hopper 110. A coin tray suitable for use in connection with the coin processing system 100 is described in detail in U.S. Patent No. 4,964,495 entitled "Pivoting Tray For Coin Sorter," which is incorporated herein by reference in its entirety.

As the disc 114 is rotated, the coins deposited on the resilient pad 118 tend to slide outwardly over the surface of the pad 118 due to centrifugal force. As the coins move outwardly, those coins which are lying flat on the pad 118 enter the gap between the surface of the pad 118 and the sorting head 112 because the underside of the inner periphery of the sorting head 112 is spaced above the pad 118 by a distance which is about the same as the thickness of the thickest coin. As is further described below, the coins are processed and sent to exit stations where they are discharged. The coin exit stations may sort the coins into their respective denominations and discharge the coins from exit channels in the sorting head 112 corresponding to their denominations.

Referring now to FIG. 2, the underside of the sorting head 112 is shown. The coin sets for any given country are sorted by the sorting head 112 due to variations in the diameter size. The coins circulate between the sorting head 112 and the pad 118 (FIG. 1) on the rotatable disc 114 (FIG. 1). The coins are deposited on the pad 118 via a central opening 130 and initially enter the entry channel 132 formed in the underside of the sorting head 112. It should be keep in mind that the circulation of the coins in FIG. 2 appears counterclockwise as FIG. 2 is a view of the underside of the sorting head 112.

An outer wall 136 of the entry channel 132 divides the entry channel 132 from the lowermost surface 140 of the sorting head 112. The lowermost surface 140 is preferably spaced from the pad 118 by a distance that is slightly less than the thickness of the thinnest coins. Consequently, the initial outward radial movement of all the coins is terminated when the coin engage the outer wall 136, although the coins continue to move more circumferentially along the wall 136 (in the counterclockwise directed as viewed in FIG. 2) by the rotational movement imparted to the coins by the pad 118 of the rotatable disc 114.

In some cases, coins may be stacked on top of each other – commonly referred to as "stacked" coins or "shingled" coins. Some of these coins, particularly thicker coins, will be under pad pressure and cannot move radially outward toward wall 136 under the centrifugal force. Stacked coins which are not against wall 136 must be recirculated and stacked coins in contact against wall 136 must be unstacked. To unstack the coins, the stacked coins encounter a stripping notch 144 whereby the upper coin of the stacked coins engages the stripping notch 144 and is channeled along the stripping notch 144 back to an area of the pad 118 disposed below the central opening 130 where the coins are then recirculated. The vertical dimension of the stripping notch 144 is slightly less the thickness of the thinnest coins so that only the upper coin is contacted and stripped. While the stripping notch 144 prohibits the further circumferential movement of the upper coin, the lower coin continues moving circumferentially across stripping notch 144 into the queuing channel 166.

Stacked coins that may have bypassed the stripping notch 144 by entering the entry channel 132 downstream of the stripping notch 144 are unstacked after the coins enter the queuing channel 166 and are turned into an inner queuing wall 170 of the queuing channel 166. The upper coin contacts the inner queuing wall 170 and is channeled along the inner queuing wall 170 while the lower coin is move by the pad 118 across the inner queuing wall 170 into the region defined by surface 172 wherein the lower coin engages a wall 173 and is recirculated. Other coins that are not properly aligned along the inner queuing wall 170, but that are not recirculated by wall 173, are recirculated by recirculating channel 173.

As the pad 118 continues to rotates, those coins that were initially aligned along the wall 136 (and the lower coins of stacked coins moving beneath the stripping notch 144) move across the ramp 162 leading to the queuing channel 166 for aligning the innermost edge of each coin along an inner queuing wall. In addition to the inner queuing wall 170, the queuing channel 166 includes a first rail 174 and a second rail 178 that form the outer edges of stepped surfaces 182 and 186, respectively. The stepped surfaces 182, 186 are acutely angled with respect to the horizontal. The surfaces 182 and 186 are sized such that the width of surface 182 is less than that of the smallest (in terms of the diameter) coins and the width of surface 184 is less than that of the largest coin.

Referring for a moment to FIG. 3, a small diameter coin (*e.g.*, a dime or a 1¢ Euro coin) is shown pressed into pad 118 by the first rail 174 of the sorting head 112. The rails 174, 178 are dimensioned to be spaced away from the top of the pad 118 by a distance less than the thickness of the thinnest coin so that the coins are gripped between the rail 174, 178 and the pad 118 as the coins move through the queuing channel 166. The coins are actually slightly tilted with respect to the sorting head 112 such that their outermost edges are digging into the pad 118. Consequently, due to this positive pressure on the outermost edges, the innermost edges of the coins tend to rise slightly away from the pad 118.

Referring back to FIG. 2, the coins are gripped between one of the two rails 174, 178 and the pad 118 as the coins are rotated through the queuing channel 166. The coins, which were initially aligned with the outer wall 136 of the entry channel 130 as the coins moved across the ramp 162 and into the queuing channel 166, are rotated into engagement with inner queuing wall 170. Because the queuing channel 166 applies a greater amount of pressure on the outside edges of the coins, the coin are less likely to bounce off the inner queuing wall 170 as the radial position of the coin is increased along the inner queuing wall 170.

Referring to FIG. 4a, the entry region 132 of the embodiment of the sorting head 112 shown in FIG. 2 includes two stepped surfaces 187a, 187b forming a rail 188 therebetween. According to an alternative embodiment of the sorting head 112, the entry channel 132 consists of one surface 189 as shown in FIG. 4b.

Referring now to FIG. 5, there is shown an oversized view of the queuing channel 166 of FIG. 2. It can be seen that the queuing channel 166 is generally "L-shaped." The L-shaped shaped queuing channel 166 is considered in two segments – a first upstream segment 190 and a second downstream segment 192. The upstream segment 190 receives the coins as the coins move across the ramp 162 and into the queuing channel 166. The coins enter the downstream segment 192 as the coins turn a corner 194 of the L-shaped queuing channel 166. As the pad 118 continues to rotate, the coins move along the second segment 192 and are still engaged on the inner queuing wall 170. The coins move across a ramp 196 as the coins enter a discrimination region 202 and a reject region having a reject channel 212 for off-sorting invalid coins, which are both located towards the downstream end of the second segment 192. The discrimination region includes a discrimination sensor 204 for discriminating between valid and invalid coins and/or identifying the denomination of coins.

The queuing channel 166 is designed such that a line tangent to the inner queuing wall 170 of the L-shaped queuing channel 166 at about the point where coins move past the ramp 196 into the discrimination region 202 (shown as point A in FIG. 5) forms an angle alpha (α) with a line tangent to the inner queuing wall 170 at about the point where coins move over ramp 162 into the queuing channel 166 (shown as point B in FIG. 5). According to one embodiment of the present invention, the angle alpha (α) is about 100°. According to alternative embodiments of the coin processing system 100, the angle alpha (α) is about 100° ranges between about 90° and about 110°.

As the pad 118 continues to rotates, the L-shaped of the queuing channel 166 imparts spacing to the coins which are initially closely spaced, and perhaps abutting one another, as the coins move across the ramp 162 into the queuing channel 166. As the coins move along the first upstream segment 190 of the queuing channel 166, the coins are pushed against inner queuing wall 170 and travel along the inner queuing wall 170 in a direction that is transverse to (*i.e.*, generally unparallel) the direction in which the pad 118 is rotating. This action aligns the coins against the inner queuing wall 170. However, as the coins round the corner 194 into the second downstream segment 192 of the queuing channel 166, the coins are turned in a direction wherein they are moving with the pad (*i.e.*, in a direction more parallel to the direction of movement of the pad). A coin rounding the corner 194 is accelerated as the coin moves in a direction with the pad; thus, the coin is spaced from the next coin upstream. Put another way, the first segment 190 receives coins from the entry channel 132 and the second segment 192 is disposed in a position that is substantially more in direction of movement of said rotatable disc 114 for creating an increased spacing between adjacent coins. Accordingly, the coins moving through the second segment 192 are spaced apart. According to one embodiment of the present invention, the coins are spaced apart by a time of approximately five milliseconds when the sorting head 112 has an eleven inch diameter and the pad 118 rotates at a speed of approximately three hundred revolutions per minute (300 r.p.m.). According to an alternative embodiment, the coins are spaced apart by a distance of less than about two inches when the sorting head 112 has an eleven inch diameter and the pad 118 rotates at a speed of about 350 r.p.m.

Referring back to FIG. 2, as the coins move into the discrimination region 202 of the second segment 194, the coins move across ramp 196 and transition to a flat surface of the discrimination region 202 as the pad 118 continues to rotate. Put another way, the two stepped surfaces 182, 186 of the queuing channel 166 transition into the flat surface of the discrimination region 202 towards the downstream second segment 194. The pad 118 holds each coin flat against the flat surface of the discrimination region 202 as the coins are moved past the discriminator sensor 204 in the downstream second segment 194.

The sorting head 112 includes a cutout for the discrimination sensor 204. The discrimination sensor 204 is disposed just below the flat surface of the discrimination region 202. Likewise, a coin trigger sensor 206 is disposed just upstream of the discrimination sensor 204 for detecting the presence of a coin. Coins first move over the coin trigger sensor 206 (*e.g.*, a photo detector or a metal proximity detector) which sends a signal to a controller indicating that a coin is approaching the coin discrimination sensor 204.

According to one embodiment, the coin discrimination sensor 204 is adapted to discriminate between valid and invalid coins. As discussed in the Background Section, use of the term "valid coin" refers to coins of the type to be sorted. Use of the term "invalid coin" refers to items being circulated on the rotating disc that are not one of the coins to be sorted. Any truly counterfeit coins (*i.e.*, a slug) are always considered "invalid." According to another alternative embodiment of the present invention, the coin discriminator sensor 204 is adapted to identify the denomination of the coins and discriminate between valid and invalid coins.

Coin discrimination sensors suitable for use with the disc-type coin sorter shown in FIGS. 1 and 2 are describe in detail in U.S. Patent Nos. 5,630,494 and 5,743,373, both of which are entitled "Coin Discrimination Sensor And Coin Handling System" and are incorporated herein by reference in their entries. Another coin discrimination sensor suitable for use with the present invention is described in detail herein in connection with FIGS. 14-27.

As discussed above according to one alternative embodiment of the present invention, the discrimination sensor 204 discriminates between valid and invalid coins. Downstream of the discrimination sensor 204 is a diverting pin 210 disposed adjacent inner queuing wall 170 that is movable to a diverting position (out of the page as viewed in FIG. 2) and a home position (into the page as viewed in FIG. 2). In the diverting position, the diverting pin 210 directs coins off of inner queuing wall 170 and into a reject channel 212. The reject channel 212 includes a reject wall 214 that rejected coins abut against as they are off-sorted to the periphery of the sorting head 112. Off-sorted coins are directed to a reject area (not shown). Coin that are not rejected (*i.e.*, valid coins) eventually engage an outer wall 252 of a gauging channel 250 where coins are aligned on a common radius for entry into the coin exit station area as is described in greater detail below.

According to one embodiment of the present invention, the diverting pin 210 is coupled to a voice coil (not shown) for moving the diverting pin between the diverting position and the home position. Using a voice coil in this application is a nontraditional use for voice coils, which are commonplace in acoustical applications as well as in servo-type applications. Typically, a discrete amount of voltage is applied to the voice coil for moving the windings of the voice coil a discrete amount within the voice coil's stroke length – the greater the voltage, the greater the movement. However, the Applicants have discovered that the when the voice coil is "flooded" with a positive voltage, for example, the voice coil rapidly moves the diverting pin 210 coupled thereto to the diverting position (*i.e.*, the end of the voice coil's stroke length) within a very short time period that is less than the time it takes for the coins to move from the discrimination sensor 204 to the diverter pin 210 when increased spacing is encountered due to the queuing channel. The voice coil is then flooded with a negative voltage for rapidly moving the diverting pin 210 windings back to its home position.

A voice coil suitable for use with the present invention is described in U.S. Patent No. 5,345,206, entitled "Moving Coil Actuator Utilizing Flux-Focused Interleaved Magnetic Circuit," which is incorporated herein by references in its entirety. As an example, a voice coil manufactured by BEI, Technologies, Inc. of San Francisco, California, model number LA15-16-024A, can move an eighth-inch (1/8 in) stroke (*e.g.*, from the home position to the diverting position) in approximately 1.3 milliseconds, which is a speed of about 0.1 inch per millisecond, and can provide approximately twenty pounds of force in either direction. Other voice coils are suitable for use with the coin sorting system of FIG. 2.

Other types of actuation devices can be used in alternative embodiments of the present invention. For example, a linear solenoid or a rotary solenoid may be used to move a pin such as diverting pin 210 between a diverting position and a home position.

As the pad 118 continues to rotate, those coins not diverted into the reject channel 212 continue along inner queuing wall 170 to the gauging region 250. The inner queuing wall 170 terminates just downstream of the reject channel 212; thus, the coins no longer abut the inner queuing wall 170 at this point and the queuing channel 166 terminates. The radial position of the coins is maintained, because the coins remain under pad pressure, until the coins contact an outer wall 252 of the gauging region 252. According to one embodiment of the present invention, the sorting head 112 includes a gauging block 254 which extends the outer wall 252 beyond the outer periphery of the sorting head 112. The gauging block 254 is useful when processing larger diameter coins such as casino tokens, $1 coins, 50¢ pieces, *etc.* that extend beyond he outer periphery of the sorting head 112. According to the embodiment of the sorting head 112 shown in FIG. 2, the gauging channel 250 includes two stepped surfaces to form rails similar to that described above in connection with the queuing channel 166. In alternative embodiments, the gauging channel 250 does not include two stepped surfaces.

The gauging wall 252 aligns the coins along a common radius as the coins approach a series of coin exit channels 261-268 which discharge coins of different denominations. The first exit channel 261 is dedicated to the smallest coin to be sorted (*e.g.*, the dime in the U.S. coin set). Beyond the first exit channel 261, the sorting head 112 shown in FIG. 2 forms seven more exit channels 261-268 which discharge coins of different denominations at different circumferential locations around the periphery of the sorting head 112. Thus, the exit channels 261-268 are spaced circumferentially around the outer periphery of the sorting head 112 with the innermost edges of successive channels located progressively closer to the center of the sorting head 112 so that coins are discharged in the order of decreasing diameter. The number of exit channels can vary according to alternative embodiments of the present invention.

The innermost edges of the exit channels 261-268 are positioned so that the inner edge of a coin of only one particular denomination can enter each channel 261-268. The coins of all other denominations reaching a given exit channel extend inwardly beyond the innermost edge of that particular exit channel so that those coins cannot enter the channel and, therefore, continue on to the next exit channel under the circumferential movement imparted on them by the pad 118. To maintain a constant radial position of the coins, the pad 118 continues to exert pressure on the coins as they move between successive exit channels 261-268.

According to one embodiment of the sorting head 112, each of the exit channels 261-268 includes a coin counting sensor 271-278 for counting the coins as coins pass though and are discharged from the coin exit channels 261-268. In an embodiment of the coin processing system utilizing a discrimination sensor capable of determining the denomination of each of the coins, it is not necessary to use the coin counting sensors 271-278 because the discrimination sensor 204 provides a signal that allows the controller to determine the denomination of each of the coins. Through the use of the system controller (FIG. 6), a count is maintained of the number of coins discharged by each exit channel 261-268.

FIG. 6 illustrates a system controller 280 and its relationship to the other components in the coin processing system 100. The operator communicates with the coin processing system 100 via an operator interface 282 for receiving information from an operator and displaying information to the operator about the functions and operation of the coin processing system 100. The controller 280 monitors the angular position of the disc 114 via an encoder 284 which sends an encoder count to the controller 280 upon each incremental movement of the disc 114. Based on input from the encoder 284, the controller 280 determines the angular velocity at which the disc 114 is rotating as well as the change in angular velocity, that is the acceleration and deceleration, of the disc 114. The encoder 284 allows the controller 280 to track the position of coins on the sorting head 112 after being sensed. According to one embodiment of the coin processing system 100, the encoder has a resolution of 2000 pulses per revolution of the disc 114.

Furthermore, the encoder 284 can be of a type commonly known as a dual channel encoder that utilizes two encoder sensors (not shown). The signals that are produced by the two encoder sensors and detected by the controller 280 are generally out of phase. The direction of movement of the disc 114 can be monitored by utilizing the dual channel encoder.

The controller 280 also controls the power supplied to the motor 116 which drives the rotatable disc 114. When the motor 116 is a DC motor, the controller 280 can reverse the current to the motor 116 to cause the rotatable disc 114 to decelerate. Thus, the controller 270 can control the speed of the rotatable disc 114 without the need for a braking mechanism.

If a braking mechanism 280 is used, the controller 280 also controls the braking mechanism 286. Because the amount of power applied is proportional to the braking force, the controller 280 has the ability to alter the deceleration of the disc 114 by varying the power applied to the braking mechanism 286.

According to one embodiment of the coin processing 100, the controller 280 also monitors the coin counting sensors 271-278 which are disposed in each of the coin exit channels 261-268 of the sorting head 112 (or just outside the periphery of the sorting head 112). As coins move past one of these counting sensors 271-278, the controller 280 receives a signal from the counting sensor 271-278 for the particular denomination of the passing coin and adds one to the counter for that particular denomination within the controller 280. The controller 280 maintains a counter for each denomination of coin that is to be sorted. In this way, each denomination of coin being sorted by the coin processing system 100 has a count continuously tallied and updated by the controller 280. The controller 280 is able to cause the rotatable disc 114 to quickly terminate rotation after a "n" number (*i.e.*, a predetermined number) of coins have been discharged from an output receptacle, but before the "n+1" coin has been discharged. For example, it may be necessary to stop the discharging of coins after a predetermined number of coins have been delivered to a coin receptacle, such as a coin bag, so that each bag contains a known amount of coins, or to prevent a coin receptacle from becoming overfilled. Alternatively, the controller 280 can cause the system to switch between bags in embodiments having more than one coin bag corresponding to each output receptacle.

According to one embodiment, the controller 280 also monitors the output of coin discrimination sensor 204 and compares information received from the discrimination sensor 204 to master information stored in a memory 288 of the coin processing system 100 including information obtained from known genuine coins. If the received information does not favorably compare to master information stored in the memory 288, the controller 280 sends a signal to the voice coil 290 causing the diverting pin 210 to move to the diverting position.

According to one embodiment of the coin processing system 100, after a coin moves past the trigger sensor 206, the coin discrimination sensor 204 begins sampling the coin. The discrimination sensor 204 begins sampling the coins within about 30 microseconds ("µs") of a coin clearing the trigger sensor 206. The sampling ends after the coin clears a portion or all of the discrimination sensor 204. A coin's signature, which consists of the samples of the coin obtained by the discrimination sensor 204, is sent to the controller 280 after the coin clears the trigger sensor 206 or, alternatively, after the coin clears the discrimination sensor 204. As an example, when the coin processing system 100 operates as a speed of 350 r.p.m. and the sorting head 112 has a diameter of eleven inches, it takes approximately 3900 µs for a 1¢ Euro coin (having a diameter of about 0.640 inch) to clear the trigger sensor 206. A larger coin would take more time.

The controller 280 then compares the coin's signature to a library of "master" signatures obtained from known genuine coins stored in the memory 288. The time required for the controller 280 to determine whether a coin is invalid is dependant on the number of master signatures stored in the memory 288 of the coin processing system 100. According to one embodiment of the present invention, there are thirty-two master signatures stored in the memory 288, while other embodiments may include any practical number of master signatures. Generally, regardless of the number of stored signatures, the controller 280 determines whether to reject a coin in less than 250 µs.

After determining that a coin is invalid, the controller 280 sends a signal to activate the voice coil 290 for moving the diverting pin 210 to the diverting position. As shown in FIG. 2, the diverting pin 210 is located about 1.8 inches downstream from the trigger sensor 206 on the eleven inch sorting head. Assuming an operating speed of 350 r.p.m., for example, the controller 280 activates the voice coil 290 within about 7300 µs from the time that the coin crosses the trigger sensor 206. As discussed above, the voice coil 290 is capable of moving the diverting pin 210 approximately an 1/8 inch in about 1300 μs.

Therefore, assuming an eleven inch sorting disk, an operational speed of 350 r.p.m. and a trigger sensor 206, discrimination sensor 204 and a diverting pin 210 arrangement as shown in FIG. 2, about 11000 μs (11 milliseconds) elapses from the time a coin crosses the trigger sensor 206 until the diverting pin 210 is lowered to the diverting position. Thus, the diverting pin 210 is located less than about two inches downstream of the trigger sensor 206. Accordingly, the spacing between coins crossing the trigger sensor 206 is less than about two inches.

Once the diverting pin 210 is moved to the diverting position, the diverting pin 210 remains in the diverting position until a valid coin is encountered by the discrimination sensor 204 according to one embodiment of the present invention. This reduces wear and tear on the voice coil 190. For example, the diverting pin 210 will only be moved to the diverting position one time when three invalid coins in a row are detected, for example, in applications involving a heavy mix of valid and invalid coins. If the fourth coin is determined to be a valid coin, the diverting pin 210 is moved to its home position. Further, according to some embodiments of the coin processing system 100, the diverting pin 210 is moved to the home position if the trigger sensor 206 sensor does not detect a coin within about two seconds of the last coin that was detected by the trigger sensor 206, which can occur when a batch of coins being processed in nearing the end of the batch. This reduces wear and tear on the pad 118, which is rotating beneath the diverting pin 210 b, because the diverting pin 210 and the rotating pad 118 are in contact when the diverting pin 210 is in the diverting position.

Because of the spacing imparted to the coins via the L-shaped queuing channel 166, it is not necessary to slow or stop the machine to off-sort the invalid coins. Rather, the combination of the increased spacing and fast-activating voice coil 290 contribute to the ability of the coin sorter system illustrated in FIGS. 1 and 2 to be able to discriminate coins on the fly.

The superior performance of coin processing systems according to one embodiment of the present invention is illustrated by the following example. Prior art coin sorters, such as those discussed in the Background Section where is was necessary to stop and then jog the disc to remove an invalid coin, that utilized an eleven inch sorting disc were capable of sorting a retail mix of coins at a rate of about 3000 coins per minute when operating at a speed for about 250 r.p.m. (A common retail mix of coins is about 30% dimes, 28% pennies, 16% nickels, 15% quarters, 7% half-dollar coins, and 4% dollar coins.) The ability to further increase the operating speed of these prior art devices is limited by the need to be able to quickly stop the rotation of the disc before the invalid coin is discharged as is discussed in the Background Section. According to one embodiment of the coin processing system 100 of FIGS. 1 and 2, the system 100 is cable of sorting a retail mix of coins at a rate of about 3300 coins per minute when the sorting head 112 has a diameter of eleven inches and the disc is rotated at about 300 r.p.m. According to another embodiment of the present invention, the coin processing system 100 is capable of sorting a "Euro financial mix" of coins at rate of about 3400 coins per minute, wherein the sorting head 112 has a diameter of eleven inches and the disc is rotated at about 350 r.p.m.. (A common Euro financial mix of coins made up of about 41.1% 2 Euro coins, about 16.7% 1 Euro coins, about 14.3 % 50¢ Euro coins, about 13.0% 20¢ Euro coins, about 11.0% 10¢ Euro coins, about 12.1% 5¢ coins and about 8.5% 1¢ Euro coins.)

In one embodiment of the coin processing system 100, the coin discrimination sensor 210 determines the denomination of each of the coins as well as discriminates between valid and invalid coins, and does not include coin counting sensors 271-278. In this embodiment, as coins move past the discrimination sensor 204, the controller 280 receives a signal from discrimination sensor 204. When the received information favorably compares to the master information, a one is added to a counter for that particular determined denomination within the controller 280. The controller 280 has a counter for each denomination of coin that is to be sorted. As each coin is moved past the discrimination sensor 204, the controller 280 is now aware of the location of the coin and is able to track the angular movement of that coin as the controller receives encoder counts from the encoder 284. Therefore, referring back to the previous coin bag example, the controller 280 is able to determined at the precise moment at which to stop the rotating disc 114 such that the "nth" coin is discharged from a particular output channel 261-286, but the "n + 1" coin is not. For example, in an application requiring one thousand dimes per coin bag, the controller counts number of dimes sensed by the discrimination sensor 204 and the precise number of encoder counts at which it should halt the rotation of the disc 114 – when the 1000th dime is discharged from the coin exit channel, but not the 1001st dime.

Referring now to FIGS. 7a and 7b, an external diverter 300 for use with an alternative embodiment of coin processing system 100 is shown. A plurality of external diverters 300 are arranged circumferentially around the sorting head 112 such that an inlet 302 of each external diverter 300 is disposed adjacent to each exit channel 261-268 for receiving coins discharged therefrom. The external diverters are used for separating valid and invalid coins according to one alternative embodiment of the coin processing system 100 in place of the voice coil 290 and pin 210. In another alternative embodiment, the diverter 300 works in connection with the voice coil 290 and pin 210 and functions to separate valid coins into two batches, rather then to separate invalid from valid coins.

The external diverter 300 includes an internal partition 304 that pivots about a base 306 between a first position 308a and a second position 308b wherein coins are directed down a first coin path 310a and a second coin path 310b, respectively. The internal partition 304 is coupled to a voice coil 310 for rapidly moving the internal partition 304 between the first and second positions 308a,b. In an alternative embodiment, the external diverter 300 is constructed such that the internal partition 304 moves from side-to-side (not up and down) to route coins between the two coin paths 310a,b.

According to one alternative embodiment of the coin processing system 100, the external diverters 300 are used in place of the diverting pin 210 (FIG. 2) for discriminating between valid and invalid coins. When an invalid coin is sensed by discrimination sensor 204 (FIG. 2), the controller 280 (FIG. 6) activates the voice coil 310 of the external diverters so that the invalid coin is directed down a second coin path 310b. The controller 280, with input from the encoder 284, is able to track the angular position of the invalid coin around the sorting head 112 as the pad 118 rotates. For each exit channel 261-268 and each corresponding external diverter 300, the controller 280 activates the voice coil 310 after a coin preceding the identified invalid coin has moved passed the exit channel 261-268, but before the identified invalid coin has reached the exit channel 261-268. For example, if the invalid coin has a diameter appropriate for the first exit channel 261, the invalid coin will be discharged from the first exit channel 261 into the second coin path 310b of the external diverter 300. The controller 280 sends a signal to the voice coil 310 to return internal partition 304 of the external diverter to the first position 308a before the coin immediately following the invalid coin reaches the first exit channel. The controller 280 repeats this sequence for each external diverter disposed around the sorting head. According to another alternative embodiment of the coin processing system 100, the controller is able to determine the diameter of each of the invalid coins using one or more sensors in the discrimination region 202 including the discrimination sensor 204; therefore, the controller 204 only activates the external diverter 300 of the exit channel 261-268 that is appropriate for the determined diameter of the invalid coin.

According to one alternative embodiment of the coin processing system 100, the external diverters 300 are used in connection with the sorting head of FIG. 2 which includes the diverting pin 210 (FIG. 2). The diverting pin 210 is used to off-sort invalid coins as described in connection with FIG. 2. The external diverters are used to separate the valid coins into two different batches. For example, in some applications the coin processing system 100 uses dual bag holders for each denomination and a predetermined number of coins discharged to each coin bag. The controller 280 maintains of a count of the coins discharged from each output receptacle and activates the external diverter 300 for routing coins to a second bag before the next coin is discharged from the corresponding exit channel 261-286. Again, because the controller 280 is tracking the angular movement of the disc 114 via the encoder 284, the controller 280 knows the precise moment that an identified valid coin is going to reach and be discharged from an exit channel.

Again, the generally L-shaped queuing channel 166 imparts a spacing to the coins allowing the coin processing system 100 to utilize the external diverters 300, which are rapidly actuated by the voice coils, on the fly. Accordingly, it is not necessary to slow or stop the rotating disc 144 when off-sorting invalid coins or routing coins down an alternate coin path.

Referring now to FIG. 8, a programmable sorting head 350 is shown for use in an alternative embodiment of the coin processing system 100 of FIG. 1. Very generally, the exit channels 351-360 of the programmable sorting head 350 are substantially the same size so that coins of any denomination can be discharged out of any exit channel 351-360. Thus, the programmable sorting head 350 does not sort coins on the basis of diameter size; rather, coins are discriminated on the basis of information obtained from a discrimination sensor and are selectively distributed from the sorting head 350. Each of the exit channels 351-360 function similar to that of the reject channel 212 of FIG. 2. A diverting pin 362 is disposed adjacent each exit channel 351-360 and move downward (out of the page in FIG. 8) to a diverting position for ejecting coins off of an inner queuing wall 364 into the corresponding exit channel 351-360.

The programmable sorting head 350 operates in a manner similar to the sorting head 112 described in connection with FIG. 2. Coins that are deposited on the rotating pad 118 via a central opening 366 in the programmable sorting head 350 initially enter an entry channel 368. As the pad 118 continues to rotate, coins are moved past a stripping notch for stripping stacked coins and then across a ramp, for increasing the pad pressure, into a queuing channel 374 having an inner queuing wall 364. In the embodiment of the programmable sorting head 350 depicted in FIG. 8, the queuing channel 374 includes three stepped surfaces and three rails (as opposed to two stepped surfaces and two rails for the sorting head 112 in FIG. 2). Alternatively, the queuing channel 374 consists of one surface.

The queuing channel 374 of the programmable sorting head 350 is L-shaped for imparting a spacing to the coins as the coins are moved past the corner 376 of the L-shaped queuing channel 374. The L-shaped queuing channel 374 of FIG. 8 imparts spacing to adjacent coins in the same manner as does the L-shaped queuing channel 166 described in connection with FIG. 2. Coins turning the corner 376 of the queuing channel 374 are accelerated and spaced-apart and engage the inner queuing channel wall 364. As the pad 118 continues to rotate, the coins aligned along wall 364 are move across a ramp 378 which transitions the coins to a flat surface for moving the coins past a coin trigger sensor 380 and a coin discrimination sensor 382.

The coin discrimination sensor 382 is adapted to discriminate between valid and invalid coins and to determine the denomination of each of the coins passing under the sensor 382. The function of the trigger sensor 380 and the discrimination sensor 382 is similar to that described in connection with FIG. 2. By processing input from the sensors 380, 382 and the encoder 284, the controller 280 tracks the angular position of each coin and is able to calculate the precise time to active a voice coil coupled to a pin 362 disposed adjacent to an exit channel 362. For example, if the coin discrimination sensor 382 determines that a coin is a dime and the coin sorting system is operating pursuant to a mode wherein dimes are to be off-sorted at the first exit channel 351, the pin 362 is lowered to the diverting position after the coin preceding the dime is moved past the first exit channel 351, but before the dime reaches the first exit channel. As the pad continues to rotates, the dime contacts the pin 362 and is knocked off the inner wall 365 into the first exit channel 351. The controller 280 raises the pin 362 before the next coin reaches the first exit channel 351. Put another way, the time to retract the pin 362 is less tan the time for the next coin to pass the pin 362 due to the increased spacing imparted to the coins by the L-shaped queuing channel 374.

In various alternative embodiments of the coin processing system 100 utilizing the programmable sorting head 350 ("the programmable processing system"), the programmable processing system operates pursuant to many predefined modes of operation and user-defined modes of operation. For example, the first exit channel 351 can operate as a reject chute for off-sorting invalid coins. In another embodiment, none of the exit channels 351-360 serve as reject chutes; rather, invalid coins are moved along wall 364 around the sorting head 350 and follow wall 364 off the sorting head at a point "C" where the coins are discharged to another off-sort area. In another application such as in the processing of coins obtained from vending machines, the first three exit channel 351-353 are used to sort nickels, dimes and quarters, respectively, until a predetermined number of coins of a denomination are delivered to the respective exit channel 351-353. Then the controller causes nickels, dimes and quarters to be off-sorted at the fourth, fifth and sixth exit channels 354-356, respectively, and so on. Accordingly, after a predetermined number of nickels have been discharged by the first exit channel 351, nickels are then off-sorted at the fourth exit channel 354, and then the by the seventh exit channel 357. No more than the predetermined number of coins are discharged from the exit channels 351-359 and the subsequent exit channel assigned to nickels, for example, is not utilized until the previous exit channel assigned to nickels has discharged a predetermined number of coins.

In another embodiment of the present invention, the programmable coin processing system operates pursuant to a mode of operation wherein the first ten coin denominations detected by the coin discrimination sensor 382 are the coin denominations assigned to the ten exit channels 351-360, respectively, and all other coins are off-sorted by following wall 364 off the sorting head 350 at point "C." As is readily apparent, the programmable sorting system can be utilized in pursuant to a myriad of modes of operation in alternative embodiments of the system.

In another embodiment of the present invention, the programmable coin processing system is utilized to separate coins from a plurality of coin sets – British pound coins, French Franc coins, German Deutschmark coins, U.S. coins, Italian Lira coins, Canadian coins and Euro coins, for example. The programmable coin processing system causes coins of each coin set to be distributed to one of the ten exit channels 351-360, while off-sorting other "invalid" coins. The programmable coins sorter can be linked to an external network which provides currency exchange rates so that the system can calculate the real-time value of all the coins processed from the different coin sets from different countries.

In FIG. 9, an alternative embodiment of a sorting head 400 is shown for use with the coin processing system 100 of the present invention. While it will be recognized that the sorting head 400 is similar to the sorting head 112 shown in FIG. 2, the alternative embodiment to be discussed in connection with FIG. 9 is also applicable to a programmable coin sorting system such as that described in connection with FIG. 8.

The sorting head 400 is similar to that of FIG. 2 in that it is designed to impart spacing to adjacent coins; however, the queuing channel 402 is designed to move coins so that the outside edge of each of the coins extends beyond an outer periphery 404 of the sorting head 400 as the coins move past an optical sensor 406 for discriminating the coins. According to one embodiment, the optical sensor 406 is adapted to discriminate between valid and invalid coins. In another alternative embodiment, the optical sensor 406 is adapted to discriminate between valid and invalid coins and to identify the denomination of coins. The optical sensor 406 can comprise a photodetector, a charge-coupled device (CCD) detector, a metal oxide semiconductor (MOS) array, a line array, a camera, a scanning laser or other type of optical sensor according to various alternative embodiments.

The radial position of the queuing channel 402 is moved outward a distance such that the diameter of the smallest coin to be processed (*e.g.*, the dime in the U.S. coin set) is moved beyond the outer periphery 404 of the sorting head 400 to obtain optical information from the coin. According to one embodiment, the coins must extend beyond the outer periphery 404 of the sorting head 400 at least about 0.010 inch (approximately 0.25 mm) for obtaining the optical information from the coin. A controller of the coin processing system 100 then processes the optical information obtained from each coin by the optical sensor 404. As the pad continues to rotate, the coin is brought back within the outer periphery 404 of the sorting head 400 as the coin moves past a diverting pin 408 and reject channel 410 similar to that described in connection with FIG. 2. Invalid coins are rejected via the reject channel 410 while valid coins are moved into engagement with an outer wall 412 of a gauging channel 414 for aligning the coin along a common radius as the coins approach the exit channels 416a-h.

Turning now to FIG. 10, a programmable power rail coin processing system 500 ("rail system 500") is shown according to an alternative embodiment of the present invention. The rail system 500 includes a guide plate 502 similar to the sorting head 350 shown and described in connection with FIG. 8. The guide plate 502 functions in substantially the same manner as the sorting head 350 in FIG. 8 by aligning coins, that are moved by a rotating disc, along an inner queuing channel wall 504 of a queuing channel 506; however, the guide plate 502 does not sort the coins. Rather, the coins are sorted along a rail 510 as is described in greater detail below.

It should be noted that the while underside of the guide plate 502 is shown in FIG. 10, the surface of the guide plate 502 shown in FIG. 10 faces downward while the rail 510 would face upward as shown in actual operation of the rail sorter 500. As with the sorting head in FIGS. 2 and 8, the queuing channel 506 of the guide plate 502 is generally L-shaped for imparting a spacing between adjacent coins. As the rotatable disc (similar to disc 114 of FIG. 1) continues to rotate, the coins are moved over a ramp 512 on to a flat surface 514 and along a wall 504. The guide plate 502 does not include any exit channels. Further, the guide plate 502 does not include a coin discrimination sensor as it can be disposed on the rail 510. Rather, the coins continue along inner queuing wall 504 and are moved onto the rail 510 and into engagement with a wall 520 of the rail 510 while the underside of each coin contacts a flat surface 521 of the rail 510.

Referring also to FIG. 11, an endless belt 522 that is looped around two pulleys 524, 526 is disposed along the longitudinal axis of the rail 510 and is disposed above the rail 510 a distance less than the thickness of the thinnest coin. (Note that the endless belt 522 is depicted with a dashed-line in FIG. 10.) The first pulley 524 rotates around a shaft 528 and the second pulley is driven by a motor 530 via another shaft 532. The belt 522, which is made out of a resilient material such as rubber, grips the coins as the upper surfaces of the coins come into contact with the belt 522 as the coins move from the guide plate 502 along queuing wall 504 to the rail 510 and into engagement with wall 520. The belt 522, which is in pressed engagement with the coins, moves the coins along the rail 510 while an underside of each coin slides along the flat surface 521 of the rail 510. The transition between the guide plate 502 and the rail 510 should appear substantially seamless to the coins so as not to decrease the spacing between the coins. The endless belt 522 moves at a speed sufficient to maintain the spacing between adjacent coins as the coins move onto the rail 510 and come under control of the belt 522. According to an alternative embodiment of the rail sorter 500, the belt 522 moves at speed sufficient to increase the spacing between adjacent coins and no L-shaped queuing channel would be needed to increase spacing between adjacent coins in such an embodiment.

As the belt 522 continues to rotate, coins are moved past a coin discrimination sensor 540 for discriminating between invalid and valid coins and for determining the denomination of the coins. A plurality of coin exit channels 551-555 are disposed in the rail 520 downstream of the coin discrimination sensor 540. While five exit channels 551-555 are shown in the embodiment of the rail system 500 shown in FIG. 10, the length of the rail 510 and the endless belt 522 can be extended (or reduced) to accommodate any reasonable number of exit channels. Also included along the rail 510 are a plurality of diverting pins 560 disposed adjacent each coin exit channel 551-526 for obstructing a coin moving along the wall 520 and forcing the coin into the corresponding exit channel. The diverting pins 560 each move from a home position, wherein the pins disposed slightly below the surface 521 of the rail, to a diverting position extending beyond the surface 521 of the rail 510 for engagement with coins. Each of the diverting pins 560 are moved from the home position to the diverting position and back to the home position by a voice coil, which provides the advantage of rapid actuation.

An encoder (not shown) is coupled to one of the two pulleys 524, 526 and is interface with a controller of the rail system 500 for tracking the linear movement of the coins along the rail 510. As discussed above in connection with FIG. 8, the controller of the rail system 500 is interfaced with the coin discrimination sensor 540, the diverter pins 560 and the encoder for selectively diverting coins into the plurality of exit channel 551-555. Coins that are not selectively diverted into one of the plurality of exit channels 551-555 are moved off a downstream end 562 and fall into an invalid coin chute 564 (FIG. 12). Alternatively, invalid coins are off-sorted via one of the coin exit channels 551-555.

Similar to the sorting head depicted in FIG. 8, the rail system 500 is programmable. Each exit channel 551-555 is sized to accommodate coins of most any diameter. Accordingly, the rail sorter can be programmed to selectively discharge coins of any denomination out of any of the exit channels 551-555. For example, in one application, U.S. coins are sorted in order of increasing value – pennies, nickels, dimes, quarters, half dollar coins and dollar coins – rather than in order of increasing diameter.

Referring also to FIG. 12 , the rail system 500 is disposed within a cabinet 570 for housing the rail sorter 500. (Note that the endless belt 522 and pulleys 524, 526 are not shown FIG. 12 .) A plurality of coin tubes 571-575 are disposed along the rail 510 adjacent the exit channels 551-555 for receiving coins discharged from each of the exit channels 551-555 and routing the coins to coin receptacles such as coin bags 580 contained within the cabinet 570. A sixth coin tube 576 routs coins from the invalid coin chute 564 to a coin receptacle disposed with the cabinet 570.

The rail system 500 provides the advantage of presenting the coin bags 580 in a substantially liner fashion. Put another way, the exit channels 551-555 output coins in the same direction which facilities a substantially linear bag presentation. Therefore, an operator of the rail system 500 can easily access the coins bags 580 from the same side of the cabinet. In alternative embodiment of the rail sorter 500, dual coin bag holders for holding two coins bags can be attached to the end of each coin tube. Dual bag holders allow the rail system 500 to route coins of a single denomination to two different bags; thus, once a predetermined number of coins have been routed to a first bag the coins of that denomination are routed to a second bag.

In an alternative embodiment of the rail system 500, the guide plate 502 includes a discrimination region having a discrimination sensor and a reject channel as does the sorting head 112 of FIG. 2. Accordingly, the discrimination sensor on the guide plate 502 discriminates between valid and invalid coins and/or determines the denomination of the coins and invalid coins are off-sorted via the reject channel. Thus, no discrimination sensor is needed on the rail in such an embodiment.

In yet another alternative embodiment of the rail system, the rail and guide plate are formed from the same piece of material such that they are integral components. The rotating pad and endless belt are disposed on the same side of the integral rail and pad – either the top-side or the bottom-side. Alternatively still, a large rotating pad can impart movement to the coins along the integral guide plate and pad.

Turning to FIG. 13, a sorting head 600 having a single exit station 602 is shown for use in an alternative embodiment of the coin processing system 100. The sorting head 600 operates in a similar manner as does the sorting heads described previously up until the point where the coins enter a queuing region 604 of the sorting head 600. In the queuing channel 604, the coins are aligned against an inner queuing wall 606, which extends around a substantial portion of the sorting head 600. At the downstream end, the queuing channel 604 includes a substantially "dog-leg-shaped" portion 610, which includes an first upstream segment 612 and a second downstream segment 614.

Similar to the generally L-shaped queuing regions described above in connection with FIGS. 2 and 8, the dog-leg-shaped portion 610 imparts a spacing to adjacent coins moving from the first segment 612 to the second downstream segment 614. As a pad (such as pad 118 of FIG. 1) rotates, the coins are pushed against inner wall 606 and travel along the inner wall 606 in a direction that is transverse to the direction in which the pad is rotating. This action aligns the coin against the wall 606. As the coins move from the first upstream segment 612 to the second downstream segment 614 of the queuing channel 166, the coins are turned in a direction wherein they are moving with the pad, which imparts spacing between adjacent coins.

As the pad continues to rotate, the coins are moved past a discrimination sensor 620 disposed along the queuing channel 604 for discriminating between valid and invalid coins and/or identifying the denomination of coins. The coins continue along the inner queuing channel wall 606 until the pad rotation causes the coins to be discharged from the single exit station 602. Note that that all coins entering the coin processing system described in connection with FIG. 13 thus far are discharged out of the single output channel 602.

An external diverter 300 actuated by a voice coil 310, such as described in connection with FIGS. 7a,b, receives coins discharged from the single output receptacle 602. A controller (not shown) monitors the output of the discrimination sensor 620 for selectively moving the internal partition 304 (FIGS. 7a,b) between the first and second positions 308a,b for routing coins to the first and second coins paths 310a,b. Alternatively, the external diverter is actuated by a solenoid.

The coin processing system described in connection with FIG. 13 can be used in applications wherein it is desirable to separate coins into two batches. For example, it may be desired to process U.S. dimes into batches of 1000 dimes each. In another application, it may be desired to separate valid coins from invalid coins. In another application, it may be desired to separate a mixed batch of coins such as a mix of U.S. coins and Euro coins into their respective coin sets. According to an alternative embodiment of the coin processing system described in connection with FIG. 13, the sorting head 600 includes a diverting pin and reject channel for off-sorting invalid coins prior to discharging valid coins from the single exit station 602. Such an embodiment can be used in an application wherein it is desired to separate Euro coins from U.S. coins, but to also remove invalid coins (*e.g.*, coins from other coin sets and/or counterfeit coins).

FIG. 14 is functional block diagrams illustrative of a coin discrimination system 298 according to one embodiment of the present invention. The system generally includes the coin discrimination sensor 204, a programmable logic device (PLD) 1300, and a microprocessor 1302. In alternate embodiments, the controller 280 (FIG. 6) of the coin processing system may include the PLD 1300 and/or the microprocessor 1302. The coin discrimination sensor 204 generally includes an excitation coil 1304 and detector coils 1306. The excitation coil 1304 is excited with a 480 KHz source wave that is added to a 30 KHz source wave. The 30 KHz source wave is generated by a 30 KHz Direct Digital Synthesis (DDS) sine wave generator 1308, and the 480 KHz source wave is generated by a 480 KHz DDS sine wave generator 1310. In a specific embodiment, the DDS sine wave generators are Analog Devices AD9850 devices, though it is understood that any suitable waveform generators may be employed.

A DDS programming logic and clock generator 1312 in the PLD 1300 allows the 30 KHz and 480 KHz sine waves to stay synchronized with the PLD 1300, and allows the PLD to track the position of each waveform as it rolls from 0 to 360 degrees. The 30 KHz and 480 KHz sine waves are combined in a combiner 1314, which may also buffer and amplify the resulting signal. The resulting signal is driven by a high frequency driver 1316 into the excitation coil 1304 of the coil discrimination sensor 204 as an excitation signal. In one embodiment, the high frequency driver 1316 is a 1 Amp high current, high frequency driver and the excitation signal is 10 volts peak-to-peak (plus or minus 5 volts).

Although the DDS sine wave generators 1308, 1310 output a 30 KHz and 480 KHz signal, respectively, other combinations of frequencies may be employed. As is known, low frequencies tend to penetrate further into a coin, whereas high frequencies penetrate only the surface of the coin. The particular selection of frequencies may be influenced by the metal contents and thicknesses of the set of coins to be analyzed, for example. Whether the coins have claddings may be another factor that influences the selection of frequencies. It is understood that the present invention is not limited to the frequencies of 30 KHz and 480 KHz, but rather is intended to encompass any combination of frequencies suitable for discriminating coins of a particular set. For example, one set may include U.S. coins, another set may include tokens, another set may include a combination of U.S. and Euro coins, and so forth.

When a coin 1320 approaches the coin discrimination sensor 204, its presence will be first detected by the coin trigger sensor 206 (FIG. 6), which signals the system 298 to begin monitoring the coin discrimination sensor 204 for the coin 1320. The PLD 1300 is also instructed to capture the current location of the coin with reference to the encoder

284. The PLD 1300 calculates how many pulses of the encoder 284 to wait until the coin 1320 will approach the voice coil 290. The projected position of the encoder 284 is stored in a FIFO memory (not shown) within the PLD 1300, until the coin 1320 can be processed and a decision whether to accept or reject the coin 1320 has been made by the microprocessor 1302.

As explained in more detail with reference to FIGS. 17-19, the detector coils 1306 should be balanced to receive the same level of induced voltage from the excitation coil 1304 so as to cancel out the currents from the locally generated magnetic field, resulting in 0 VDC difference between the induced voltages in each of the detector coils 1306. As a coin 1320 passes by the coin discrimination sensor 1306, eddy currents in the coin 1320 induce different voltages in each of the detector coils 1306. The difference between these voltages results in a detection signal which is indicative of the amplitude and phase differences with respect to the excitation signal. In one embodiment, the detection signal is 1 volt peak-to-peak.

The detection signal is buffered and amplified in a buffer 1322 and is scaled to, for example, 5 volts peak-to-peak (0 to 5 volts), and is then processed in a high-speed analog-to-digital converter (ADC) 1324. In a specific embodiment, the ADC 1324 is clocked at 7.68 MHz and generates a 12-bit number with each rising clock edge. The ADC 1324 thus produces 256 samples of the detection signal for each full cycle of the 30 KHz source wave. Next, the output of the ADC 1324 is presented to the PLD 1300, which includes a Fast Fourier Transform (FFT) Logic 1326, System Diagnostics and Mode Control Logic 1328, Peak Detector Logic 1330, Quadrature Decoder and Coin Position Tracking Logic 1332, and Voice Coil Control Logic 1334. The FFT Logic 1326 of the PLD 1300 separates the 480 KHz and 30 KHz components of the detection signal, and provides the instantaneous amplitudes of the 30 KHz component of the detection signal at the 0 degree (sine) and 90 degree (cosine) positions of the 30 KHz component of the source wave, and the instantaneous amplitudes of the 480 KHz component of the detection signal at the sine and cosine positions of the 480 KHz component of the source wave.

It will be appreciated that the phase angles 0 degrees and 90 degrees are merely illustrative of numerous possible combinations of phase angles. For example, in one embodiment, the phase angles could be 45 degrees and 135 degrees. Preferably, the phase angles are selected to be about 90 degrees apart, however other phase angle differences may be employed.

The source wave is used as a phase reference for the calculations, so therefore, the difference, or phase shift, can be represented as coin signature values. Because the FFT Logic 1326 completes its calculations with each set of the 256 samples of the ADC 1324, the FFT Logic 1326 can generate 30,000 coin signatures per second. Each coin signature is comprised of the Sine 30 KHz Amplitude, the Cosine 30 KHz Amplitude, the Sine 480 KHz Amplitude, and the Cosine 480 KHz Amplitude.

The PLD 1300 monitors the 30,000 signatures per second, and the Peak Detector Logic 1330 component of the PLD 1300 stores the one signature that represents the largest amplitude of the 480 KHz component of the detection signal. This is the point in which the greatest amount of surface area of the coin is proximate the coin discrimination sensor 204, i.e., the coin is generally centered relative to the discrimination sensor 204. For a particular coin set, each coin should present a unique coin signature so long as each coin in the coin set has unique combinations of metal content, thickness, and diameter. For example, even if two coins have the same metal content and diameter, their difference in thickness may be sufficient to present uniquely discernible coin signatures.

The coin signature stored by the Peak Detector Logic 1330 in the PLD 1300 is processed by the microprocessor 1302. In a specific embodiment, the microprocessor 1302 generally includes the following components: a Signature Calibration Control 1336, a Coin Signature Training System 1338, a Coin Data Table 1340, and a Coin Identification System 1342. Instructions and/or logic that comprise the Signature Calibration Control 1336 may adjust the coin signature to compensate for calibration offsets and/or temperature drifts. The adjusted coin signature is compared against the Coin Data Table 1340, which, according to one embodiment, contains a window of acceptable coin signature values for a given coin. If the adjusted coin signature falls within that window, the Coin Identification System 1342 instructs the PLD 1300 to allow the coin to pass by the voice coil 290. If the microprocessor 1302 cannot find a window into which the current coin falls, then the microprocessor 1302 instructs the PLD 1300 to cause the voice coil 290 to reject the coin. A more detailed description of the coin signature values is provided below.

In another embodiment, the Coin Data Table 1340 includes a plurality of mathematical formula, where each formula corresponds to a curve. For example, if the voltages generated by the eddy currents in a coin passing by the coin discrimination sensor 204 are plotted against the position of the coin, the plot will resemble a curve which can be represented mathematically. This mathematical formula can be stored in the Coin Data Table 1340, and when a passing coin's position and voltage data can be supplied to the formula to determine if this particular coin falls on the curve (within a certain tolerance, if desired).

As mentioned above, the PLD 1300 monitors the position of the coin via the encoder 284. When the position of the coin from the encoder 284 matches the projected location stored in the FIFO memory of the PLD 1300, the PLD 1300 commands the Voice Code Control Logic 1334 to move the pin of the voice coil 290 in a direction which depends on whether a valid coin was detected. For example, if a valid coin is detected, the voice coil 290 may be retracted to allow the coin to pass by the voice coil 290. If an invalid coin is detected, it may be flagged by the microprocessor 1302, and the voice coil 290 may be extended to divert the coin out of the sorting head 112 (FIG. 2) and into a reject bin. Note that as a coin is moved toward the voice coil 290, the system 298 can process one or more additional coins, and the FIFO memory of the PLD 1300 can keep track of each coin, where it is located relative to the sorting head 112, and flag a particular coin according to a desired characteristic, such a whether the coin is a valid or invalid coin. In this manner, the voice coil 290 can be located a distance away from the coin discrimination sensor 204.

The Coin Signature Training System 1338 aspect of the microprocessor 1302 may be used to place the system 298 into a learning mode to develop signature windows for coins and/or to expand the library of recognized coins stored in the Coin Data Table 1340. For example, a new coin set may be desired to be sorted, such as the British coin set. In the learning mode, several to hundreds of British coins are processed by the system 298, and the microprocessor 1302 develops signature windows for each denomination of coin and stores each window in the Coin Data Table 1340. If a new token (which, as used herein, is a type of coin) is added to an existing token set, the new tokens can be processed by the system 298 in the learning mode, and a new signature window is developed and stored in the Coin Data Table 1340.

It will be appreciated that the blocks shown in the PLD 1300 and the microprocessor 1302 shown in FIG. 14 are functional and are not intended to represent all of the functional aspects to the PLD 1300 or the microprocessor 1302. In addition, various of the blocks may be eliminated, such as, for example, the Coin Signature Training System 1338 in the microprocessor 1302, without departing from the present invention. Moreover, some blocks which are shown as a functional aspect of the PLD 1300 may instead be a functional aspect of the microprocessor 1302. For example, the Voice Coil Control Logic 1334 in the PLD 1300 may instead be a functional aspect of the microprocessor 1302. Similarly, one or both of the encoder 284 and the voice coil 290 may be coupled to the microprocessor 1302 in alternate embodiments. Finally, as mentioned above, the controller 280 shown in FIG. 6 is a general functional representation of the processing and logic circuitry of the system 298 and may include one or both of the PLD 1300 and the microprocessor 1302.

FIG. 15 shows a functional block diagram of a coin discrimination system 1400 according to an embodiment of the present invention that lacks the PLD 1300 shown in FIG. 14. The system 1400 generally includes a coin discrimination sensor 1402 which is coupled to a controller 1404. A 30 KHz sine wave generator 1406 and a 1480 KHz sine wave generator 1408 produce a 30 KHz source wave and a 480 KHz source wave, respectively, which are added together in a combiner 1410, amplified and buffered in a buffer 1412, and driven into an excitation coil 1414 of the coin discrimination sensor 1402. The coin discrimination sensor 1402 also includes detector coils 1416 which detect the eddy currents in a coin 1440 passing proximate the coin discrimination sensor 1402. The detection signal is buffered and amplified in a buffer 1418. The resulting detection signal is presented to a high bandpass filter 1420 and a low bandpass filter 1422, which isolate the 1480 KHz and 30 KHz frequency components, respectively, of the detection signal. Thus, the signal from the high bandpass filter 1420 includes amplitude and phase information of the 1480 KHz component of the detection signal, and the signal from the low bandpass filter 1422 includes amplitude and phase information of the 30 KHz component of the detection signal.

The signal from the high bandpass filter 1420 is presented to a 0° sample and hold circuit 1424 and a 90° sample and hold circuit 1426, which provide the amplitudes of the 480 KHz component of the detection signal at two phase points that are 90° apart. Similarly, the signal from the low bandpass filter 1422 is presented to a 0° sample and hold circuit 1428 and a 90° sample and hold circuit 1430, which provide the amplitudes of the 30 KHz component of the detection signal at two phase points that are 90° apart. The voltage outputs of the sample and hold circuits 1424, 1426, 1428, 1430 are presented to an ADC 1432, which samples the outputs to provide digital values of the amplitudes to the controller 1404. As mentioned before, the controller 1404 uses the data from an encoder 1436 to communicate instructions to a voice coil 1434 based on the values from the ADC 1432 and the coin signature tables stored in memory.

FIGS. 16a-16c illustrate top, side, and end views, respectively, of a coil bobbin 1500 for use in a coin discrimination sensor according to one embodiment of the present invention. The coil bobbin 1500 includes a top retaining layer 1502, a bottom retaining layer 1504, a projection 1506, a first wire recess 1508, and a second wire recess 1510. An aperture 1512 is formed in the top retaining layer 1502 to accept therethrough wire ends from wires wound around the bobbin 1500. In a specific embodiment, the bobbin 1500 is made of Delrin, however in other embodiments the bobbin 1500 may be made of any other suitable material such as Nylon, ceramic, alumina, or any other non-metallic material.

In a specific embodiment, the top retaining layer 1502 has approximate dimensions of 1.5 inches x 0.22 inches x 0.04 inches (length x width x height). The first wire recess 1508 and the second wire recess 1510 have approximate dimensions of 1.34 inches x 0.06 inches x 0.08 inches (length x width x height). The projection 1506 has approximate dimensions of 1.42 inches x 0.14 inches x 0.12 inches (length x width x height). The aperture 1512 is approximately 0.01 inches wide. The overall dimensions of the bobbin 1500 are approximately 1.5 inches x 0.22 inches x 0.36 inches (length x width x height). The bobbin 1500 is positioned a distance away from a passing coin such that the thickest coin to be processed can move past the bobbin 1500 without causing undesired frictional contact with the surface of the bobbin 1500 proximate to the passing coin.

Turning to FIGS. 17-19, one embodiment of the present invention employs a coin discrimination sensor 1610, which may be employed in the embodiments described with reference to FIGS. 14 and 15. The coin discrimination sensor 1610 includes an excitation coil 1612 for generating alternating magnetic fields that induce eddy currents in a coin 1614. The excitation coil 1612 has a start end 1616 and a finish end 1618. In one embodiment, an excitation coil voltage, e.g., a signal having 30 KHz and 480 KHz frequency components and 10 volts peak-to-peak, is applied across the start end 1616 and the finish end 1618 of the excitation coil 1612. The excitation voltage produces a corresponding current in the excitation coil 1612 which in turn produces corresponding alternating magnetic fields. The alternating magnetic fields exist within and around the excitation coil 1612 and extend outwardly to the coin 1614. The magnetic fields penetrate the coin 614 as the coin 614 is moved proximate to the excitation coil 1612, and eddy currents are induced in the coin 1614 as it moves through the alternating magnetic fields. The strength of the eddy currents flowing in the coin 1614 is dependent on the material composition of the coin, and particularly the electrical resistance of that material. Resistance affects how much current will flow in the coin 1614 according to Ohm's Law. Another characteristic by which the material composition of a coin is measured is conductivity according to the IACS scale, for example, which defines copper has having a conductivity of 100%.

The eddy currents themselves also produce corresponding magnetic fields. A proximal detector coil 1622 and a distal detector coil 1624 are disposed relative to the coin 1614 so that the eddy current-generated magnetic fields induce voltages upon the coils 1622, 1624. The distal detector coil 1624 is positioned above the coin 1614, and the proximal detector coil 1622 is positioned between the distal detector coil 1624 and the passing coin 1614.

In one embodiment, the excitation coil 1612, the proximal detector coil 1622 and the distal detector coil 1624 are all wound in the same direction (either clockwise or counterclockwise). The proximal detector coil 1622 and the distal detector coil 1624 are wound in the same direction so that the voltages induced on these coils by the eddy currents are properly oriented. As shown in FIG. 17, the proximal detector coil 1622 is wound around the second wire recess 1510 of the bobbin 1500 and is bounded by the bottom retaining layer 1504 and the projection 1506. The distal detector coil 1624 is wound around the first wire recess 1508 of the bobbin 1500 and is bounded by the top retaining layer 1502 and the projection 1506. Finally, the excitation coil 1612 is wound around the proximal detector coil 1622, the distal detector coil 1624, and the projection 1506, and is bounded by the top retaining layer 1502 and the bottom retaining layer 1504.

The length dimension of the proximal detector coil 1622 once wound around the bobbin 1500 is substantially equal to the length dimension of the distal detector coil 1624 once wound around the bobbin 1500, which dimensions substantially correspond to the length of the projection 1506 of the bobbin 1500. In one embodiment, the length dimensions of the proximal and distal detector coils 1622, 1624 are longer than the diameter of the largest coin to be processed. Because the magnetic fields radiate slightly beyond the length dimensions of the coils 1622, 1624, in another embodiment, the length dimensions of the coils 1622, 1624 are about the same as the diameter of the largest coin to be processed. In both embodiments, passing coins of varying diameters create unique disruptions in the magnetic fields so as to induce distinctive eddy currents in each coin depending on its diameter.

An exploded diagrammatic perspective view of the coils 1612, 1622, 1624 of the coil discrimination sensor 1610 is shown in FIG. 19 . Note that the number of windings and the shape of the coils 1612, 1622, 1624 are not shown to scale for ease of illustration.

The proximal detector coil 1622 has a starting end 1626 and a finish end 1628. Similarly, the distal detector coil 1624 has a starting end 1630 and a finish end 1632. In order of increasing distance from the coin 1614, the detector coils 1622, 1624 are positioned as follows: finish end 1628 of the proximal detector coil 1622, start end 1626 of the proximal detector coil 1622, finish end 1632 of the distal detector coil 1624 and start end 1630 of the distal detector coil 1624. As shown in FIGS. 18 and 19, the finish end 1628 of the proximal detector coil 1622 is connected to the finish end 1632 of the distal detector coil 1624 via a conductive wire 1634. It will be appreciated by those skilled in the art that other detector coil 1622, 1624 combinations are possible. For example, in an alternative embodiment the proximal detector coil 1622 is wound in the opposite direction of the distal detector coil 624. In such an embodiment, the start end 1626 of the proximal coil 1622 would be connected to the finish end 1632 of the distal coil 1624.

Eddy currents in the coin 1614 induce voltages V_{prox} and V_{dist} respectively on the detector coils 1622, 1624. Likewise, the excitation coil 1612 also induces a common-mode voltage on each of the detector coils 1622, 1624. The common-mode voltage is effectively the same on each detector coil due to the symmetry of the detector coils' physical arrangement within the excitation coil 1612. Because the detector coils 1622, 1624 are wound and physically oriented in the same direction and connected at their finish ends 1628, 1632, the common-mode voltage induced by the excitation coil 1612 is subtracted out, leaving only a difference voltage V_{diff} corresponding to the eddy currents in the coin 1614. Thus, the need for additional circuitry to subtract out the common-mode voltage is eliminated. The common-mode voltage is effectively subtracted out because both the distal detector coil 1624 and the proximal detector coil 1622 receive the same level of induced voltage from the excitation coil 1612.

Unlike the common-mode voltage, the voltages induced by the eddy current in the detector coils 1622, 1624 are not effectively the same because the proximal detector coil 1622 is positioned closer to the passing coin than the distal detector coil 1624. Thus, the voltage induced in the proximal detector coil 1622 is significantly stronger, i.e. has greater amplitude, than the voltage induced in the distal detector coil 1624. Although the present invention subtracts the eddy current-induced voltage on the distal coil 1624 from the eddy current-induced voltage on the proximal coil 1622, the voltage amplitude difference is sufficiently great to permit detailed resolution of the eddy current response.

As shown in FIG. 17, the excitation coil 1612 is surrounded by a magnetic shield 1644. The magnetic shield 1644 has a high level of magnetic permeability in order to help contain the magnetic fields surrounding the excitation coil 1612. The magnetic shield 1644 advantageously prevents stray magnetic fields from interfering with other nearby eddy current sensors. The magnetic shield 1644 is not a closed cylinder and has a small longitudinal air gap so that it does not act as a shorter turn of conducting material that absorbs the electrical energy and prevents it from forming a useful magnetic field. The magnetic shield 1644 is itself optionally surrounded by an outer case 1646 made of, for example, steel. Optionally, the magnetic shield 1644 and/or the outer case 1646 may be extended to surround the bottom retaining layer 1504 and/or the top retaining layer 1502 of the bobbin 1500.

To form the coin discrimination sensor 1610, the detector coils 1622, 1624 are wound on the bobbin 1500. Both the proximal detector coil 1622 and the distal detector coil 1624 have 350 turns of #44 AWG enamel-covered magnet wire wound to generally uniformly fill the available spaces as described above. Each of the detector coils 1622, 1624 are wound in the same direction with the finish ends 1628, 1632 and are connected together by the conductive wire 1634. The start ends 1626, 1630 of the detector coils 1622, 1624 are connected to separately identified wires in a connecting cable. The excitation coil 1612 is wound with 135 turns of #42 AWG enamel-covered magnet wire in the same direction as the detector coils 1622, 1624. An excitation coil voltage 1620 is applied across the start end 1616 and the finish end 1618.

In one embodiment, the coin discrimination sensor 1610 is calibrated such that common-mode voltage is subtracted out when no coin is present (hereafter referred to as the "nominal" condition). The coin discrimination sensor 1610 is connected to a test oscillator (not shown) which applies the excitation voltage to the excitation coil 1612. The position of the excitation coil 1612 is adjusted along the axis of the coil to give a null response from the detector coils 1622, 1624 on an a-c. voltmeter with no metal near the coil windings. Optionally, the magnetic shield 1644 is positioned over the excitation coil 1612 and the position of the excitation coil 1612 is again adjusted to give a null response from the detector coils 1622, 1624.

The magnetic shield 1644 and coils 1612, 1622, 1624 within the magnetic shield 1644 are optionally placed in the outer case 1646 and encapsulated with a polymer resin (not shown) to "freeze" the position of the magnetic shield 1644 and coils 1612, 1622, 1624.

After curing the resin, an end of the coin discrimination sensor 1610 nearest the proximal detector coil 1622 is sanded and lapped to produce a flat and smooth surface with the coils 1612, 1622 slightly recessed within the resin.

The voltage 1620 applied to the excitation coil 1612 causes current to flow in the coil 1612 which lags behind the voltage 1620. For example, the current may lag the voltage 1620 by about 90 degrees. In effect, the eddy currents of the coin 614 impose a resistive loss on the current in the excitation coil 1612. Because the voltage 1620 has two frequency components, e.g., a 30 KHz component and a 480 KHz component in one embodiment, each frequency component will have a phase and amplitude characteristic associated therewith, resulting in four parameters associated with a detection signal from the detector coils 1622, 1624, i.e., the phase and amplitude of the 30 KHz component and the phase and amplitude of the 480 KHz component. These four parameters can be varied based upon three characteristics of a coin – composition, thickness, and diameter. The parameters for each coin are unique, and each coin signature is characterized by the values of these four parameters, such as graphically illustrated in FIGS. 24 and 25, discussed below.

FIGS. 20-23 graphically illustrate various waveforms which are generated according to one embodiment of the present invention. FIG. 20 is waveform of an excitation signal, such as the one outputted in FIG. 14 by the high frequency driver 1316. The waveform is 10 volts peak-to-peak with a -5 volt minimum and +5 volt maximum. The waveform is a composite waveform comprised of a 30 KHz frequency component and a 480 KHz frequency component. Each of the 30 KHz and 480 KHz frequency components have a phase of 0 degrees and an amplitude of 2.0.

FIG. 21 illustrates a waveform of a detection signal when no coin is present (nominal condition). The 30 KHz frequency component has a phase of about 74 degrees and an amplitude of about 0.687, and the 480 KHz frequency component has a phase of about 38 degrees and an amplitude of about 0.482.

FIG. 22 is a waveform of a detection signal when a 5 cent coin is present. The 5 cent is comprised of a copper alloy, and therefore has a relatively high conductivity. The 30 KHz frequency component has a phase of about 78 degrees and an amplitude of about 0.787, and the 480 KHz frequency component has a phase of about 44 degrees and an amplitude of about 0.433.

FIG. 23 illustrates the waveforms shown in FIGS. 21 and 22 superimposed one over the other. Waveform 700 corresponds to a detection signal when no coin is present, and waveform 702 corresponds to a detection signal when a 5 cent coin is present.

Turning now to FIGS. 24 and 25, the amplitude values corresponding to each coin in a coin set are plotted on a chart. As is shown, each coin in the coin set generates a unique set of four values corresponding to each coin. Note that, for example, although the 480 KHz sine and cosine amplitudes for the 5 cent coin and the 2 Euro coin are relatively close in value (FIG. 25), the 30 KHz sine and cosine amplitude values for the same coins are significantly disparate (FIG. 24). By detecting coins according to three variables--composition, thickness, and diameter – the present invention reduces the probability that two different coins will generate the same coin signatures (i.e., have the same four values within a predetermined tolerance). Thus, the present invention offers a significant advantage over discrimination sensors that process coins based on an excitation signal oscillating at a single frequency, because such sensors are more likely to generate identical coin signatures for different coins.

It is understood that the coin set has been selected for illustrative purposes, and it will be appreciated that the present invention is not limited to processing the selected coins only. Rather, the discrimination sensor of the present invention may be employed to process any coin set, which may include any combination of coins and/or tokens.

FIG. 26 illustrates yet another embodiment of a coin discrimination system 800 having a coin discrimination sensor 1802 with only two coils L1 and L2 in a configuration commonly referred to as a Wheatstone bridge. A dual-frequency driver 1804 drives the inputs to the coils L1 and L2. In one embodiment, the dual-frequency driver 1804 may include the 30 KHz DDS sine wave generator 1308, the 480 KHz DDS sine wave generator, the combiner 1314, and the high frequency driver 1316 shown in FIG. 14. In another embodiment, the dual-frequency driver 1804 may include the 30 KHz sine wave generator 406, the 480 KHz sine wave generator 1408, the combiner 1410, and the buffer 1412 shown in FIG. 15. In a specific embodiment, the coils L1 and L2 have an impedance of 150 μH. For maximum sensitivity, the values of R1 and R2 should be 28.3 ohms at 30 KHz to have the same impedance as 150 μH. Similarly, the values of R1 and R2 should be 452 ohms at 480 KHz to have the same impedance as 150 μH. Therefore, for maximum sensitivity, the values of R1 and R2 shown in FIG. 26 are 113 ohms, which represents the geometric mean of 28.3 ohms and 452 ohms. As is known, maximum sensitivity is achieved when the impedance levels of the resistors R1 and R2 match the inductive reactance of the coils L1 and L2.

The outputs of the coils L1 and L2 are provided to a differential amplifier 1806. Preferably, the differential amplifier 1806 has a high common-mode rejection ratio (CMRR). As is known, a high CMRR differential amplifier results in a small or negligible output signal when a zero differential voltage is applied across its input. In a specific embodiment, the differential amplifier 1806 is an LT-1630 manufactured by Linear Technology. In a specific embodiment, the values of R3, R4, R5, and R6 are 1000 ohms accurate to within a +/- 0.1% tolerance.

The output of the differential amplifier 1806 is provided to a controller 1808. In alternate embodiments, the output of the differential amplifier 1806 may be provided to the ADC 1324 shown in FIG. 14 or to the high bandpass filter 1420 and low bandpass filter 1422 shown in FIG. 15, and processed in accordance with the associated circuitry shown in FIGS. 14 and 15.

FIG. 27 is a cross-sectional view of a coin discrimination sensor 1920 according to the embodiment shown in FIG. 26. The coin discrimination sensor 1920 of FIG. 27 lacks the excitation coil 1612 of the coin discrimination sensor 1610 shown in FIG. 24. The coin discrimination sensor 1920 includes a bobbin 1900, a magnetic shield 1944, and optionally an outer case 1946. The bobbin 1900 includes a top retaining layer 1902, a bottom retaining layer 1904, a projection 1906, a first wire recess 1908, and a second wire recess 1910. A proximal detector coil 1922 is wound around the second wire recess 1910, and a distal detector coil 1924 is wound around the first wire recess 1908. The proximal detector coil 1922 and the distal detector coil 1924 correspond to the coils L1 and L2 shown in FIG. 26.

When a coin 1914 passes by the coin discrimination sensor 1920, the magnetic fields associated with the proximal detector coil 1922 and the distal detector coil 1924 will be disturbed differently, resulting in a voltage differential across the differential amplifier 1806 shown in FIG. 26. The frequency components of the signal from the differential amplifier 1806 are then analyzed separately and compared against known coin signature values and/or formulae in a lookup table as described above.

Although the above-described coin discrimination sensor of the present invention can be used in a variety of devices, it is particularly useful in high-speed coin sorters of the disc type. Thus, the coin sensor of the present invention has been described with specific reference to the use of disc-type coin sorters as an exemplary device in which the coin discrimination sensor is utilized. However, it is expressly understood that the coin discrimination sensor of the present invention may be used in any device which requires that coins be discriminated.

In addition to embodiments described above and in the accompanying claims, several embodiments of the present inventions will now be described.

Alternative Embodiment A1

A1. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a queuing channel and at least two exit channels for sorting and discharging coins, the queuing channel having an interior wall against which coins abut when moving toward the exit channels, the queuing channel having a first segment for receiving coins from an input coin region and a second segment disposed in a position that is substantially more in direction of movement of the rotatable disc positioned thereunder than the first segment to create an increased spacing between adjacent coins, the discriminator being located in the queuing region, the lower surface having a reject region between the first segment of the queuing region and the plurality of exit channels;

a sensor for differentiating between valid and invalid coins;

a diverter disposed toward an end of the second segment, the diverter being moveable between a first position wherein coins remain abutted against the wall for proceeding toward the at least two exit channels and a second position for diverting coins away from the interior wall to the reject region; and a controller communicatively coupled to the sensor, the controller moving the diverter from the first position to the second position in response to the sensor detecting an invalid coin.

Alternative Embodiment A2

A2. The coin processing system of Alternate Embodiment A1, further including a gauging channel for aligning outer edges of the coins along a gauging wall immediately prior to the at least two exit channels.

Alternative Embodiment A3

A3. The coin processing system of Alternate Embodiment A2, further including a transition area between the gauging channel and the queuing channel to allow coins to move from an interior wall within the queuing channel to the gauging wall within the gauging channel.

Alternative Embodiment A4

A4. The coin processing system of Alternate Embodiment A3, wherein the coins are under pressure between the rotatable disc and the sorting head when moving through the transition area.

Alternative Embodiment A5

A5. The coin processing system of Alternate Embodiment A3, wherein the coins are under no pressure when moving through the transition area.

Alternative Embodiment A6

A6. The coin processing system of Alternate Embodiment A1, wherein the reject region includes a reject slot into which coins are diverted by the diverter.

Alternative Embodiment A7

A7. The coin processing system of Alternate Embodiment A6, wherein the reject slot leads coins to a periphery of the sorting head.

Alternative Embodiment A8

A8. The coin processing system of Alternate Embodiment A7, wherein the reject slot has a length of no more than about three times the diameter of the smallest authentic coin to be processed.

Alternative Embodiment A9

A9. The coin processing system of Alternate Embodiment A1, wherein the rotatable disc includes a pad, the coins being under pad pressure when moving through the queuing region.

Alternative Embodiment A10

A10. The coin processing system of Alternate Embodiment A1, wherein the queuing region includes an inner wall against which the coins abut and has, in a cross-sectional view, a stepped profile that defines a first edge and a second edge, the first edge being closer to the inner wall than the second edge.

Alternative Embodiment A11

A11. The coin processing system of Alternate Embodiment A10, wherein inner edges of the coins engage the inner wall, coins of a smaller diameter engaging the first edge, coins of a larger diameter engaging the second edge.

Alternative Embodiment A12

A12. The coin processing system of Alternate Embodiment A11, wherein the coins remain under pressure between the rotatable disc and the sorting head while moving along the first edge and the second edge.

Alternative Embodiment A13

A13. The coin processing system of Alternate Embodiment A1, wherein the queuing region terminates at a location adjacent to a periphery of the rotatable disc.

Alternative Embodiment A14

A14. The coin processing system of Alternate Embodiment A1, wherein the sensor determines the denomination of each valid coin, the controller determining the value of the coins being processed based on input from the sensor.

Alternative Embodiment A15

A15. The coin processing system of Alternate Embodiment A1, wherein the at least two exit channels includes in exit channel for each available denomination to be sorted.

Alternative Embodiment A16

A16. The coin processing system of Alternate Embodiment A15, further including a counting sensor in each of the exit channels, the counting sensors being coupled to the controller, the controller determining the value of the coins being processed based on inputs received from the counting sensors.

Alternative Embodiment A17

A17. The coin processing system of Alternate Embodiment A1, further including a trigger sensor positioned immediately upstream from the sensor, the sensor being activated to determine characteristics of a particular coin in response to the expiration of a certain time period occurring after the trigger sensor detects the particular coin.

Alternative Embodiment A18

A18. The coin processing system of Alternate Embodiment A1, wherein the diverter includes a voice coil for high speed activation.

Alternative Embodiment A19

A19. The coin processing system of Alternate Embodiment A1, wherein the coins are aligned along an inner wall of the second segment of the queuing region, the diverter being immediately adjacent to the inner wall for causing coins to be diverted away from the inner wall and toward the reject region.

Alternative Embodiment A20

A20. The coin processing system of Alternate Embodiment A19, wherein the second segment of the queuing channel includes a coin engaging surface immediately adjacent to the inner wall, the reject region including a reject slot that is immediately adjacent to the coin engaging surface.

Alternative Embodiment A21

A21. The coin processing system of Alternate Embodiment A20, wherein the coin engaging surface has a width measured in a radial direction that is approximately the width of the diverter when the diverter is in the second position.

Alternative Embodiment A22

A22. The coin processing system of Alternate Embodiment A21, wherein the diverter is a diverting pin that protrudes downwardly from the coin engaging surface.

Alternative Embodiment A23

A23. The coin processing system of Alternate Embodiment A1, wherein the discriminator determines a metal content and a dimension of the coins.

Alternative Embodiment A24

A24. The coin processing system of Alternate Embodiment A1, wherein the diverter is actuated by a solenoid.

Alternative Embodiment A25

A25. The coin processing system of Alternate Embodiment A1, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A26

A26. The coin processing system of Alternate Embodiment A1, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A27

A27. The coin processing system of Alternate Embodiment A26, wherein the angle is about 100 degrees.

Alternative Embodiment A28

A28. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a sensor for differentiating between valid and invalid coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a queuing channel and a plurality of exit channels for sorting and discharging coins of particular denominations, the queuing channel having a first segment for receiving coins and a second segment for moving the coins past the sensor, the queuing channel being configured to move coins at a faster rate along the second segment for increasing the spacing between adjacent coins;

a diverter disposed along the second segment beyond the sensor, the diverter being moveable between a first position permitting coins to proceed to the plurality of exit channels and a second position for diverting coins to a reject region; and

a controller for moving the diverter from the first position to the second position when the sensor detects an invalid coin.

Alternative Embodiment A29

A29. The coin processing system of Alternate Embodiment A28, wherein the reject region includes a reject slot into which coins are diverted by the diverter.

Alternative Embodiment A30

A30. The coin processing system of Alternate Embodiment A26, wherein the reject slot leads coins to a periphery of the sorting head.

Alternative Embodiment A31

A31. The coin processing system of Alternate Embodiment A28, wherein the coins are aligned along an inner wall of the second segment of the queuing region, the diverter being disposed immediately adjacent to the inner wall for causing coins to be diverted away from the inner wall and toward the reject region.

Alternative Embodiment A32

A32. The coin processing system of Alternate Embodiment A28, wherein the diverter includes a voice coil for high speed activation.

Alternative Embodiment A33

A33. The coin processing system of Alternate Embodiment A28, wherein the queuing region includes an inner wall against which the coins abut and has, in a cross-sectional view, a stepped profile that defines a first edge and a second edge, the first edge being closer to the inner wall than the second edge.

Alternative Embodiment A34

A34. The coin processing system of Alternate Embodiment A33, wherein inner edges of the coins engage the inner wall, coins of a smaller diameter engaging the first edge, coins of a larger diameter engaging the second edge.

Alternative Embodiment A35

A35. The coin processing system of Alternate Embodiment A34, wherein the coins remain under pressure between the rotatable disc and the sorting head while moving along the first edge and the second edge.

Alternative Embodiment A36

A36. The coin processing system of Alternate Embodiment A33, wherein the stepped profile of the queuing region transitions to a substantially flat profile.

Alternative Embodiment A37

A37. The coin processing system of Alternate Embodiment A28, wherein the diverter is actuated by a solenoid.

Alternative Embodiment A38

A38. The coin processing system of Alternate Embodiment A28, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A39

A39. The coin processing system of Alternate Embodiment A28, wherein the first segment is disposed at an angle of 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A40

A40. The coin processing system of Alternate Embodiment A39, wherein the angle is about 100 degrees.

Alternative Embodiment A41

A41. A method for processing coins, comprising:

receiving coins in a coin receiving area;

moving coins along a queuing region after the coin receiving area, the queuing region including a first segment and a second segment of the queuing region;

creating additional spacing between adjacent coins as the coins transition from the first segment to the second segment;

determining the authenticity of each of the coins passing through the second segment; and

diverting non-authentic coins away from a coin path leading to a discharge region for authentic coins at a point upstream from the discharge region.

Alternative Embodiment A42

A42. The method of Alternate Embodiment A41, wherein the diverting includes activating a voice coil in response to the step of determining.

Alternative Embodiment A43

A43. The method of Alternate Embodiment A41, wherein the creating additional spacing includes moving coins along the second segment at a higher rate to speed.

Alternative Embodiment A44

A44. The method of Alternate Embodiment A41, wherein the discharge region includes a plurality of coin exit channels, the method further including the step of sorting coins of each denomination into a corresponding one of the plurality of coin exit channels.

Alternative Embodiment A45

A45. The method of Alternate Embodiment A44, wherein the plurality of coin exit channels are of different dimensions.

Alternative Embodiment A46

A46. The method of Alternate Embodiment A41, wherein the steps of moving, creating, determining and diverting are performed while the coins are located between a rotatable disc and a stationary sorting head.

Alternative Embodiment A47

A47. The method of Alternate Embodiment A41, wherein the step of diverting occurs along the second segment.

Alternative Embodiment A48

A48. The method of Alternate Embodiment A41, wherein the coins being processed move at a constant operational speed during the steps of determining and diverting.

Alternative Embodiment A49

A49. A method for processing coins, comprising;

receiving coins in a coin receiving region;

imparting motion to the coins with a rotatable disc;

engaging the coins with a stationary sorting head during the step of imparting motion;

increasing the spacing between adjacent coins in a queuing region of the sorting head;

determining the authenticity of each of the coins after the step of increasing the spacing;

diverting non-authentic ones of the coins to a coin reject region; and

moving authentic ones of the coins to a coin discharge region at a location that is beyond the coin reject region.

Alternative Embodiment A50

A50. The method of Alternate Embodiment A49, wherein the queuing region includes a first segment and a second segment, the second segment being arranged in a position on the sorting head that is more in alignment with the direction of movement of the rotatable disc than the first segment, the second segment providing the step of increasing the spacing between adjacent coins.

Alternative Embodiment A51

A51. The method of Alternate Embodiment A49, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A52

A52. The method of Alternate Embodiment A51 wherein the angle is about 100 degrees.

Alternative Embodiment A53

A53. The method of Alternate Embodiment A49, wherein the diverting includes activating a voice coil in response to the step of determining.

Alternative Embodiment A54

A54. The method of Alternate Embodiment A49, wherein the diverting includes activating a solenoid in response to the step of determining.

Alternative Embodiment A55

A55. The method of Alternate Embodiment A49, wherein the step of moving authentic ones of the coins occurs while the coins are under pressure between the rotatable disc and the sorting head.

Alternative Embodiment A56

A56. The method of Alternate Embodiment A49, wherein the step of determining occurs within the queuing region.

Alternative Embodiment A57

A57. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface of the sorting head forming a queuing channel and at least one coin exit channel for discharging coins, the queuing channel having a first segment for receiving coins from an input coin region and a second segment disposed in a position that is substantially more in direction of movement of the rotatable disc positioned immediately thereunder than the first segment to create an increased spacing between adjacent coins as the coins move toward the at least one exit channel;

a sensor disposed along the at least one coin exit channel for differentiating between valid and invalid coins as each of the coins passing through the at least one coin exit channel;

at least one diverter disposed outside the periphery of the sorting head for receiving coins discharged from the at least one coin exit channel, the diverter being movable between a first position for directing coins into a first area and a second position for directing coins into a second area; and

a controller for controlling the movement of the at least one diverter and the movement of the rotatable disc, the controller causing the diverter to move to the first position when a coin is determined to be valid, the controller causing the diverter to move to the second position when a coin is determined to be invalid, wherein the increased spacing between adjacent coins permits the controller to maintain the rotatable disc at a substantially constant operating speed when causing the diverter to move between the first position and the second position.

Alternative Embodiment A58

A58. The coin processing system of Alternate Embodiment A57, wherein the diverter includes a voice coil providing high-speed switching between the first position and the second position, the voice coil providing a force in both directions of movement toward the first and second positions.

Alternative Embodiment A59

A59. The coin processing system of Alternate Embodiment A58, wherein the voice coil provides at least about 20 pounds of force in both directions.

Alternative Embodiment A60

A60. The coin processing system of Alternate Embodiment A58, wherein the voice coil undergoes a displacement of at least about 1/8 inch in about 1.3 millisecond.

Alternative Embodiment A61

A61. The coin processing system of Alternate Embodiment A58, wherein the voice coil provides high-speed switching at a speed of at about 0.1 inch per millisecond.

Alternative Embodiment A62

A62. The coin processing system of Alternate Embodiment A58, wherein the voice coil maintains a diverting structure at the first position until activation to the second position is necessary and maintains the diverting structure at the second position until activation to the first position is necessary.

Alternative Embodiment A63

A63. The coin processing system of Alternate Embodiment A57, wherein the at least one exit channel is exactly one exit channel.

Alternative Embodiment A64

A64. The coin processing system of Alternate Embodiment A57, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A65

A65. The coin processing system of Alternate Embodiment A64, wherein the angle is about 100 degrees.

Alternative Embodiment A66

A66. The coin processing system of Alternate Embodiment A57, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A67

A67. The coin processing system of Alternate Embodiment A57, wherein the diverter includes a solenoid for switching between the first position and the second position.

Alternative Embodiment A68

A68. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface of the sorting head forming a queuing channel and two coin exit stations for receiving coins having different characteristics, the queuing channel having a first segment for receiving coins from an input coin region and a second segment disposed in a position that is substantially more in direction of movement of the rotatable disc positioned immediately thereunder than the first segment to create an increased spacing between adjacent coins;

a sensor disposed along the queuing channel for obtaining information from each of the coins for differentiating between valid and invalid coins as the coins move through the queuing channel;

a diverter disposed at an end of the second segment for directing coins between the two exit stations based on information obtained by the sensor, the diverter moving at a rate that allows the rotatable disc to maintain a substantially constant operational speed while the diverter directs coins between the two exit stations channels.

Alternative Embodiment A69

A69. The coin processing system of Alternate Embodiment A68, wherein the sensor is located at a beginning portion of the second segment.

Alternative Embodiment A70

A70. The coin processing system of Alternate Embodiment A68, wherein the first and second exit stations are first and second exit channels, respectively, the first exit channel being in general alignment with the second segment of the queuing channel, the diverter directing coins away from the first exit channel and into the second exit channel.

Alternative Embodiment A71

A71. The coin processing system of Alternate Embodiment A68, wherein the first and second exit stations are located at an end portion of an exit channel, the diverter being at the end portion of an exit channel and deflecting coins toward one of the first and second exit stations.

Alternative Embodiment A72

A72. The coin processing system of Alternate Embodiment A68, wherein the diverter includes a voice coil providing high-speed switching between the first position and the second position, the voice coil providing a force in both directions of movement toward the first and second positions.

Alternative Embodiment A73

A73. The coin processing system of Alternate Embodiment A72, wherein the force is at least about 20 pounds of force in both directions.

Alternative Embodiment A74

A74. The coin processing system of Alternate Embodiment A73, wherein the voice coil undergoes a displacement of at least about 1/8 inch in about 1.3 milliseconds.

Alternative Embodiment A75

A75. The coin processing system of Alternate Embodiment A68, wherein the characteristics include metal content, thickness and diameter.

Alternative Embodiment A76

A76. The coin processing system of Alternate Embodiment A75, wherein the coin processing system discriminates between two coin sets, each coin set being distributed to a corresponding one of the two exit stations.

Alternative Embodiment A77

A77. The coin processing system of Alternate Embodiment A76, further including a controller for determining a value of each coin set that is distributed to the two exit stations.

Alternative Embodiment A78

A78. The coin processing system of Alternate Embodiment A68, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A79

A79. The coin processing system of Alternate Embodiment A78, wherein the angle is about 100 degrees.

Alternative Embodiment A80

A80. The coin processing system of Alternate Embodiment A68, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A81

A81. The coin processing system of Alternate Embodiment A68, wherein the diverter includes a solenoid for switching between the first position and the second position.

Alternative Embodiment A82

A82. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface of the sorting head forming a queuing channel and an exit channel for receiving the coins, the queuing channel having a first segment for receiving coins from an input coin region and a second segment disposed in a position that is substantially more in direction of movement of the rotatable disc positioned immediately thereunder than the first segment to create an increased spacing between adjacent coins;

a discrimination sensor disposed along the queuing channel for detecting characteristics of the coins moving through the queuing channel;

a diverter disposed outside the periphery of the sorting head in a path of the coin exit channel for receiving coins discharged from the corresponding exit channel, each of the diverters being movable between a first position for receiving the coins having a certain characteristic detected by the discrimination sensor and a second position for receiving all other coins, the diverter moveable between the first and the second position in a time that is less than the time required for a coin to move a distance corresponding to the increased spacing.

Alternative Embodiment A83

A83. The coin processing system of Alternate Embodiment A82, wherein the diverter includes a voice coil providing high-speed switching between the first position and the second position, the voice coil providing a force in both directions of movement toward the first and second positions.

Alternative Embodiment A84

A84. The coin processing system of Alternate Embodiment A83, wherein the force is at least about 20 pounds of force in both directions.

Alternative Embodiment A85

A85. The coin processing system of Alternate Embodiment A83, wherein the voice coil undergoes a displacement of at least about 1/8 inch in about 1.3 milliseconds.

Alternative Embodiment A86

A86. The coin processing system of Alternate Embodiment A83, wherein the voice coil maintains a diverting structure at the first position until activation to the second position is necessary and maintains the diverting structure at the second position until activation to the first position is necessary.

Alternative Embodiment A87

A87. The coin processing system of Alternate Embodiment A82, wherein the diverter includes a solenoid for moving the diverting between the first position and the second position.

Alternative Embodiment A88

A88. The coin processing system of Alternate Embodiment A83, wherein the rotatable disc includes a pad and the coins are under pad pressure while moving past the discrimination sensor.

Alternative Embodiment A89

A89. The method of Alternate Embodiment A82, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A90

A90. The method of Alternate Embodiment A89 wherein the angle is about 100 degrees.

Alternative Embodiment A91

A91. The coin processing system of Alternate Embodiment A82, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A92

A92. A coin processing machine for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a queuing channel and a coin exit station, the queuing channel having an interior wall against which the coins abut, the queuing channel having a first segment for receiving coins and aligning the coins along the interior wall and a second segment for moving the coins to an outer periphery of the sorting head such that a portion of each coin extends beyond the outer periphery;

an optical sensor disposed outside the periphery of the sorting head for obtaining optical information from the portion of each coin extending beyond the periphery of the sorting head;

a diverter disposed toward an end of the second segment, the diverter being moveable between a first position wherein coins remain along a coin path toward the coin exit station and a second position for diverting coins to a reject station; and

a controller for moving the diverter from the first position to the second position in response to the optical information obtained by the optical sensor indicating a coin should not proceed to the coin exit station.

Alternative Embodiment A93

A93. The coin processing machine of Alternate Embodiment A92, wherein the second segment creates an increased spacing between adjacent coins.

Alternative Embodiment A94

A94. The coin processing machine of Alternate Embodiment A92, wherein the information from the optical sensor determines the authenticity of each coin.

Alternative Embodiment A95

A95. The coin processing machine of Alternate Embodiment A94, wherein the optical information from the optical sensor determines the denomination of each coin.

Alternative Embodiment A96

A96. The coin processing machine of Alternate Embodiment A92, wherein the information from the optical sensor determines that denomination of each coin.

Alternative Embodiment A97

A97. The coin processing machine of Alternate Embodiment A92, wherein the exit station includes a plurality of exit channels for sorting coins into particular denominations.

Alternative Embodiment A98

A98. The coin processing machine of Alternate Embodiment A97, wherein the sorting head includes a gauging channel for aligning coins along a common radius prior to the plurality of exit channels.

Alternative Embodiment A99

A99. The coin processing machine of Alternate Embodiment A92, wherein the diverter includes a voice coil.

Alternative Embodiment A100

A100. The coin processing machine of Alternate Embodiment A92, wherein the diverter includes a solenoid.

Alternative Embodiment A101

A101. The coin processing machine of Alternate Embodiment A92, wherein the reject station includes a reject slot leading from the diverter to a periphery of the sorting head.

Alternative Embodiment A102

A102. The coin processing machine of Alternate Embodiment A92, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A103

A103. The coin processing machine of Alternate Embodiment A102 wherein the angle is about 100 degrees.

Alternative Embodiment A104

A104. The coin processing machine of Alternate Embodiment A92, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A105

A105. A coin processing machine for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a coin path leading to a coin exit station at which coins are discharged, the coin path moving the coins toward an outer periphery such that a portion of each coin extends beyond the outer periphery;

an optical sensor for obtaining optical information from the portion of each coin extending beyond the outer periphery;

a diverter disposed downstream of the optical sensor, the diverter being moveable between a first position allowing coins to remain on the coin path and a second position for diverting coins toward a reject station; and

a controller for moving the diverter from the first position to the second position in response to the optical information obtained by the optical sensor indicates a certain coin should not proceed to the coin exit station.

Alternative Embodiment A106

A106. The coin processing machine of Alternate Embodiment A105, wherein the exit station includes a plurality of exit channels for sorting coins into particular denominations.

Alternative Embodiment A107

A107. The coin processing machine of Alternate Embodiment A106, wherein the sorting head includes a gauging channel for aligning coins along a common radius prior to the plurality of exit channels.

Alternative Embodiment A108

A108. The coin processing machine of Alternate Embodiment A105, wherein the optical information from the optical sensor determines the authenticity of each coin.

Alternative Embodiment A109

A109. The coin processing machine of Alternate Embodiment A108, wherein the information from the optical sensor determines that denomination of each coin.

Alternative Embodiment A110

A110. The coin processing machine of Alternate Embodiment A105, wherein the information from the optical sensor determines that denomination of each coin.

Alternative Embodiment A111

A111. The coin processing machine of Alternate Embodiment A105, wherein the reject station includes a reject slot leading from the diverter to a periphery of the sorting head.

Alternative Embodiment A112

A112. The coin processing machine of Alternate Embodiment A105, wherein the diverter includes a voice coil.

Alternative Embodiment A113

A113. The coin processing machine of Alternate Embodiment A105, wherein the diverter includes a solenoid.

Alternative Embodiment A114

A114. The coin processing machine of Alternate Embodiment A105, wherein the sorting head provides for an increased spacing between adjacent coins before the coins encountered the sensor.

Alternative Embodiment A115

A115. The coin processing machine of Alternate Embodiment A114, wherein the coin path includes a queuing region having a first and second segment, the second segment being positioned in a direction that is more in alignment with a direction of movement of the rotatable disc, the transition between the first segment and the second segment providing the increased spacing.

Alternative Embodiment A116

A116. The coin processing machine of Alternate Embodiment A115, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A117

A117. The coin processing machine of Alternate Embodiment A116, wherein the angle is about 100 degrees.

Alternative Embodiment A118

A118. The coin processing system of Alternate Embodiment A115, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A119

A119. A method of processing coins, comprising:

receiving the coins in a coin receiving region;

imparting motion to the coins with a rotatable disc;

engaging the coins with a stationary sorting head during the step of imparting motion;

moving coins along a coin path within the stationary sorting head, a portion of the coin path being adjacent to a periphery of the sorting head causing a portion of each coin to be exposed outside of the sorting head;

optically sensing the portion of each coin while exposed outside of the sorting head; and

moving at least some of the coins to a coin exit station after optical sensing.

Alternative Embodiment A120

A120. The method of Alternate Embodiment A119, wherein the sensing includes determining the authenticity of each of the coins.

Alternative Embodiment A121

A121. The method of Alternate Embodiment A119, further including diverting non-authentic ones of the coins to a coin reject region after the step of sensing.

Alternative Embodiment A122

A122. The method of Alternate Embodiment A119, further including sorting authentic ones of the coins in a plurality of coin exit channels located within the coin exit station.

Alternative Embodiment A123

A123. The method of Alternate Embodiment A119, further including increasing the spacing between adjacent coins prior to the step of sensing.

Alternative Embodiment A124

A124. The method of Alternate Embodiment A119, wherein the step of sensing includes determining the denomination of each coin.

Alternative Embodiment A125

A125. The method of Alternate Embodiment A119, wherein less than half a diameter of each of the coins is exposed.

Alternative Embodiment A126

A126. A coin processing machine for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface of the sorting head having formed therein a gauging channel for aligning the coins along a common radius and a plurality of exit channels for discharging coins, the gauging region having an interior wall against which the coins abut, each of the exit channels having substantially the same width;

a sensor for obtaining information indicative of the denomination of each of the coins from each of the coins;

a plurality of diverters disposed along the interior wall of the gauging channel, each of the plurality of diverters corresponding to one of the plurality of exit channels, each of the plurality of diverters being movable between a first position wherein coins remain abutted again the interior and a second position wherein coins are diverted to the corresponding exit channel; and

a controller for selectively controlling the movement of each of the diverters between the first and second positions in response to input from the sensor.

Alternative Embodiment A127

A127. The coin processing machine of Alternate Embodiment A126, wherein the sorting head includes a coin reject station with an associated diverter, the coin reject station being adjacent to the sensor.

Alternative Embodiment A128

A128. The coin processing machine of Alternate Embodiment A127, wherein the sensor determines the authenticity of each of the coins, non-authentic ones of the coins being diverted to the coin reject station.

Alternative Embodiment A129

A129. The coin processing machine of Alternate Embodiment A126, wherein each of the plurality of diverters includes a voice coil for providing high-speed diverting.

Alternative Embodiment A130

A130. The coin processing machine of Alternate Embodiment A126, wherein each of the coins remains entirely sandwiched between the sorting head and the rotatable disc prior to being diverted by one of the diverters.

Alternative Embodiment A131

A131. The coin processing machine of Alternate Embodiment A126, wherein the sorting head includes a queuing region for increasing the spacing between adjacent the coins.

Alternative Embodiment A132

A132. The coin processing machine of Alternate Embodiment A131, wherein the sensor is located within the queuing region at a point after the spacing between adjacent coins has been increased.

Alternative Embodiment A133

A133. The coin processing machine of Alternate Embodiment A126, wherein the coins remain under pressure between the rotatable disc and the stationary sorting head while within the gauging region.

Alternative Embodiment A134

A134. The coin processing machine of Alternate Embodiment A126, wherein each of the plurality of diverters is a peg-like structure extending downwardly from openings within the sorting head.

Alternative Embodiment A135

A135. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface of the sorting head having formed therein a gauging channel for aligning the coins in a certain formation and a plurality of exit channels for discharging coins at spaced circumferential locations along the sorting head, each of the coin exit channels capable of receiving each coin in a coin set;

a sensor for determining the denomination of each of the coins; and

a plurality of diverters disposed along the gauging channel, each of the plurality of diverters corresponding to one of the plurality of coin exit channels, each of the plurality of diverters being movable between a first position wherein coins remain in movement along the gauging channel and a second position wherein coins are diverted into the corresponding exit channel.

Alternative Embodiment A136

A136. The coin processing system of Alternate Embodiment A135, wherein the sorting head includes a coin reject station with an associated diverter, the coin reject station being adjacent to the sensor.

Alternative Embodiment A137

A137. The coin processing system of Alternate Embodiment A136, wherein the sensor determines the authenticity of each of the coins, non-authentic ones of the coins being diverted to the coin reject station.

Alternative Embodiment A138

A138. The coin processing system of Alternate Embodiment A135, wherein each of the exit channels is dimensionally same.

Alternative Embodiment A139

A139. The coin processing system of Alternate Embodiment A135, wherein the gauging region all lines the coins along a common radius.

Alternative Embodiment A140

A140. The coin processing system of Alternate Embodiment A135, wherein each of the plurality of diverters includes a voice coil for providing high-speed diverting.

Alternative Embodiment A141

A141. The coin processing system of Alternate Embodiment A135, wherein each of the coins remains entirely sandwiched between the sorting head and the rotatable disc prior to being diverted by one of the diverters.

Alternative Embodiment A142

A142. The coin processing system of Alternate Embodiment A135, wherein the sorting head includes a queuing region for increasing the spacing between adjacent the coins.

Alternative Embodiment A143

A143. The coin processing system of Alternate Embodiment A135, further including an encoder coupled to the controller for tracking the position of each coin sensed by the sensor.

Alternative Embodiment A144

A144. The coin processing system of Alternate Embodiment A135, wherein a portion of the queuing channel is generally L-shaped for imparting spacing between each coin.

Alternative Embodiment A145

A145. A method of processing coins, comprising:

receiving the coins in a coin receiving region;

imparting motion to the coins with a rotatable disc;

engaging the coins with a stationary sorting head during the step of imparting motion;

moving coins along a coin path within the stationary sorting head;

actuating a single sensor that determines the authenticity of each coin and the denomination of each coin;

tracking the position of each coin that has been sensed by the single sensor; and

selectively actuating a plurality of diverters to discharge certain denominations of the coins into corresponding exit stations.

Alternative Embodiment A146

A146. The method of Alternate Embodiment A145, further including diverting not authentic ones of the coins to a reject station.

Alternative Embodiment A147

A147. The method of Alternate Embodiment A145, further including increasing the spacing between adjacent coins prior to actuating the single sensor.

Alternative Embodiment A148

A148. The method of Alternate Embodiment A145, further including determining a value of authentic ones of the coins that have been sensed.

Alternative Embodiment A149

A149. The method of Alternate Embodiment A145, wherein the step of selectively actuating the plurality of diverters includes the step of selectively actuating a series of voice coils.

Alternative Embodiment A150

A150. A method of processing coins, comprising:

moving coins along a coin path within a stationary sorting head;

actuating a single sensor that determines the denomination of each coin;

tracking the position of each coin that has been sensed by the single sensor; and

selectively actuating a plurality of diverters to discharge certain denominations of the coins into corresponding exit stations.

Alternative Embodiment A151

A151. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a coin driving member for imparting motion to the plurality of coins so that the coins move along a certain coin path;

at least one coin exit station along the coin path;

a diverting structure for diverting the coin from the coin path to the coin exit station; and

a voice coil mechanically coupled to the diverting structure for providing movement to the diverting structure.

Alternative Embodiment A152

A152. The coin processing system of Alternate Embodiment A151, further including a plurality of diverters disposed along the coin path, each of the plurality of diverters having a corresponding voice coil mechanically coupled thereto.

Alternative Embodiment A153

A153. The coin processing system of Alternate Embodiment A151, wherein the coin path is curved.

Alternative Embodiment A154

A154. The coin processing system of Alternate Embodiment A151, wherein the coin path is straight.

Alternative Embodiment A155

A155. The coin processing system of Alternate Embodiment A151, wherein the coin driving member is a rotatable disc.

Alternative Embodiment A156

A156. The coin processing system of Alternate Embodiment A155, further including a stationary sorting head for defining the coin path.

Alternative Embodiment A157

A157. A programmable rail coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary guide plate head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a queuing channel and a exit station, the queuing channel having an interior wall against which coins abut when moving toward the exit station, the queuing channel having a first segment for receiving coins from an input coin region and a second segment disposed in a position that is substantially more in direction of movement of the rotatable disc positioned thereunder than the first segment to create an increased spacing between adjacent coins;

a rail for receiving coins from the exit station, the rail having a wall against which coins abut when moving toward a plurality of exit channel for discharging coins;

a driven endless belt disposed above and spaced slightly from the rail for imparting movement to the coin received by the rail

a diverter corresponding to each of the plurality each exit channels of the rail for diverting coins from the wall into the plurality of exit channels; and

a sensor disposed upstream of the plurality of exit channels obtain information from each of the coins for differentiating between valid and invalid coins; and

a controller for selectively activating each of the diverting structures.

Alternative Embodiment A158

A158. The system of Alternate Embodiment A157, wherein each of the diverters have a corresponding voice coil mechanically coupled thereto for actuating the diverter.

Alternative Embodiment A159

A159. The system of Alternate Embodiment A157, wherein each of the diverters have a corresponding solenoid mechanically coupled thereto for actuating the diverter.

Alternative Embodiment A160

A160. The system of Alternate Embodiment A157, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A161

A161. The system of Alternate Embodiment A160, wherein the angle is about 100 degrees.

Alternative Embodiment A162

A162. The system of Alternate Embodiment A157, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A163

A163. The system of Alternate Embodiment A157, wherein the plurality of exit channels are linearly aligned along the rail.

Alternative Embodiment A164

A164. The system of Alternate Embodiment A157, wherein the plurality of exit channels discharge coins from a common side of the rail.

Alternative Embodiment A165

A165. The system of Alternate Embodiment A157, further comprising at least one coin bag per exit channel for receiving coins from each of the exit channels, the bags being arranged in a substantially linear presentation.

Alternative Embodiment A166

A166. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a queuing channel and a plurality of exit channels for sorting and discharging coins, the queuing channel having an interior wall against which coins abut when moving toward the exit channels, the queuing channel having a first segment for receiving coins from an input coin region and a second segment disposed in a position that is substantially more in direction of movement of the rotatable disc positioned thereunder than the first segment to create an increased spacing between adjacent coins, the discriminator being located in the queuing region, the lower surface having a reject region between the first segment of the queuing region and the plurality of exit channels;

a sensor for obtaining characteristic information from each of the coins, the sensor producing a signal indicative of the obtained information;

a diverting pin disposed toward an end of the second segment, the diverter being moveable between a first position wherein coins remain abutted against the wall for proceeding toward the plurality of exit channels and a second position for diverting coins away from the interior wall to the reject region;

a voice coin mechanically coupled to the diverting pin for rapidly moving the diverting pin from the first position to the second position and from the second position to the first position;

a memory for sorting master characteristic information obtained for known genuine coins; and

a controller electrically coupled to the sensor and the voice coils, the controller adapted to compare the denominating characteristic information obtained from each of the coins to the master denomination characteristic information stored in memory, the controller actuating the voice coil when the obtained information does not favorably compare to master information corresponding to a group of valid coins.

Alternative Embodiment A167

A167. The coin processing system of Alternate Embodiment A166, further including a gauging channel for aligning outer edges of the coins along a gauging wall immediately prior to the at least two exit channels.

Alternative Embodiment A168

A168. The coin processing system of Alternate Embodiment A167, further including a transition area between the gauging channel and the queuing channel to allow coins to move from an interior wall within the queuing channel to the gauging wall within the gauging channel.

Alternative Embodiment A169

A169. The coin processing system of Alternate Embodiment A168, wherein the coins are under pressure between the rotatable disc and the sorting head when moving through the transition area.

Alternative Embodiment A170

A170. The coin processing system of Alternate Embodiment A168, wherein the coins are under no pressure when moving through the transition area.

Alternative Embodiment A171

A171. The coin processing system of Alternate Embodiment A166, wherein the reject region includes a reject slot into which coins are diverted by the diverter.

Alternative Embodiment A172

A172. The coin processing system of Alternate Embodiment A171, wherein the reject slot leads coins to a periphery of the sorting head.

Alternative Embodiment A173

A173. The coin processing system of Alternate Embodiment A171, wherein the reject slot has a length of no more than about three times the diameter of the smallest authentic coin to be processed.

Alternative Embodiment A174

A174. The coin processing system of Alternate Embodiment A166, wherein the rotatable disc includes a pad, the coins being under pad pressure when moving through the queuing region.

Alternative Embodiment A175

A175. The coin processing system of Alternate Embodiment A166, wherein the queuing region includes an inner wall against which the coins abut and has, in a cross-sectional view, a stepped profile that defines a first edge and a second edge, the first edge being closer to the inner wall than the second edge.

Alternative Embodiment A176

A176. The coin processing system of Alternate Embodiment A171, wherein inner edges of the coins engage the inner wall, coins of a smaller diameter engaging the first edge, coins of a larger diameter engaging the second edge.

Alternative Embodiment A177

A177. The coin processing system of Alternate Embodiment A176, wherein the coins remain under pressure between the rotatable disc and the sorting head while moving along the first edge and the second edge.

Alternative Embodiment A178

A178. The coin processing system of Alternate Embodiment A166, wherein the queuing region terminates at a location adjacent to a periphery of the rotatable disc.

Alternative Embodiment A179

A179. The coin processing system of Alternate Embodiment A166, wherein the controller determines the denomination of each authentic coin, the controller determining the value of the coins being processed based on input from the sensor.

Alternative Embodiment A180

A180. The coin processing system of Alternate Embodiment A179, wherein the controller maintains a count of the number of coins discharged from each exit channel.

Alternative Embodiment A181

A181. The coin processing system of Alternate Embodiment A179, further including a counting sensor in each of the exit channels, the counting sensor is being coupled to the controller, the controller determining the value of the coins being processed based on inputs received from the counting sensors.

Alternative Embodiment A182

A182. The coin processing system of Alternate Embodiment A166, further including a trigger sensor positioned immediately upstream from the sensor, the sensor being activated to determine characteristics of a particular coin in response to the expiration of a certain time period occurring after the trigger sensor detects the particular coin.

Alternative Embodiment A183

A183. The coin processing system of Alternate Embodiment A166, wherein the coins are aligned along an inner wall of the second segment of the queuing region, the diverting pin being immediately adjacent to the inner wall for causing coins to be diverted away from the inner wall and toward the reject region.

Alternative Embodiment A184

A184. The coin processing system of Alternate Embodiment A183, wherein the second segment of the queuing channel includes a coin engaging surface immediately adjacent to the inner wall, the reject region including a reject slot that is immediately adjacent to the coin engaging surface.

Alternative Embodiment A185

A185. The coin processing system of Alternate Embodiment A184, wherein the coin engaging surface has a width measured in a radial direction that is approximately the width of the diverter when the diverter is in the second position.

Alternative Embodiment A186

A186. The coin processing system of Alternate Embodiment A184, wherein the diverting pin is a diverting pin that protrudes downwardly from the coin engaging surface.

Alternative Embodiment A187

A187. The coin processing system of Alternate Embodiment A166, wherein the discriminator determines a metal content and a dimension of the coins.

Alternative Embodiment A188

A188. The coin processing machine of Alternate Embodiment A166, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

Alternative Embodiment A189

A189. The coin processing system of Alternate Embodiment A188, wherein the angle is about 100 degrees.

Alternative Embodiment A190

A190. The coin processing system of Alternate Embodiment A166, wherein the queuing channel is generally L-shaped.

Alternative Embodiment A191

A191. A coin processing machine for sorting a plurality of coins having different characteristics, comprising:

a rotatable disc for imparting motion to said plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, said lower surface forming a coin path leading to an exit station at which said coins are discharged;

a discrimination sensor for discriminating among said plurality of coins based on said characteristics of said coins, said sensor being located over said coin path and within said stationary sorting head, said sensor having a transmission coil and two reception coils, said transmission coil for producing a magnetic field over a section of said coin path, said two reception coils being configured to detect signals that are indicative of said characteristics of each coin passing along said coin path, said characteristics including at least a coin composition, a coin thickness, and a coin diameter; and

a processor coupled to said discrimination sensor for selectively processing said coins in response to said signals received from said discrimination sensor.

Alternative Embodiment A192

A192. The coin processing machine of Alternate Embodiment A191, further including a diverter coupled to said processor, said processor selectively actuating said diverter in response to said signals received from said discrimination sensor.

Alternative Embodiment A193

A193. The coin processing machine of Alternate Embodiment A192, further including a reject region along said coin path, said diverter diverting invalid coins from said coin path to said reject region.

Alternative Embodiment A194

A194. The coin processing machine of Alternate Embodiment A193, wherein said reject region is adjacent to said discrimination sensor.

Alternative Embodiment A195

A195. The coin processing machine of Alternate Embodiment A194, wherein said reject region is positioned along said coin path substantially closer to said discrimination sensor than to said coin exit station.

Alternative Embodiment A196

A196. The coin processing machine of Alternate Embodiment A195, wherein said coin exit station includes a plurality of coin exit channels.

Alternative Embodiment A197

A197. The coin processing machine of Alternate Embodiment A196, wherein each of said plurality of coin exit channels is dedicated to a specific denomination.

Alternative Embodiment A198

A198. The coin processing machine of Alternate Embodiment A196, wherein each of said plurality of coin exit channels is capable of receiving each denomination in a coin set, each of said plurality of coin exit channels having an associated diverter that is coupled to said processor and selectively actuatable by said processor.

Alternative Embodiment A199

A199. The coin processing machine of Alternate Embodiment A191, wherein said coins are under pressure between said rotatable disc and said sorting head when moving along said coin path past said discrimination sensor.

Alternative Embodiment A200

A200. The coin processing machine of Alternate Embodiment A191, further including a trigger sensor coupled to said processor and positioned immediately upstream along said coin path from said discrimination sensor, said discrimination sensor being activated by said processor in response to the expiration of a certain time period occurring after said processor receives a signal from said trigger sensor.

Alternative Embodiment A201

A201. The coin processing machine of Alternate Embodiment A191, wherein said sorting head is configured to create an increased spacing between adjacent coins that are to pass by said discrimination sensor.

Alternative Embodiment A202

A202. The coin processing machine of Alternate Embodiment A191, wherein said two reception coils are symmetrically arranged and connected in series to cause a cancellation of the individual signals received by each of said two reception coils when no coin is sensed.

Alternative Embodiment A203

A203. The coin processing machine of Alternate Embodiment A191, wherein said discrimination sensor has a generally rectangular shape, a longest dimension of said generally rectangular shape being greater than a diameter of the largest one of said coins to be processed.

Alternative Embodiment A204

A204. The coin processing machine of Alternate Embodiment A203, wherein said transmission coil encloses said two reception coils.

Alternative Embodiment A205

A205. The coin processing machine of Alternate Embodiment A204, wherein said transmission coil produces a high frequency magnetic field and a low frequency magnetic field, said low frequency magnetic field penetrating more into a thickness dimension of said coin than said high frequency magnetic field thereby causing said high frequency magnetic field to be more influenced by a surface area of said coin and said low frequency magnetic field to be more influenced by a volume of said coin.

Alternative Embodiment A206

A206. The coin processing machine of Alternate Embodiment A205, wherein said reception coils detect a phase shift and amplitude shift associated with both said high frequency magnetic field and said low frequency magnetic field, said processor determining a type of coin being sensed based on said phase shifts in said amplitude shifts associated with said high frequency magnetic field and said low frequency magnetic field.

Alternative Embodiment A207

A207. The coin processing machine of Alternate Embodiment A206, wherein said high frequency signal oscillates at approximately 480 KHz and said low frequency signal oscillates at about 30 KHz.

Alternative Embodiment A208

A208. The coin processing machine of Alternate Embodiment A191, wherein said transmission coil produces a magnetic field at two frequencies.

Alternative Embodiment A209

A209. The coin processing machine of Alternate Embodiment A208, wherein said reception coils detect a phase shift and amplitude shift for each of said two frequencies.

Alternative Embodiment A210

A210. The coin processing machine of Alternate Embodiment A209, wherein said reception coils are configured to have a dimension that is larger than a diameter of the largest coins to be processed for a certain coin set.

Alternative Embodiment A211

A211. The coin processing machine of Alternate Embodiment A210, wherein said discrimination sensor has a generally rectangular shape.

Alternative Embodiment A212

A212. The coin processing machine of Alternate Embodiment A210, wherein said transmission coil is configured to have a dimension that is larger than a diameter of the largest coins to be processed for a certain coin set.

Alternative Embodiment A213

A213. The coin processing machine of Alternate Embodiment A210, wherein said high frequency signal oscillates at a frequency at least eight times greater than the frequency at which said low frequency signal oscillates.

Alternative Embodiment A214

A214. The coin processing machine of Alternate Embodiment A210, wherein said high frequency signal oscillates at a frequency at least twelve times greater than the frequency at which said low frequency signal oscillates.

Alternative Embodiment A215

A215. A discrimination sensor for determining an authenticity of coins in a coin processing machine, comprising:

a transmission coil for producing a magnetic field over a coin path in said coin processing machine, said magnetic field coupling to said coins to induce eddy currents within said coin; and

two reception coils configured to detect signals corresponding to said eddy currents, said signals being indicative of a metal content, a coin thickness, and a coin diameter for each coin passing along said coin path.

Alternative Embodiment A216

A216. The discrimination sensor of Alternate Embodiment A215, wherein said transmission coil receives a composite signal including a high frequency component and a low frequency component.

Alternative Embodiment A217

A217. The discrimination sensor of Alternate Embodiment A216, wherein said low frequency component is indicative of information about a thickness of said coin and said high frequency is indicative of information about a diameter of said coin.

Alternative Embodiment A218

A218. The discrimination sensor of Alternate Embodiment A217, wherein said reception coils detect a phase shift and amplitude shift associated with both said high frequency component and said low frequency component.

Alternative Embodiment A219

A219. The discrimination sensor of Alternate Embodiment A215, wherein said transmission coil and said reception coils are located on the same side of said coin path.

Alternative Embodiment A220

A220. The discrimination sensor of Alternate Embodiment A219, wherein said transmission coil produces a magnetic field at a high frequency and a low frequency.

Alternative Embodiment A221

A221. The discrimination sensor of Alternate Embodiment A220, wherein said low frequency provides information about a thickness of said coin and said high frequency provides information about a diameter of said coin.

Alternative Embodiment A222

A222. The discrimination sensor of Alternate Embodiment A221, wherein said reception coils detect a phase shift and amplitude shift for both said high frequency and said low frequency.

Alternative Embodiment A223

A223. The discrimination sensor of Alternate Embodiment A221, wherein a first of said two reception coils is positioned proximal to said coin path and a second of said two reception coils is positioned in a distal relationship relative to said first of said two reception coils.

Alternative Embodiment A224

A224. The discrimination sensor of Alternate Embodiment A221, wherein said transmission coil substantially surrounds said two reception coils.

Alternative Embodiment A225

A225. The method of determining characteristics of a coin and a coin processing machine, comprising:

moving said coin along a coin path within said coin processing machine;

inducing eddy currents in said coin by subjecting said coin to a magnetic field of a high frequency and a low frequency;

detecting signals corresponding to said eddy currents that are indicative of a coin diameter, a coin thickness, and a composition of said coin; and

processing said signals to determine an identity of said coin.

Alternative Embodiment A226

A226. The method of Alternate Embodiment A225, wherein said identity of said coin includes an invalid coin for a particular operating session of said coin operating machine.

Alternative Embodiment A227

A227. The method of Alternate Embodiment A226, further including diverting said invalid coin away from said coin path to a reject station.

Alternative Embodiment A228

A228. The method of Alternate Embodiment A227, wherein said invalid coin is a non-authentic coin.

Alternative Embodiment A229

A229. The method of Alternate Embodiment A227, wherein said invalid coin is an authentic coin of a particular denomination.

Alternative Embodiment A230

A230. The method of Alternate Embodiment A225, wherein said inducing said eddy currents and detecting said signals is accomplished through coils positioned along said coin path on one side of said coin.

Alternative Embodiment A231

A231. A discrimination sensor for determining an authenticity of coins in a coin processing machine, comprising a first coil coupled to a second coil, said first coil and said second coil producing a magnetic field over a coin path in said coin processing machine, said magnetic field coupling to said coins to induce eddy currents within said coin, said first coil and said second coil detecting signals corresponding to said eddy currents, said signals being indicative of a coin composition, a coin thickness, and a coin diameter for each coin passing along said coin path.

While the invention is susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and described in detail herein. It should be understood, however, that the invention is not intended to be limited to the particular forms disclosed. Rather, the invention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a queuing channel and at least two exit channels for sorting and discharging coins, the queuing channel having an interior wall against which coins abut when moving toward the exit channels, the queuing channel having a first segment for receiving coins from an input coin region and a second segment disposed in a position that is substantially more in direction of movement of the rotatable disc positioned thereunder than the first segment to create an increased spacing between adjacent coins, the discriminator being located in the queuing region, the lower surface having a reject region between the first segment of the queuing region and the plurality of exit channels;

a sensor for differentiating between valid and invalid coins;

a diverter disposed toward an end of the second segment, the diverter being moveable between a first position wherein coins remain abutted against the wall for proceeding toward the at least two exit channels and a second position for diverting coins away from the interior wall to the reject region; and

a controller communicatively coupled to the sensor, the controller moving the diverter from the first position to the second position in response to the sensor detecting an invalid coin.

2. The coin processing system of claim 1, further including a gauging channel for aligning outer edges of the coins along a gauging wall immediately prior to the at least two exit channels.

3. The coin processing system of claim 2, further including a transition area between the gauging channel and the queuing channel to allow coins to move from an interior wall within the queuing channel to the gauging wall within the gauging channel.

4. The coin processing system of claim 3, wherein the coins are under pressure between the rotatable disc and the sorting head when moving through the transition area.

5. The coin processing system of claim 3, wherein the coins are under no pressure when moving through the transition area.

6. The coin processing system of claim 1, wherein the reject region includes a reject slot into which coins are diverted by the diverter.

7. The coin processing system of claim 6, wherein the reject slot leads coins to a periphery of the sorting head.

8. The coin processing system of claim 7, wherein the reject slot has a length of no more than about three times the diameter of the smallest authentic coin to be processed.

9. The coin processing system of claim 1, wherein the rotatable disc includes a pad, the coins being under pad pressure when moving through the queuing region.

10. The coin processing system of claim 1, wherein the queuing region includes an inner wall against which the coins abut and has, in a cross-sectional view, a stepped profile that defines a first edge and a second edge, the first edge being closer to the inner wall than the second edge.

11. The coin processing system of claim 10, wherein inner edges of the coins engage the inner wall, coins of a smaller diameter engaging the first edge, coins of a larger diameter engaging the second edge.

12. The coin processing system of claim 11, wherein the coins remain under pressure between the rotatable disc and the sorting head while moving along the first edge and the second edge.

13. The coin processing system of claim 1, wherein the queuing region terminates at a location adjacent to a periphery of the rotatable disc.

14. The coin processing system of claim 1, wherein the sensor determines the denomination of each valid coin, the controller determining the value of the coins being processed based on input from the sensor.

15. The coin processing system of claim 1, wherein the at least two exit channels includes in exit channel for each available denomination to be sorted.

16. The coin processing system of claim 15, further including a counting sensor in each of the exit channels, the counting sensors being coupled to the controller,

the controller determining the value of the coins being processed based on inputs received from the counting sensors.

17. The coin processing system of claim 1, further including a trigger sensor positioned immediately upstream from the sensor, the sensor being activated to determine characteristics of a particular coin in response to the expiration of a certain time period occurring after the trigger sensor detects the particular coin.

18. The coin processing system of claim 1, wherein the diverter includes a voice coil for high speed high-speed switching between the first position and the second position, the voice coil providing a force in both directions of movement toward the first and second positions.

19. The coin processing system of claim 18, wherein the force is at least about 20 pounds of force in both directions.

20. The coin processing system of claim 18, wherein the voice coil undergoes a displacement of at least about 1/8 inch in about 1.3 milliseconds.

21. The coin processing system of claim 1, wherein the coins are aligned along an inner wall of the second segment of the queuing region, the diverter being immediately adjacent to the inner wall for causing coins to be diverted away from the inner wall and toward the reject region.

22. The coin processing system of claim 21, wherein the second segment of the queuing channel includes a coin engaging surface immediately adjacent to the inner wall, the reject region including a reject slot that is immediately adjacent to the coin engaging surface.

23. The coin processing system of claim 22, wherein the coin engaging surface has a width measured in a radial direction that is approximately the width of the diverter when the diverter is in the second position.

24. The coin processing system of claim 23, wherein the diverter is a diverting pin that protrudes downwardly from the coin engaging surface.

25. The coin processing system of claim 1, wherein the discriminator determines a metal content and a dimension of the coins.

26. The coin processing system of claim 1, wherein the diverter is actuated by a solenoid.

27. The coin processing system of claim 1, wherein the queuing channel is generally L-shaped.

28. The coin processing system of claim 1, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

29. The coin processing system of claim 28, wherein the angle is about 100 degrees.

30. The coin processing system of claim 1, wherein the sensor is disposed along the queuing channel.

31. The coin processing system of claim 30, wherein the sensor is located at aaa beginning portion of the second segment.

32. The coin processing system of claim 1, wherein the sensor obtains information from each of the coins for differentiating between valid and invalid coins.

33 The coin processing system of claim 1, wherein the diverter moves at a rate that allows the rotatable disc to maintain a substantially constant operation speed while the diverter moves between the first position and the second position.

34. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a sensor for differentiating between valid and invalid coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface forming a queuing channel and a plurality of exit channels for sorting and discharging coins of particular denominations, the queuing channel having a first segment for receiving coins and a second segment for moving the coins past the sensor, the queuing channel being configured to move coins at a faster rate along the second segment for increasing the spacing between adjacent coins;

a diverter disposed along the second segment beyond the sensor, the diverter being moveable between a first position permitting coins to proceed to the plurality of exit channels and a second position for diverting coins to a reject region; and

a controller for moving the diverter from the first position to the second position when the sensor detects an invalid coin.

35. The coin processing system of claim 34, wherein the reject region includes a reject slot into which coins are diverted by the diverter.

36. The coin processing system of claim 35, wherein the reject slot leads coins to a periphery of the sorting head.

37. The coin processing system of claim 34, wherein the coins are aligned along an inner wall of the second segment of the queuing region, the diverter being disposed immediately adjacent to the inner wall for causing coins to be diverted away from the inner wall and toward the reject region.

38. The coin processing system of claim 34, wherein the diverter includes a voice coil for high speed activation.

39. The coin processing system of claim 34, wherein the queuing region includes an inner wall against which the coins abut and has, in a cross-sectional view, a stepped profile that defines a first edge and a second edge, the first edge being closer to the inner wall than the second edge.

40. The coin processing system of claim 39, wherein inner edges of the coins engage the inner wall, coins of a smaller diameter engaging the first edge, coins of a larger diameter engaging the second edge.

41. The coin processing system of claim 40, wherein the coins remain under pressure between the rotatable disc and the sorting head while moving along the first edge and the second edge.

42. The coin processing system of claim 39, wherein the stepped profile of the queuing region transitions to a substantially flat profile.

43. The coin processing system of claim 34, wherein the diverter is actuated by a solenoid.

44. The coin processing system of claim 34, wherein the queuing channel is generally L-shaped.

45. The coin processing system of claim 34, wherein the first segment is disposed at an angle of 90 degrees to about 110 degrees relative to the second segment.

46. The coin processing system of claim 45, wherein the angle is about 100 degrees.

47. A method for processing coins, comprising:

receiving coins in a coin receiving area;

moving coins along a queuing region after the coin receiving area, the queuing region including a first segment and a second segment of the queuing region;

creating additional spacing between adjacent coins as the coins transition from the first segment to the second segment;

determining the authenticity of each of the coins passing through the second segment; and

diverting non-authentic coins away from a coin path leading to a discharge region for authentic coins at a point upstream from the discharge region.

48. The method of claim 47, wherein the diverting includes activating a voice coil in response to the step of determining.

49. The method of claim 47, wherein the creating additional spacing includes moving coins along the second segment at a higher rate to speed.

50. The method of claim 47, wherein the discharge region includes a plurality of coin exit channels, the method further including the step of sorting coins of each denomination into a corresponding one of the plurality of coin exit channels.

51. The method of claim 50, wherein the plurality of coin exit channels are of different dimensions.

52. The method of claim 47, wherein the steps of moving, creating, determining and diverting are performed while the coins are located between a rotatable disc and a stationary sorting head.

53. The method of claim 47, wherein the step of diverting occurs along the second segment.

54. The method of claim 47, wherein the coins being processed move at a constant operational speed during the steps of determining and diverting.

55. A method for processing coins, comprising;

receiving coins in a coin receiving region;

imparting motion to the coins with a rotatable disc;

engaging the coins with a stationary sorting head during the step of imparting motion;

increasing the spacing between adjacent coins in a queuing region of the sorting head;

determining the authenticity of each of the coins after the step of increasing the spacing;

diverting non-authentic ones of the coins to a coin reject region; and

moving authentic ones of the coins to a coin discharge region at a location that is beyond the coin reject region.

56. The method of claim 55, wherein the queuing region includes a first segment and a second segment, the second segment being arranged in a position on the sorting head that is more in alignment with the direction of movement of the rotatable disc than the first segment, the second segment providing the step of increasing the spacing between adjacent coins.

57. The method of claim 51, wherein the first segment is disposed at an angle of about 90 degrees to about 110 degrees relative to the second segment.

58. The method of claim 57 wherein the angle is about 100 degrees.

59. The method of claim 55, wherein the diverting includes activating a voice coil in response to the step of determining.

60. The method of claim 55, wherein the diverting includes activating a solenoid in response to the step of determining.

61. The method of claim 55, wherein the step of moving authentic ones of the coins occurs while the coins are under pressure between the rotatable disc and the sorting head.

62. The method of claim 55, wherein the step of determining occurs within the queuing region.

63. A coin processing machine for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface of the sorting head having formed therein a gauging channel for aligning the coins along a common radius and a plurality of exit channels for discharging coins, the gauging region having an interior wall against which the coins abut, each of the exit channels having substantially the same width;

a sensor for obtaining information indicative of the denomination of each of the coins from each of the coins;

a plurality of diverters disposed along the gauging channel, each of the plurality of diverters corresponding to one of the plurality of exit channels, each of the plurality of diverters being movable between a first position wherein coins remain abutted against the interior wall and a second position wherein coins are diverted to the corresponding exit channel; and

a controller for selectively controlling the movement of each of the diverters between the first and second positions in response to input from the sensor.

64. The coin processing machine of claim 63, wherein the sorting head includes a coin reject station with an associated diverter, the coin reject station being adjacent to the sensor.

65. The coin processing machine of claim 64, wherein the sensor determines the authenticity of each of the coins, non-authentic ones of the coins being diverted to the coin reject station.

66. The coin processing machine of claim 63, wherein each of the plurality of diverters includes a voice coil for providing high-speed diverting.

67. The coin processing machine of claim 63, wherein each of the coins remains entirely sandwiched between the sorting head and the rotatable disc prior to being diverted by one of the diverters.

68. The coin processing machine of claim 63, wherein the sorting head includes a queuing region for increasing the spacing between adjacent the coins.

69. The coin processing machine of claim 68, wherein the sensor is located within the queuing region at a point after the spacing between adjacent coins has been increased.

70. The coin processing machine of claim 63, wherein the coins remain under pressure between the rotatable disc and the stationary sorting head while within the gauging region.

71. The coin processing machine of claim 63, wherein each of the plurality of diverters is a peg-like structure extending downwardly from openings within the sorting head.

72. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a rotatable disc for imparting motion to the plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, the lower surface of the sorting head having formed therein a gauging channel for aligning the coins in a certain formation and a plurality of exit channels for discharging coins at spaced circumferential locations along the sorting head, each of the coin exit channels capable of receiving each coin in a coin set;

a sensor for determining the denomination of each of the coins; and

a plurality of diverters disposed along the gauging channel, each of the plurality of diverters corresponding to one of the plurality of coin exit channels, each of the plurality of diverters being movable between a first position wherein coins remain in movement along the gauging channel and a second position wherein coins are diverted into the corresponding exit channel.

73. The coin processing system of claim 72, wherein the sorting head includes a coin reject station with an associated diverter, the coin reject station being adjacent to the sensor.

74. The coin processing system of claim 73, wherein the sensor determines the authenticity of each of the coins, non-authentic ones of the coins being diverted to the coin reject station.

75. The coin processing system of claim 72, wherein each of the exit channels is dimensionally same.

76. The coin processing system of claim 72, wherein the gauging region all lines the coins along a common radius.

77. The coin processing system of claim 72, wherein each of the plurality of diverters includes a voice coil for providing high-speed diverting.

78. The coin processing system of claim 72, wherein each of the coins remains entirely sandwiched between the sorting head and the rotatable disc prior to being diverted by one of the diverters.

79. The coin processing system of claim 72, wherein the sorting head includes a queuing region for increasing the spacing between adjacent the coins.

80. The coin processing system of claim 72, further including an encoder coupled to the controller for tracking the position of each coin sensed by the sensor.

81. The coin processing system of claim 72, wherein a portion of the queuing channel is generally L-shaped for imparting spacing between each coin.

82. A method of processing coins, comprising:

moving coins along a coin path within a stationary sorting head;

actuating a single sensor that determines the denomination of each coin;

tracking the position of each coin that has been sensed by the single sensor; and

selectively actuating a plurality of diverters to discharge certain denominations of the coins into corresponding exit stations.

83. The method of claim 82 comprising receiving the coins in a coin receiving region.

84. The method of claim 82 comprising imparting motion to the coins with a rotatable disc.

85. The method of claim 84 comprising engaging the coins with a stationary sorting head while imparting motion to the coins with the rotatable disc.

86. The method of claim 82 comprising determining the authenticity of each of coin with the single sensor.

87. The method of claim 86, further including diverting not authentic ones of the coins to a reject station.

88. The method of claim 86, further including determining a value of authentic ones of the coins that have been sensed.

89. The method of claim 82, further including increasing the spacing between adjacent coins prior to actuating the single sensor.

90. The method of claim 82, wherein the step of selectively actuating the plurality of diverters includes the step of selectively actuating a series of voice coils.

91. A coin processing system for processing a plurality of coins of mixed denominations, comprising:

a coin driving member for imparting motion to the plurality of coins so that the coins move along a certain coin path;

at least one coin exit station along the coin path;

a diverting structure for diverting the coin from the coin path to the coin exit station; and

a voice coil mechanically coupled to the diverting structure for providing movement to the diverting structure.

92. The coin processing system of claim 91, further including a plurality of diverters disposed along the coin path, each of the plurality of diverters having a corresponding voice coil mechanically coupled thereto.

93. The coin processing system of claim 91, wherein the coin path is curved.

94. The coin processing system of claim 91, wherein the coin path is straight.

95. The coin processing system of claim 91, wherein the coin driving member is a rotatable disc.

96. The coin processing system of claim 95, further including a stationary sorting head for defining the coin path.

97. A coin processing machine for sorting a plurality of coins having different characteristics, comprising:

a rotatable disc for imparting motion to said plurality of coins;

a stationary sorting head having a lower surface generally parallel to and spaced slightly away from the rotatable disc, said lower surface forming a coin path leading to an exit station at which said coins are discharged;

a discrimination sensor for discriminating among said plurality of coins based on said characteristics of said coins, said sensor being located over said coin path and within said stationary sorting head, said sensor having a transmission coil and two reception coils, said transmission coil for producing a magnetic field over a section of said coin path, said two reception coils being configured to detect signals that are indicative of said characteristics of each coin passing along said coin path, said characteristics including at least a coin composition, a coin thickness, and a coin diameter; and a processor coupled to said discrimination sensor for selectively processing said coins in response to said signals received from said discrimination sensor.

98. The coin processing machine of claim 97, further including a diverter coupled to said processor, said processor selectively actuating said diverter in response to said signals received from said discrimination sensor.

99. The coin processing machine of claim 98, further including a reject region along said coin path, said diverter diverting invalid coins from said coin path to said reject region.

100. The coin processing machine of claim 99, wherein said reject region is adjacent to said discrimination sensor.

101. The coin processing machine of claim 100, wherein said reject region is positioned along said coin path substantially closer to said discrimination sensor than to said coin exit station.

102. The coin processing machine of claim 101, wherein said coin exit station includes a plurality of coin exit channels.

103. The coin processing machine of claim 102, wherein each of said plurality of coin exit channels is dedicated to a specific denomination.

104. The coin processing machine of claim 102, wherein each of said plurality of coin exit channels is capable of receiving each denomination in a coin set, each of said plurality of coin exit channels having an associated diverter that is coupled to said processor and selectively actuatable by said processor.

105. The coin processing machine of claim 97, wherein said coins are under pressure between said rotatable disc and said sorting head when moving along said coin path past said discrimination sensor.

106. The coin processing machine of claim 97, further including a trigger sensor coupled to said processor and positioned immediately upstream along said coin path from said discrimination sensor, said discrimination sensor being activated by said processor in response to the expiration of a certain time period occurring after said processor receives a signal from said trigger sensor.

107. The coin processing machine of claim 97, wherein said sorting head is configured to create an increased spacing between adjacent coins that are to pass by said discrimination sensor.

108. The coin processing machine of claim 97, wherein said two reception coils are symmetrically arranged and connected in series to cause a cancellation of the individual signals received by each of said two reception coils when no coin is sensed.

109. The coin processing machine of claim 97, wherein said discrimination sensor has a generally rectangular shape, a longest dimension of said generally rectangular shape being greater than a diameter of the largest one of said coins to be processed.

110. The coin processing machine of claim 109, wherein said transmission coil encloses said two reception coils.

111. The coin processing machine of claim 110, wherein said transmission coil produces a high frequency magnetic field and a low frequency magnetic field, said low frequency magnetic field penetrating more into a thickness dimension of said coin than said high frequency magnetic field thereby causing said high frequency magnetic field to be more influenced by a surface area of said coin and said low frequency magnetic field to be more influenced by a volume of said coin.

112. The coin processing machine of claim 111, wherein said reception coils detect a phase shift and amplitude shift associated with both said high frequency magnetic field and said low frequency magnetic field, said processor determining a type of coin being sensed based on said phase shifts in said amplitude shifts associated with said high frequency magnetic field and said low frequency magnetic field.

113. The coin processing machine of claim 112, wherein said high frequency signal oscillates at approximately 480 KHz and said low frequency signal oscillates at about 30 KHz.

114. The coin processing machine of claim 97, wherein said transmission coil produces a magnetic field at two frequencies.

115. The coin processing machine of claim 114, wherein said reception coils detect a phase shift and amplitude shift for each of said two frequencies.

116. The coin processing machine of claim 115, wherein said reception coils are configured to have a dimension that is larger than a diameter of the largest coins to be processed for a certain coin set.

117. The coin processing machine of claim 116, wherein said discrimination sensor has a generally rectangular shape.

118. The coin processing machine of claim 116, wherein said transmission coil is configured to have a dimension that is larger than a diameter of the largest coins to be processed for a certain coin set.

119. The coin processing machine of claim 116, wherein said high frequency signal oscillates at a frequency at least eight times greater than the frequency at which said low frequency signal oscillates.

120. The coin processing machine of claim 116, wherein said high frequency signal oscillates at a frequency at least twelve times greater than the frequency at which said low frequency signal oscillates.

121. A discrimination sensor for determining an authenticity of coins in a coin processing machine, comprising:

a transmission coil for producing a magnetic field over a coin path in said coin processing machine, said magnetic field coupling to said coins to induce eddy currents within said coin; and

two reception coils configured to detect signals corresponding to said eddy currents, said signals being indicative of a metal content, a coin thickness, and a coin diameter for each coin passing along said coin path.

122. The discrimination sensor of claim 121, wherein said transmission coil receives a composite signal including a high frequency component and a low frequency component.

123. The discrimination sensor of claim 122, wherein said low frequency component is indicative of information about a thickness of said coin and said high frequency is indicative of information about a diameter of said coin.

124. The discrimination sensor of claim 123, wherein said reception coils detect a phase shift and amplitude shift associated with both said high frequency component and said low frequency component.

125. The discrimination sensor of claim 121, wherein said transmission coil and said reception coils are located on the same side of said coin path.

126. The discrimination sensor of claim 125, wherein said transmission coil produces a magnetic field at a high frequency and a low frequency.

127. The discrimination sensor of claim 126, wherein said low frequency provides information about a thickness of said coin and said high frequency provides information about a diameter of said coin.

128. The discrimination sensor of claim 127, wherein said reception coils detect a phase shift and amplitude shift for both said high frequency and said low frequency.

129. The discrimination sensor of claim 127, wherein a first of said two reception coils is positioned proximal to said coin path and a second of said two reception coils is positioned in a distal relationship relative to said first of said two reception coils.

130. The discrimination sensor of claim 127, wherein said transmission coil substantially surrounds said two reception coils.

131. A method of determining characteristics of a coin and a coin processing machine, comprising:

moving said coin along a coin path within said coin processing machine;

inducing eddy currents in said coin by subjecting said coin to a magnetic field of a high frequency and a low frequency;

detecting signals corresponding to said eddy currents that are indicative of a coin diameter, a coin thickness, and a composition of said coin; and

processing said signals to determine an identity of said coin.

132. The method of claim 131, wherein said identity of said coin includes an invalid coin for a particular operating session of said coin operating machine.

133. The method of claim 132, further including diverting said invalid coin away from said coin path to a reject station.

134. The method of claim 133, wherein said invalid coin is a non-authentic coin.

135. The method of claim 133, wherein said invalid coin is an authentic coin of a particular denomination.

136. The method of claim 131, wherein said inducing said eddy currents and detecting said signals is accomplished through coils positioned along said coin path on one side of said coin.

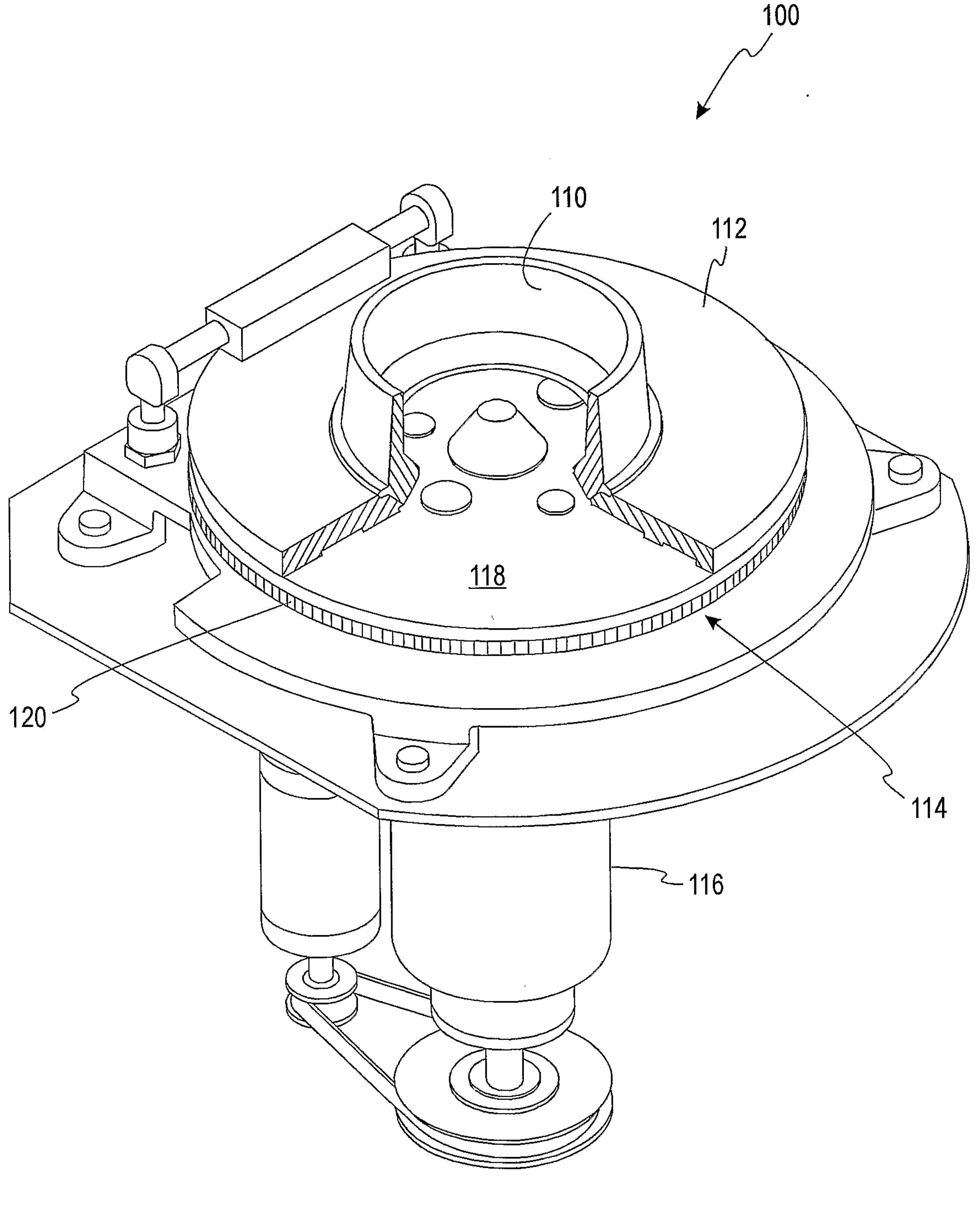


FIG. 1

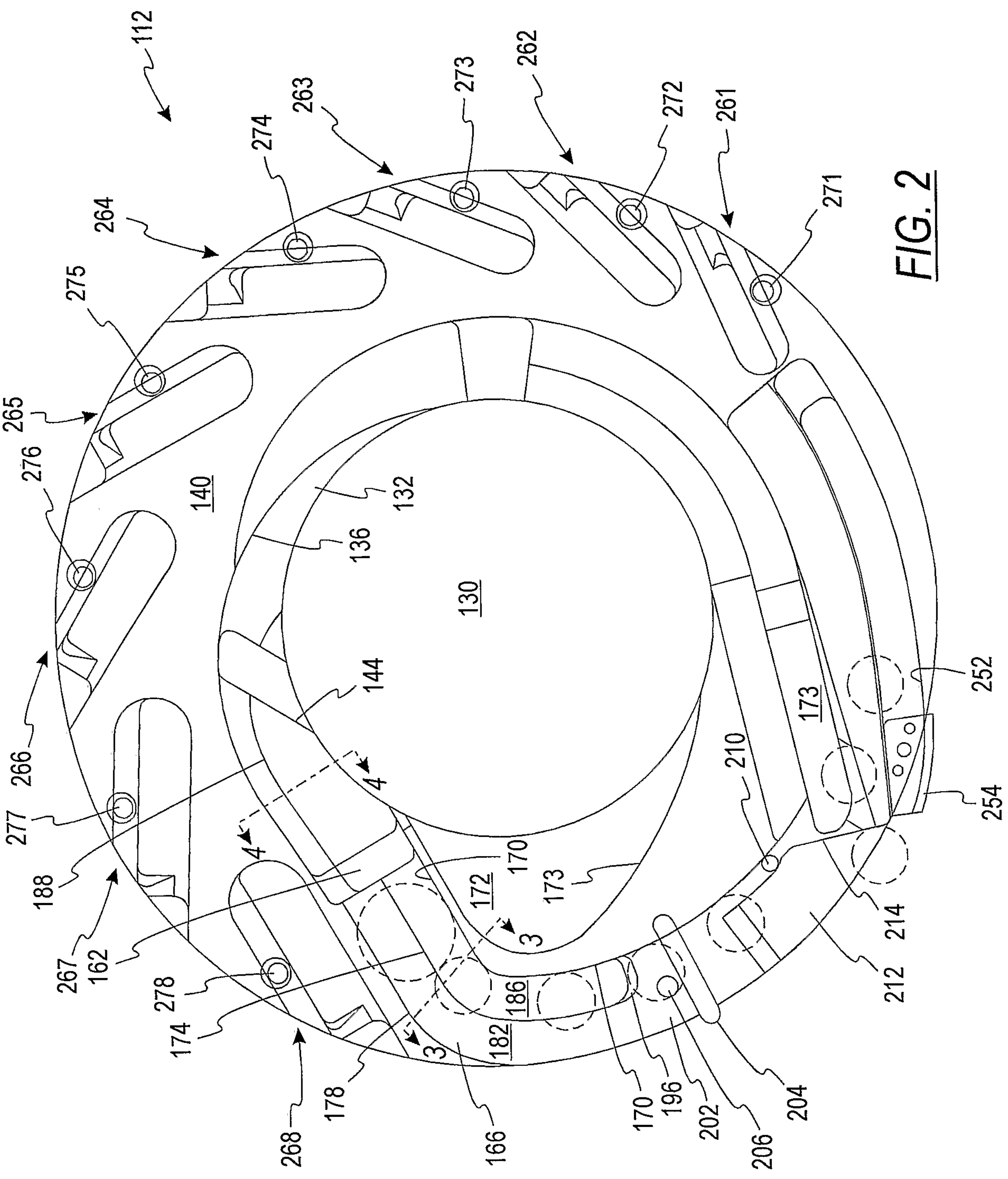

112
261
262
263
264
265
266
267
268
271
272
273
274
275
276
277
278
140
130
132
136
144
188
162
174
178
166
182
186
170
172
173
173
210
212
214
252
254
196
202
204
206
170
3
3
4
4

FIG. 2

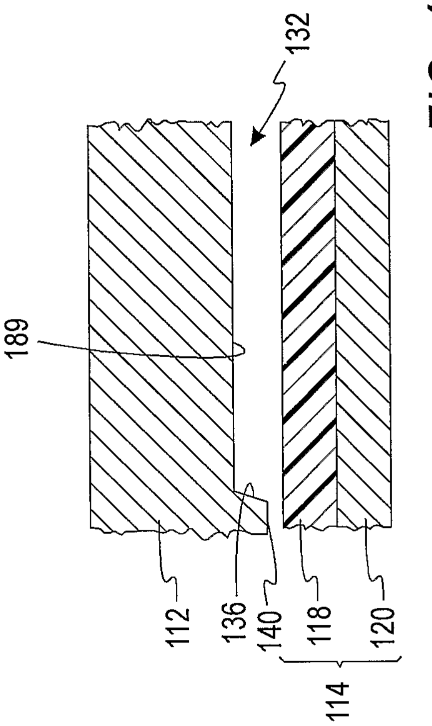


FIG. 4b

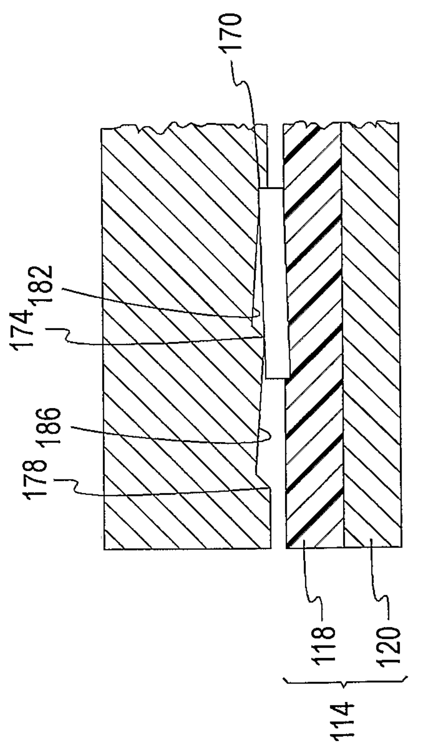


FIG. 3

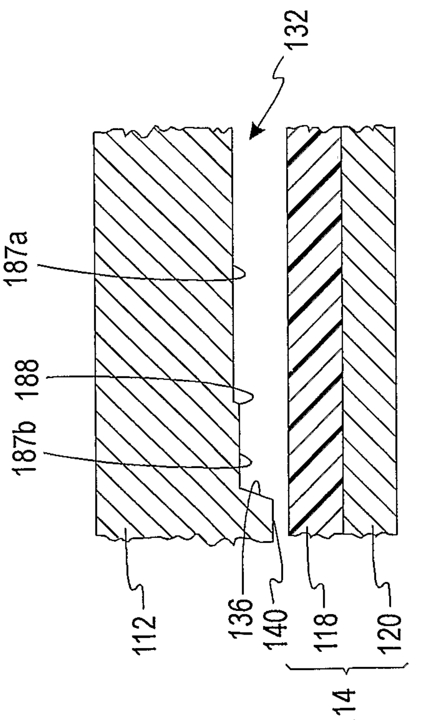


FIG. 4a

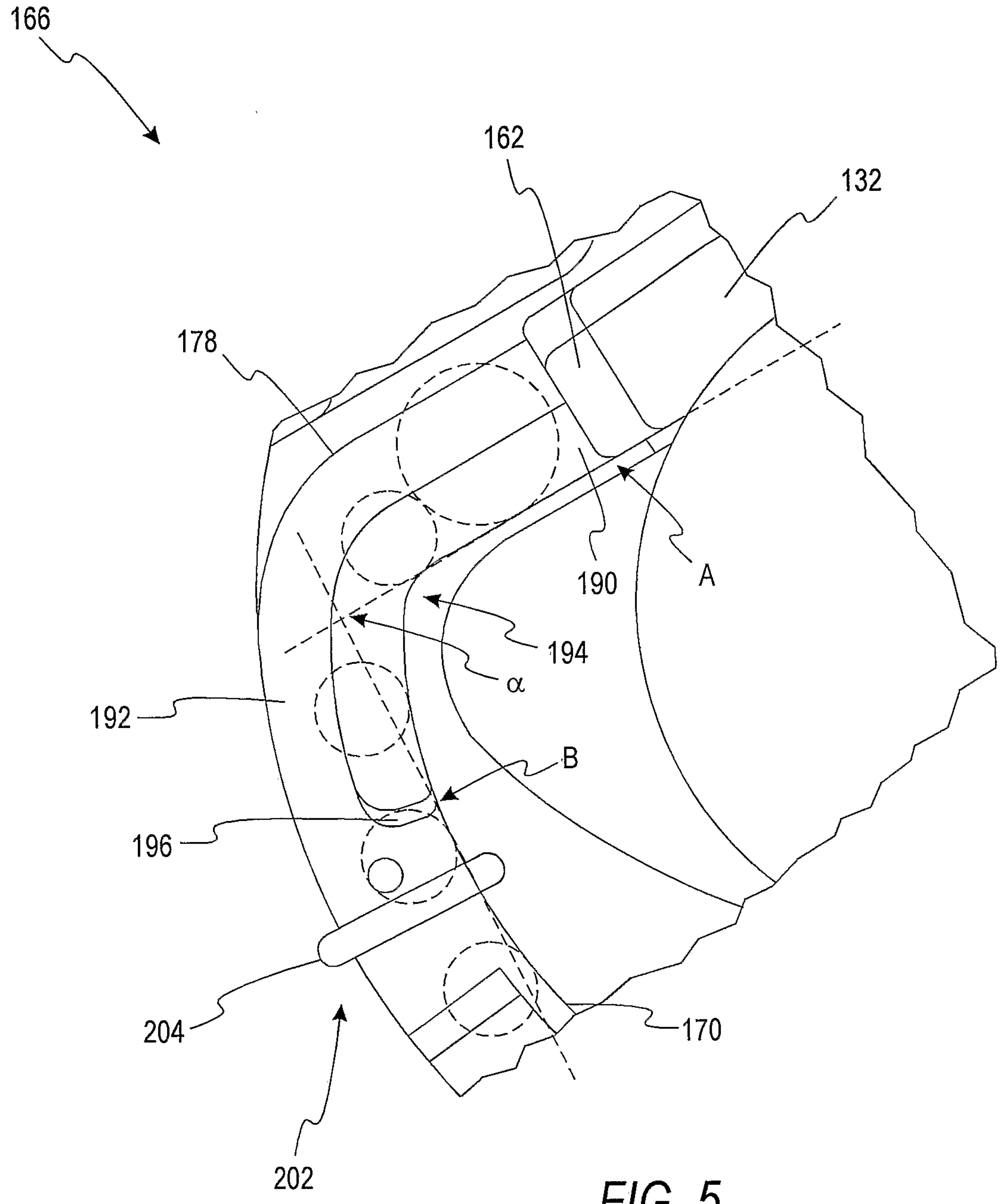


FIG. 5

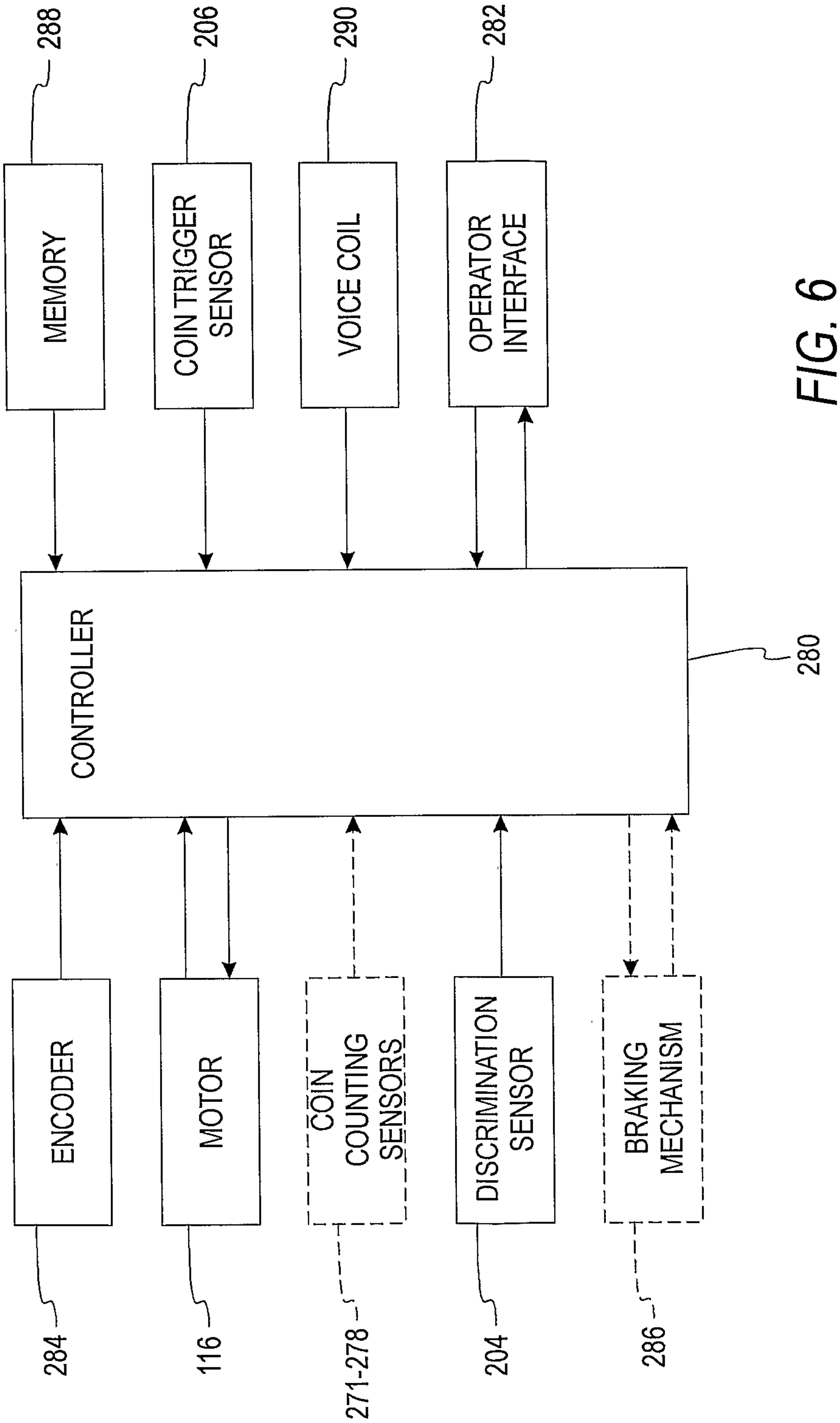

MEMORY
COIN TRIGGER SENSOR
VOICE COIL
OPERATOR INTERFACE
288
206
290
282
CONTROLLER
280
ENCODER
MOTOR
COIN COUNTING SENSORS
DISCRIMINATION SENSOR
BRAKING MECHANISM
284
116
271-278
204
286

FIG. 6

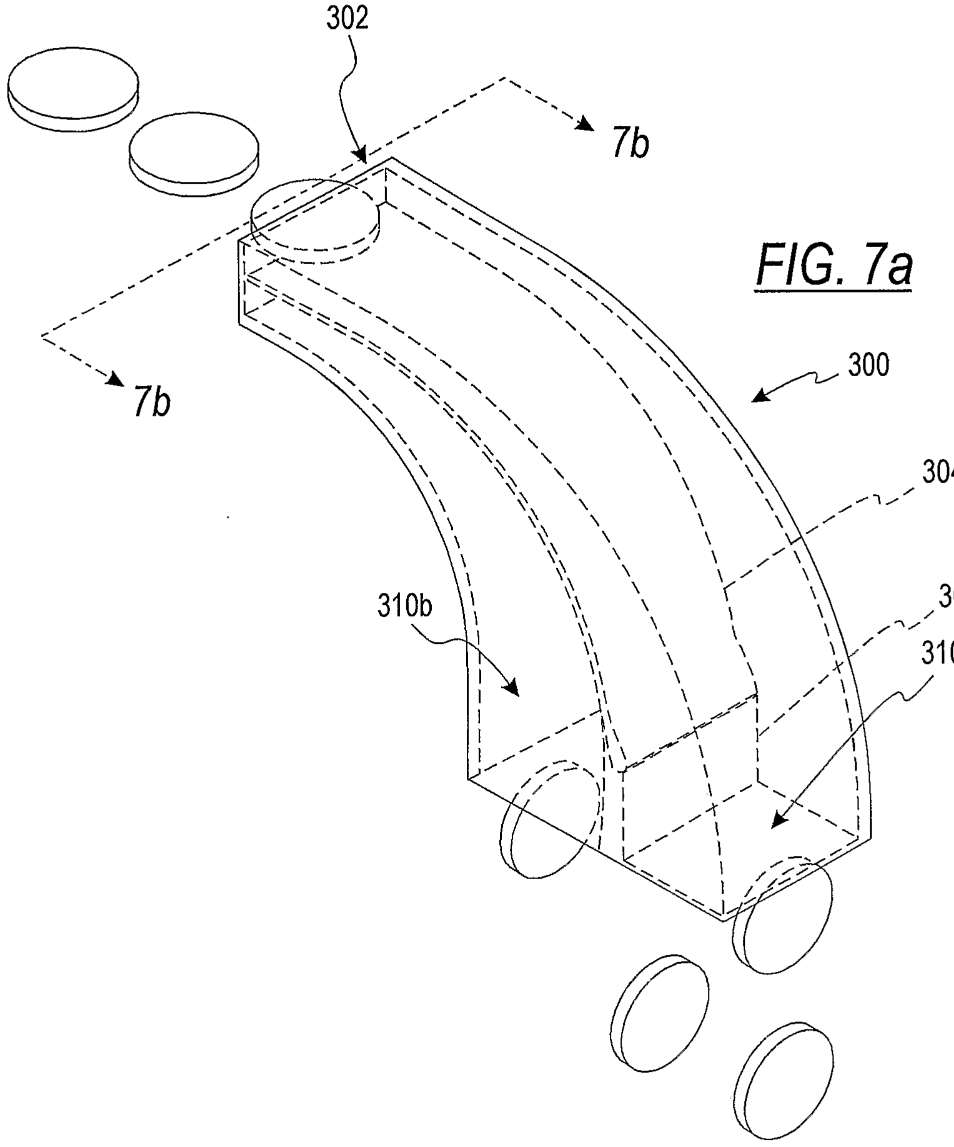

302
7b
7b
300
304
310b
306
310a

FIG. 7a

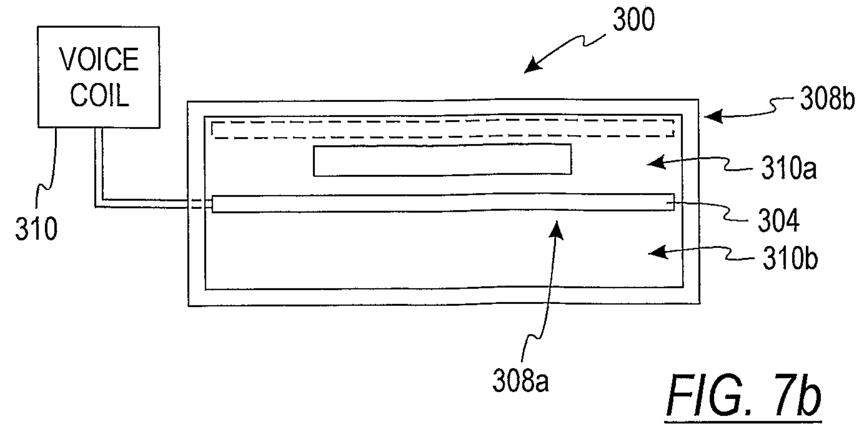

VOICE COIL
300
308b
310a
304
310b
310
308a

FIG. 7b

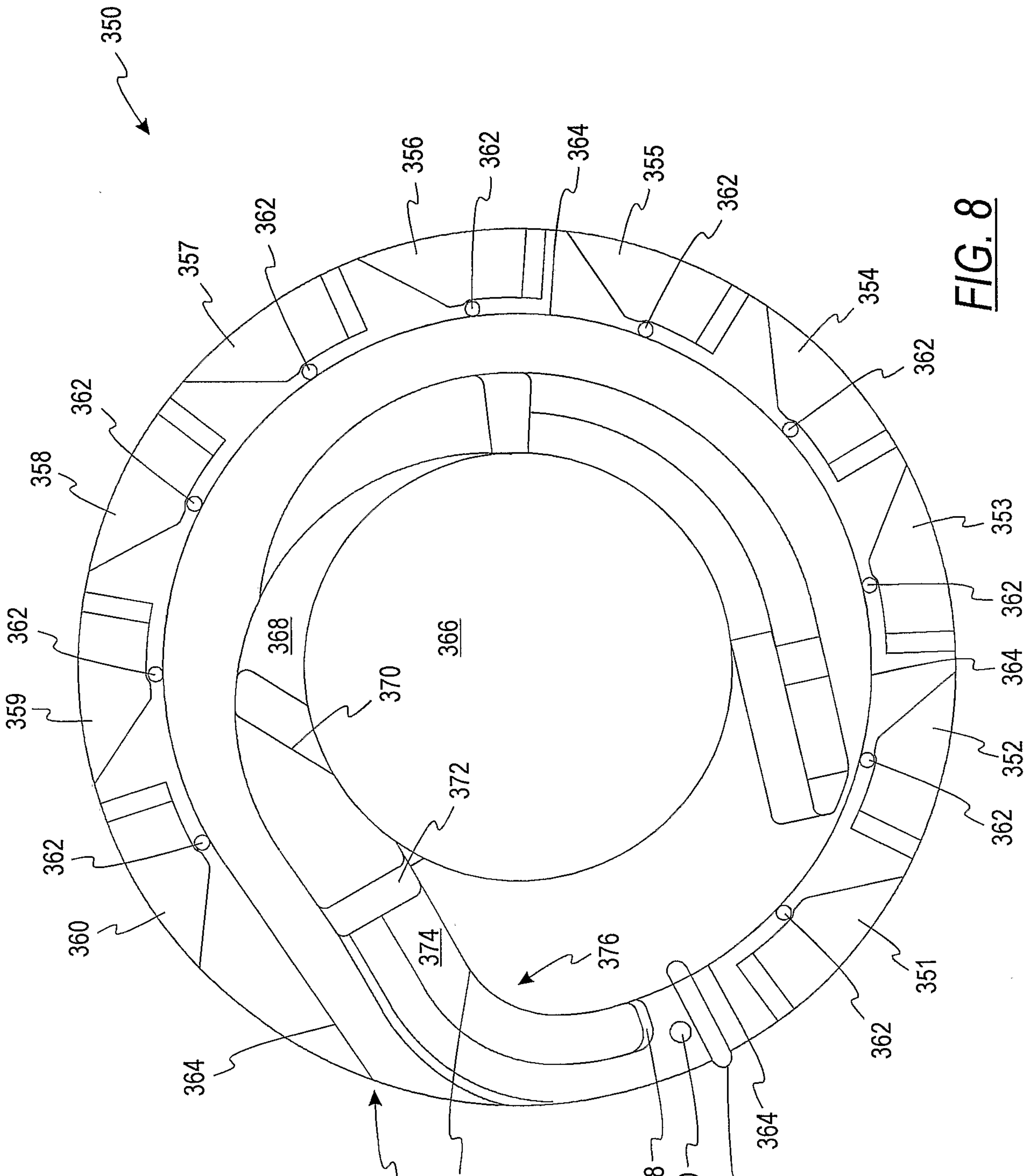

350
356
362
364
355
362
357
362
354
362
358
362
353
362
368
366
362
359
370
364
352
362
372
362
360
374
376
362
351
364
364
C
364
378
380
385
364

FIG. 8

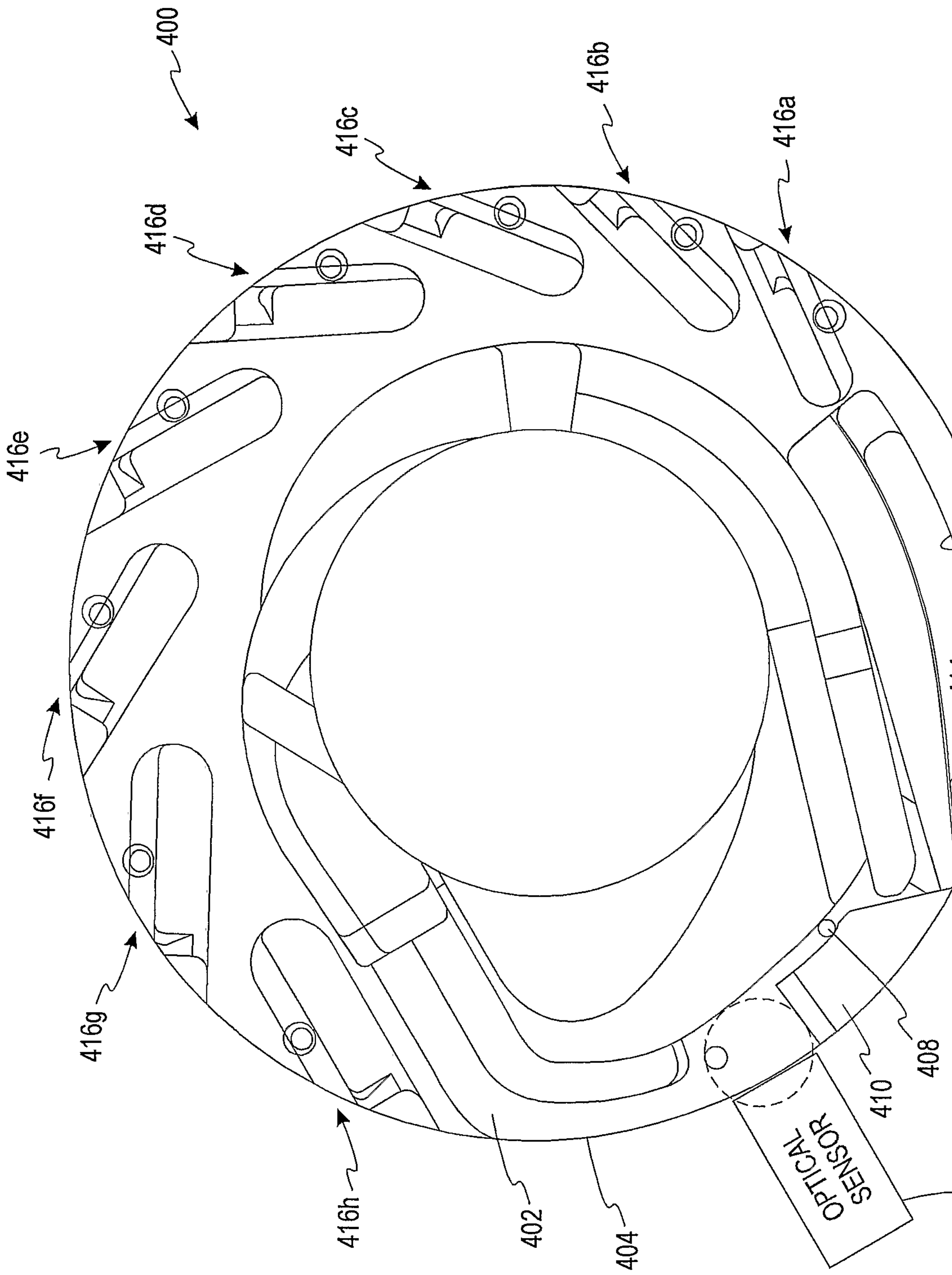

400
416a
416b
416c
416d
416e
416f
416g
416h
412
414
402
404
406
408
410
OPTICAL SENSOR

FIG. 9

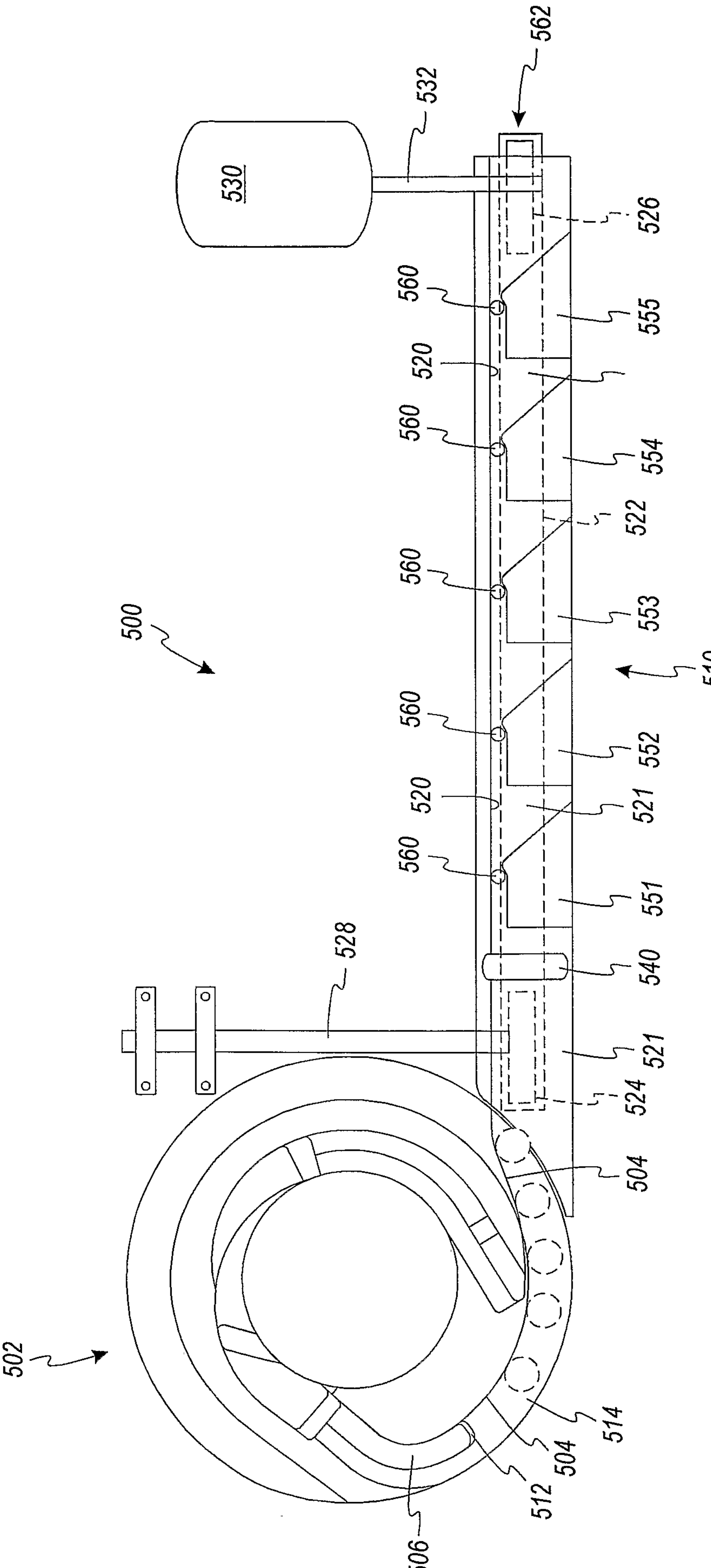

500
502
504
504
506
510
512
514
520
520
521
521
522
524
526
528
530
532
540
551
552
553
554
555
560
560
560
560
560
562

FIG. 10

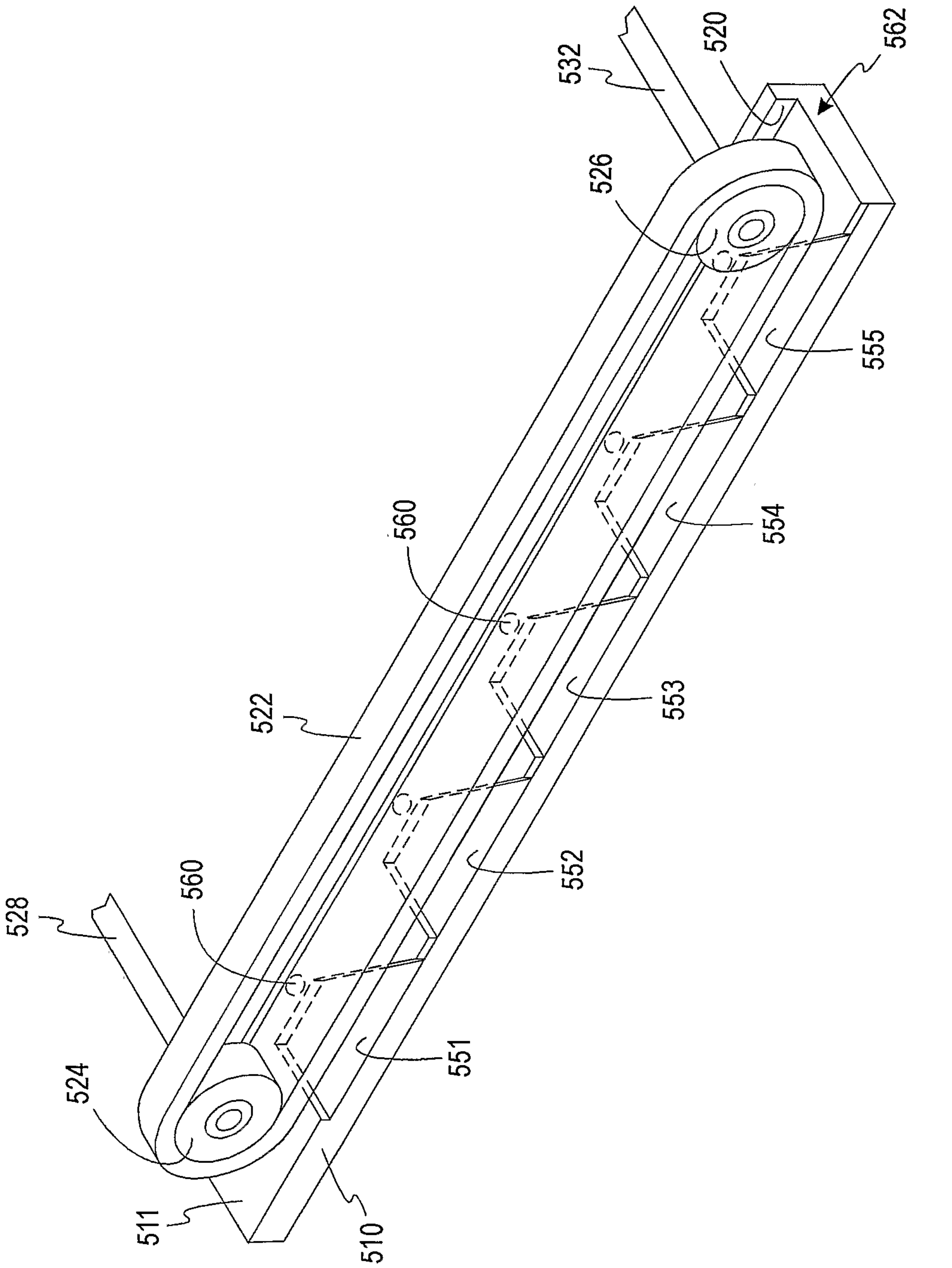


FIG. 11

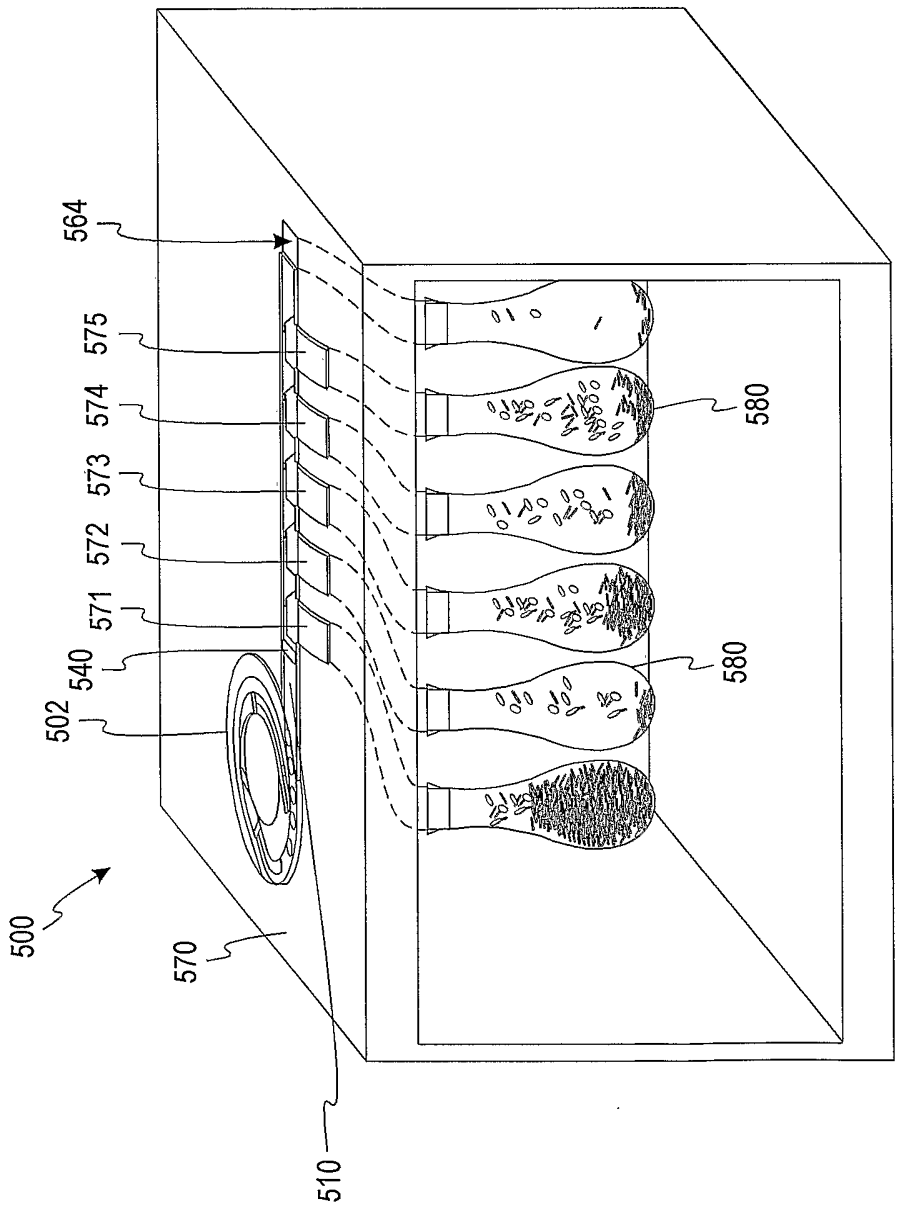


FIG. 12

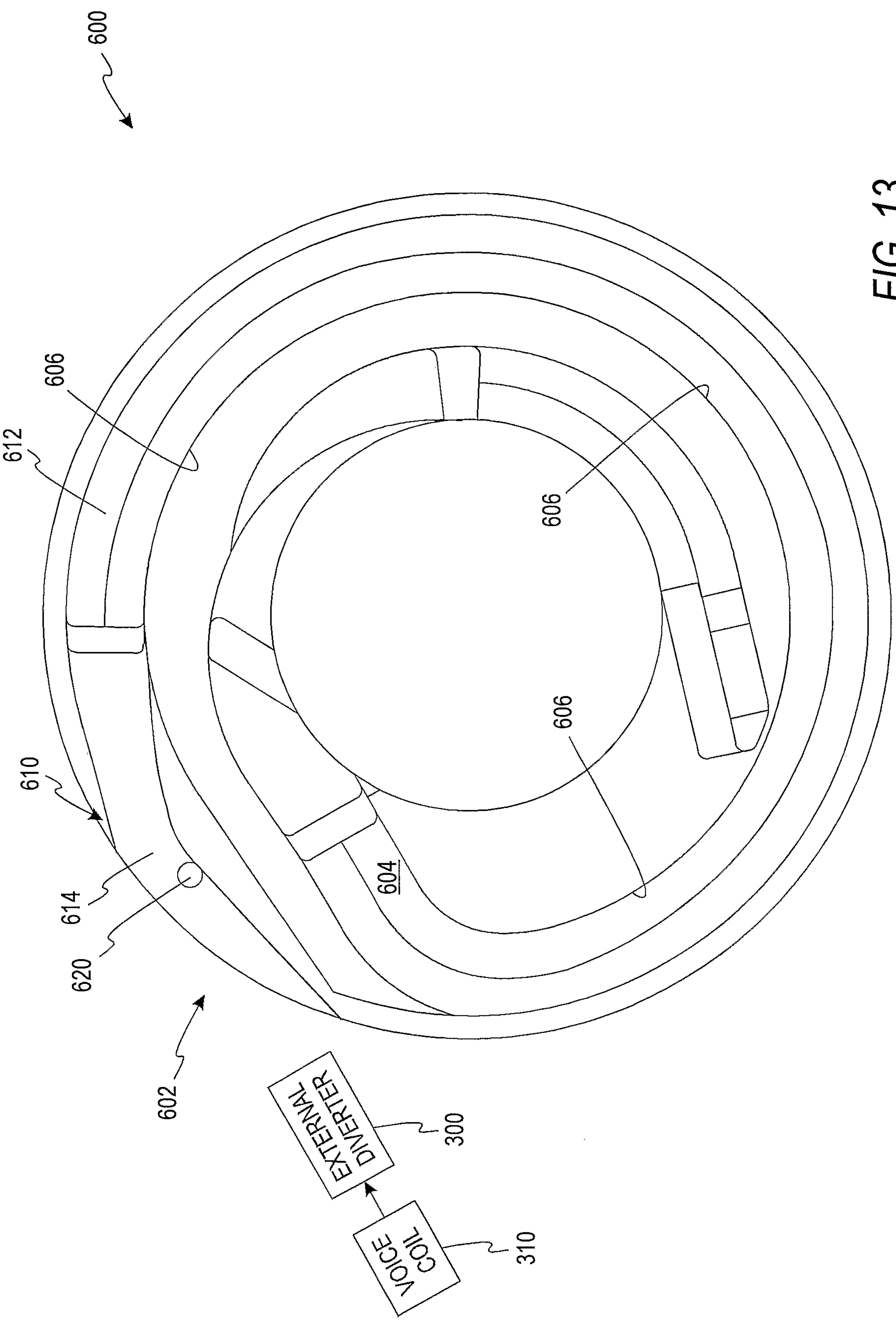

600
606
612
606
606
610
614
620
604
602
EXTERNAL DIVERTER
300
VOICE COIL
310

FIG. 13

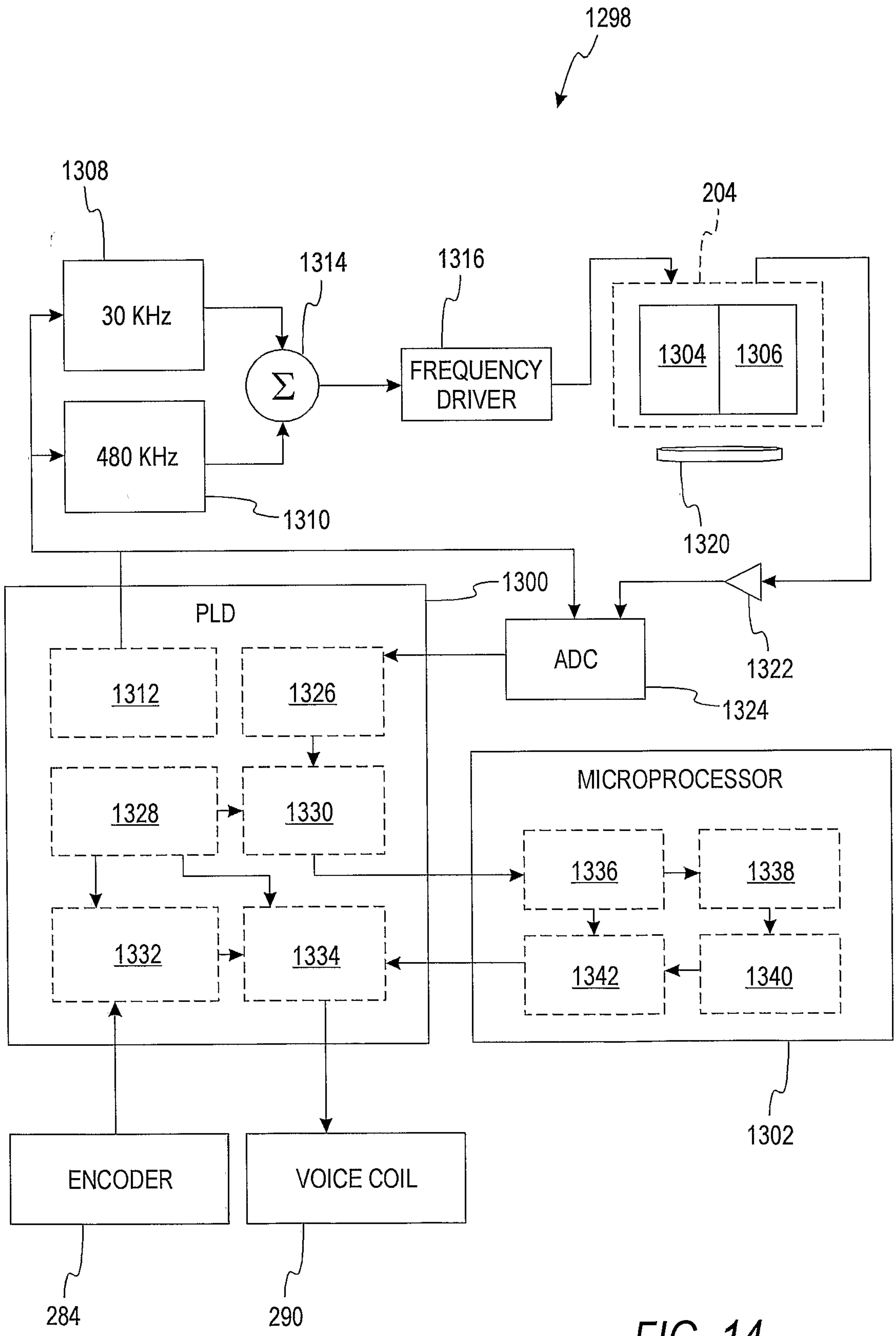

1298
1308
30 KHz
480 KHz
1310
1314
Σ
1316
FREQUENCY DRIVER
204
1304
1306
1320
1322
1300
PLD
1312
1326
1328
1330
1332
1334
ADC
1324
MICROPROCESSOR
1336
1338
1342
1340
1302
ENCODER
VOICE COIL
284
290

FIG. 14

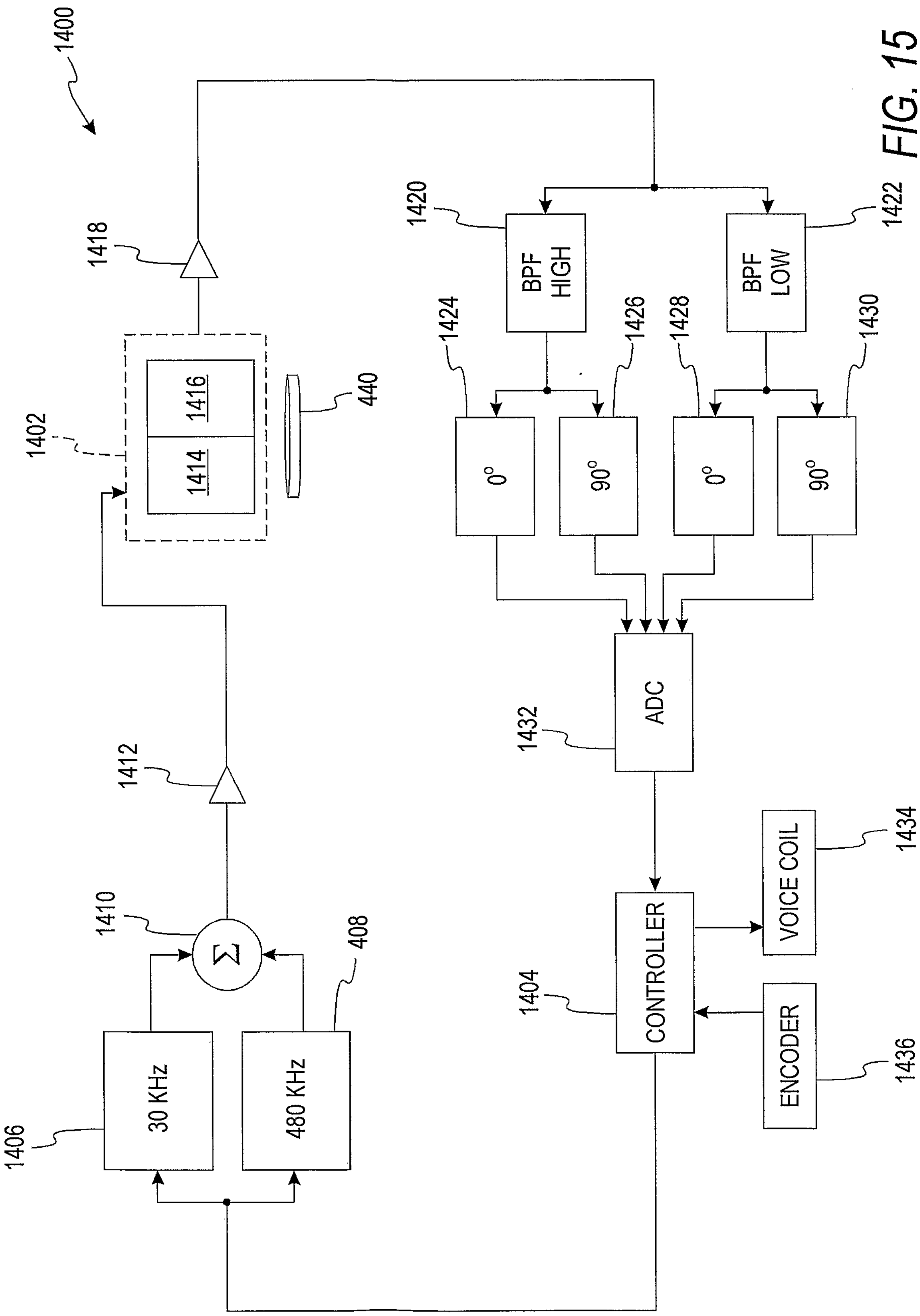

1400
1418
1402
1416
1414
440
1412
1410
408
1406
30 KHz
480 KHz
1420
1422
BPF HIGH
BPF LOW
1424
1426
1428
1430
0°
90°
0°
90°
ADC
1432
CONTROLLER
1404
VOICE COIL
1434
ENCODER
1436

FIG. 15

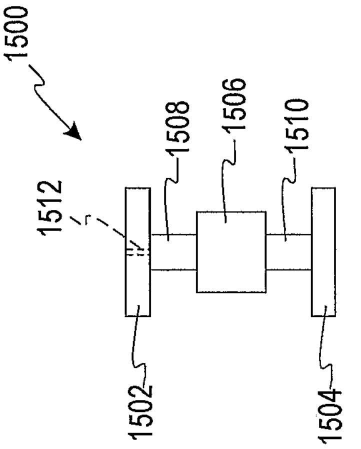


FIG. 16c

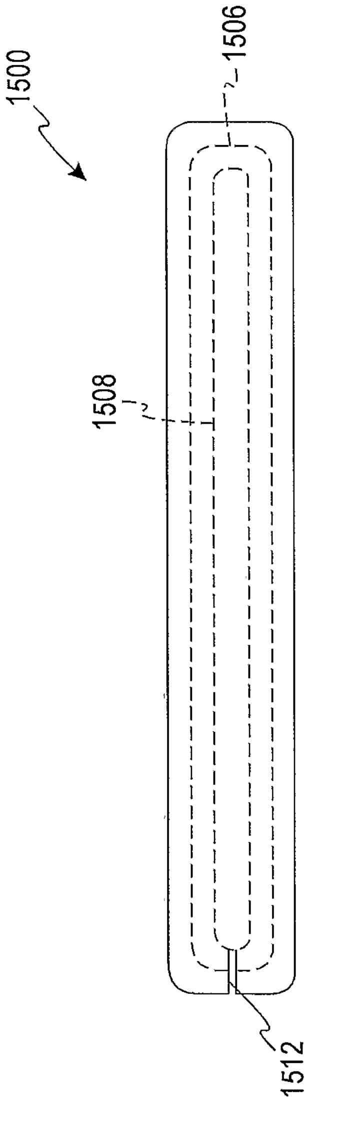


FIG. 16a

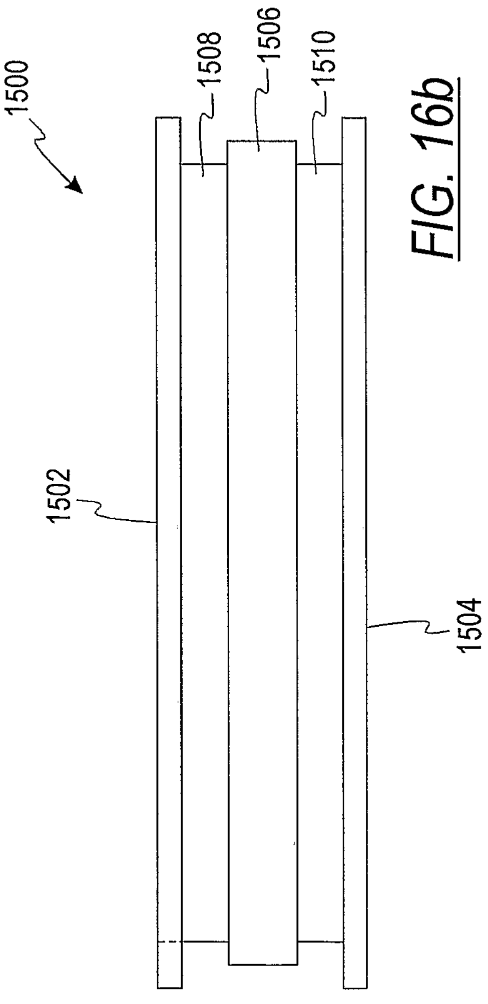


FIG. 16b

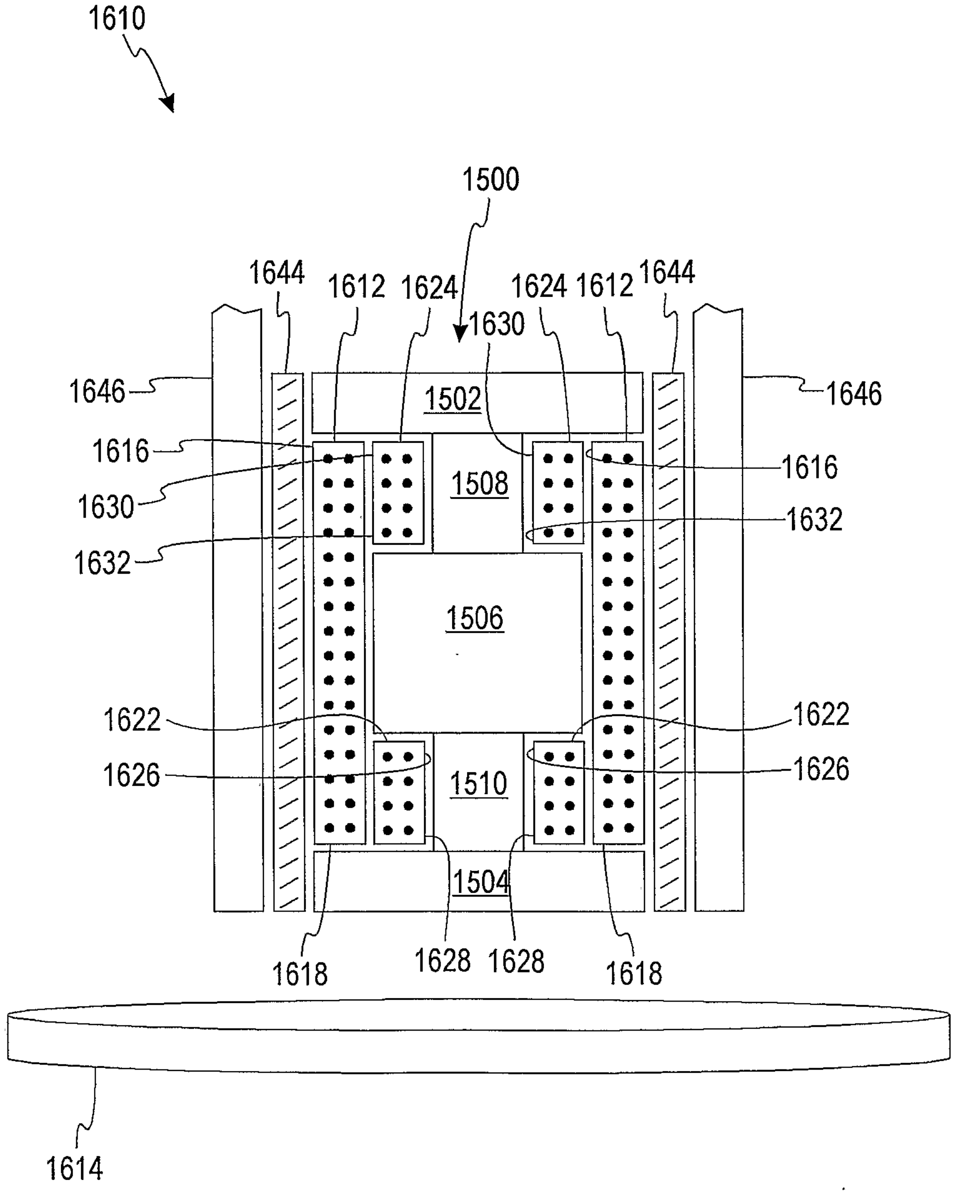

1610
1500
1644
1612
1624
1630
1624
1612
1644
1646
1502
1646
1616
1508
1616
1630
1632
1632
1506
1622
1622
1626
1510
1626
1504
1618
1628
1628
1618
1614

FIG. 17

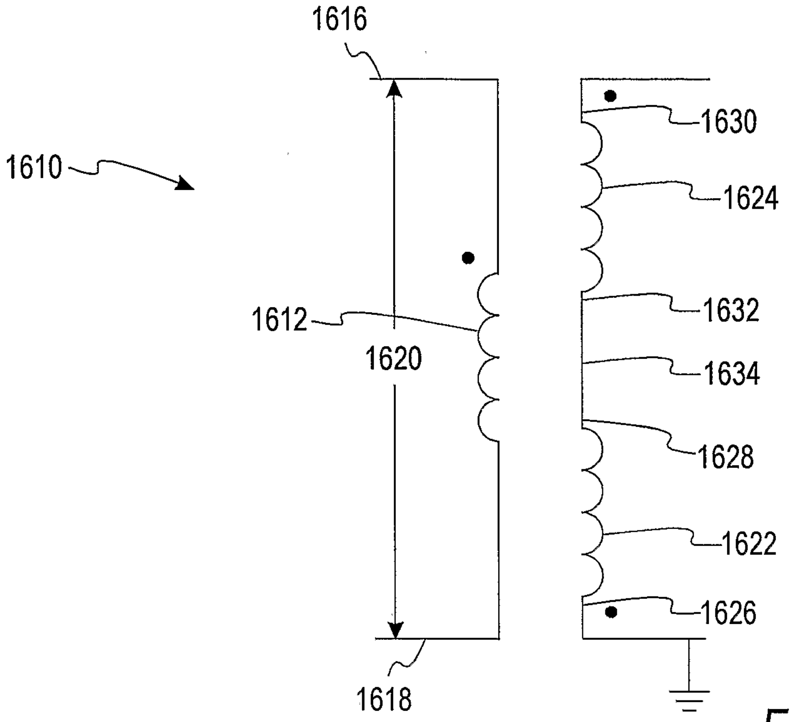

1616
1610
1612
1620
1618
1630
1624
1632
1634
1628
1622
1626

FIG. 18

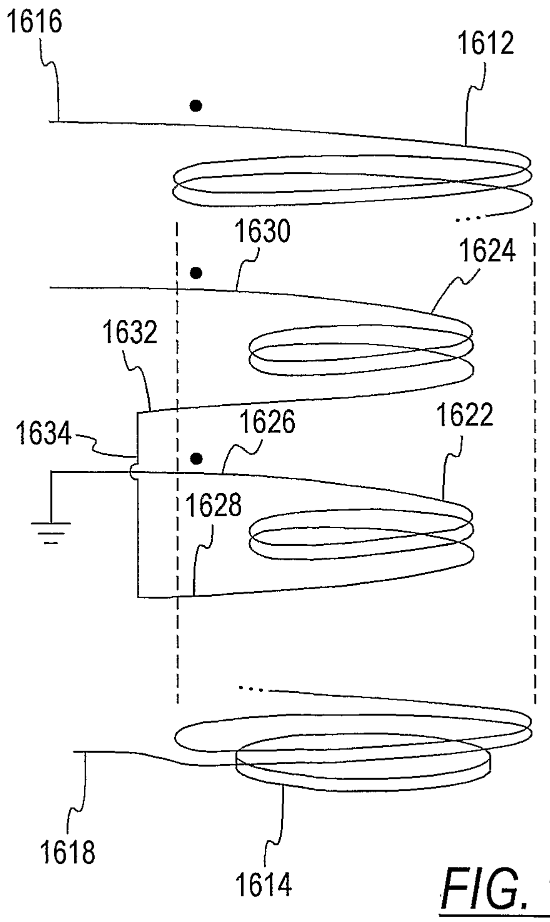

1616
1612
1630
1624
1632
1634
1626
1622
1628
1618
1614

FIG. 19

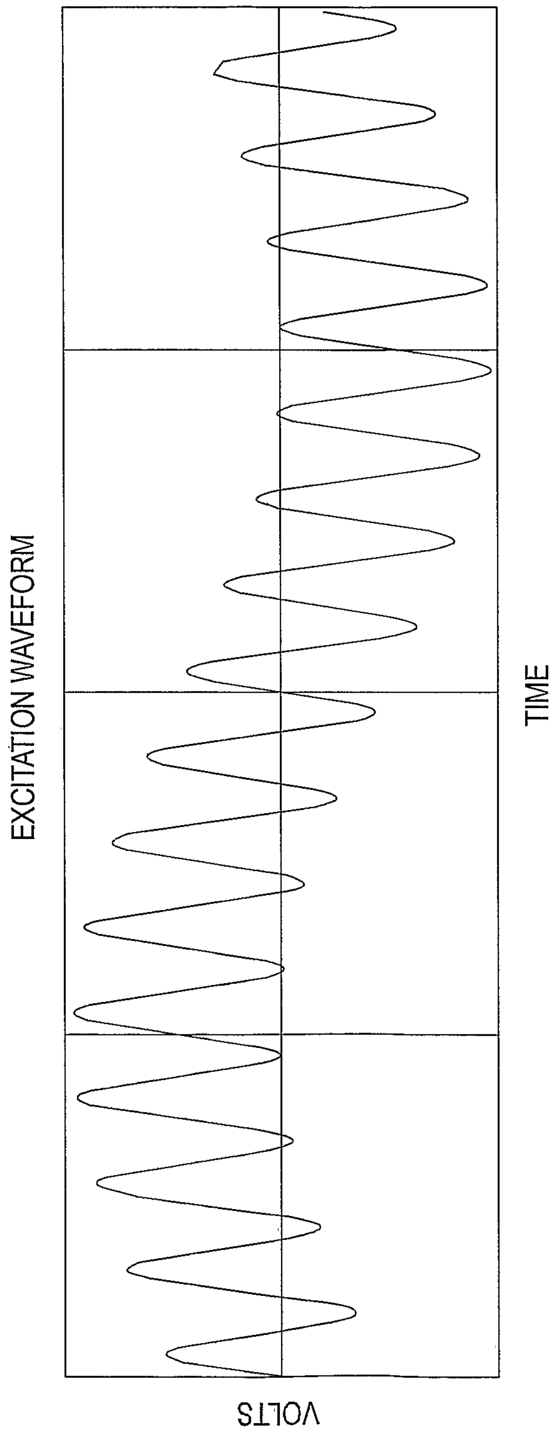


FIG. 20

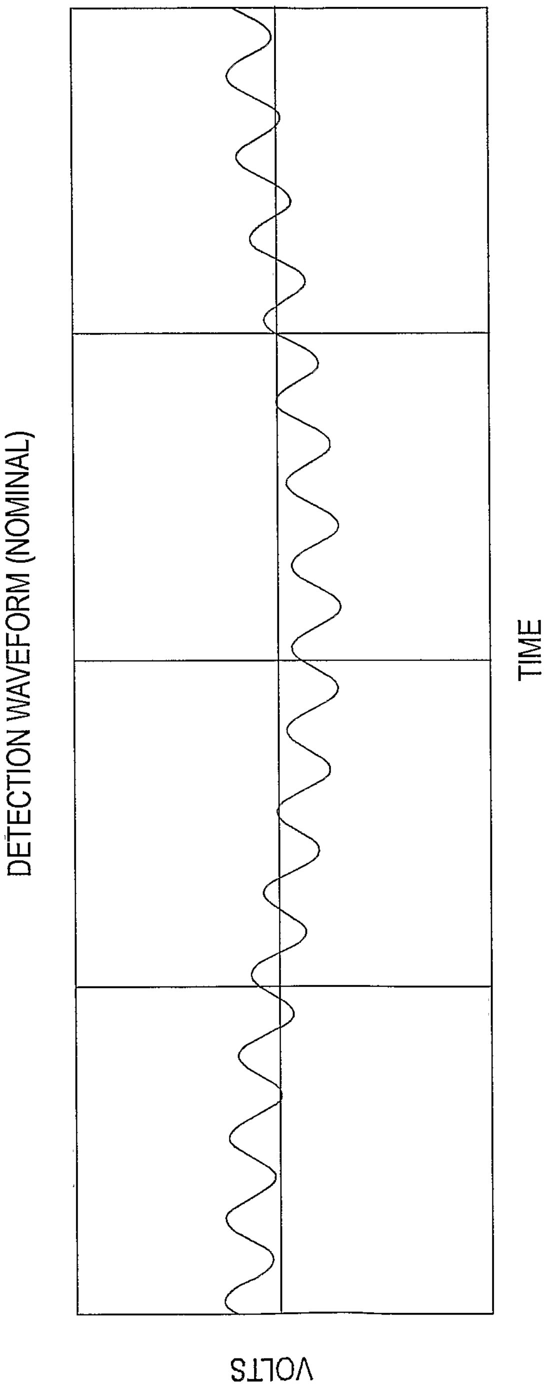


FIG. 21

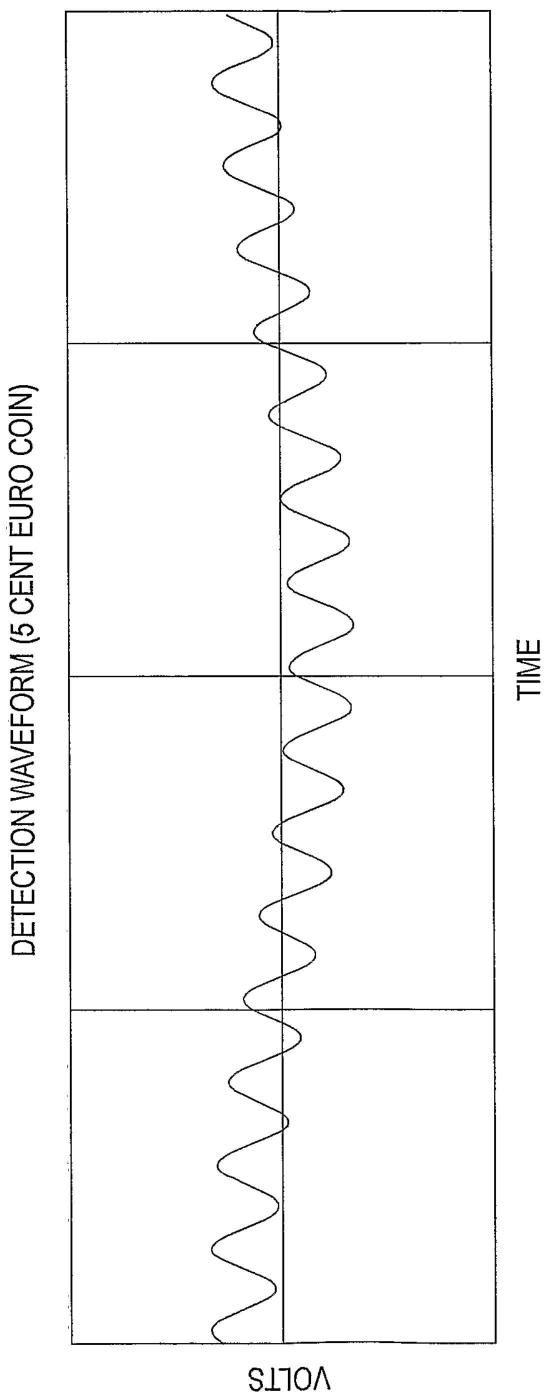


FIG. 22

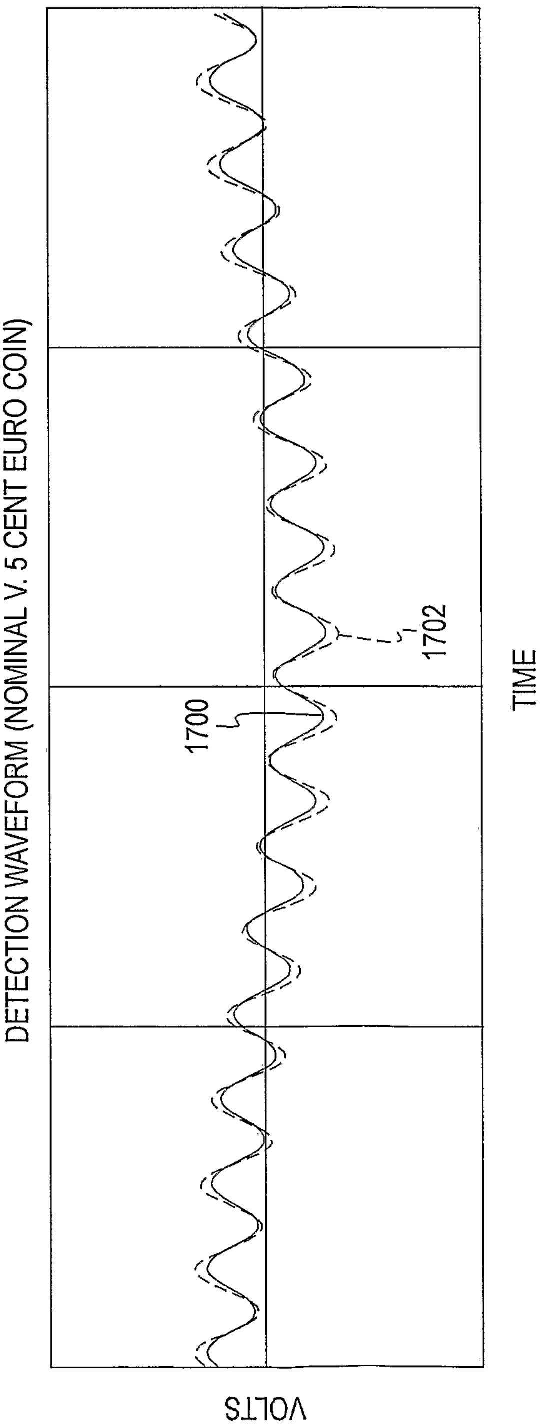

DETECTION WAVEFORM (NOMINAL V. 5 CENT EURO COIN)
1700
1702
TIME
VOLTS

FIG. 23

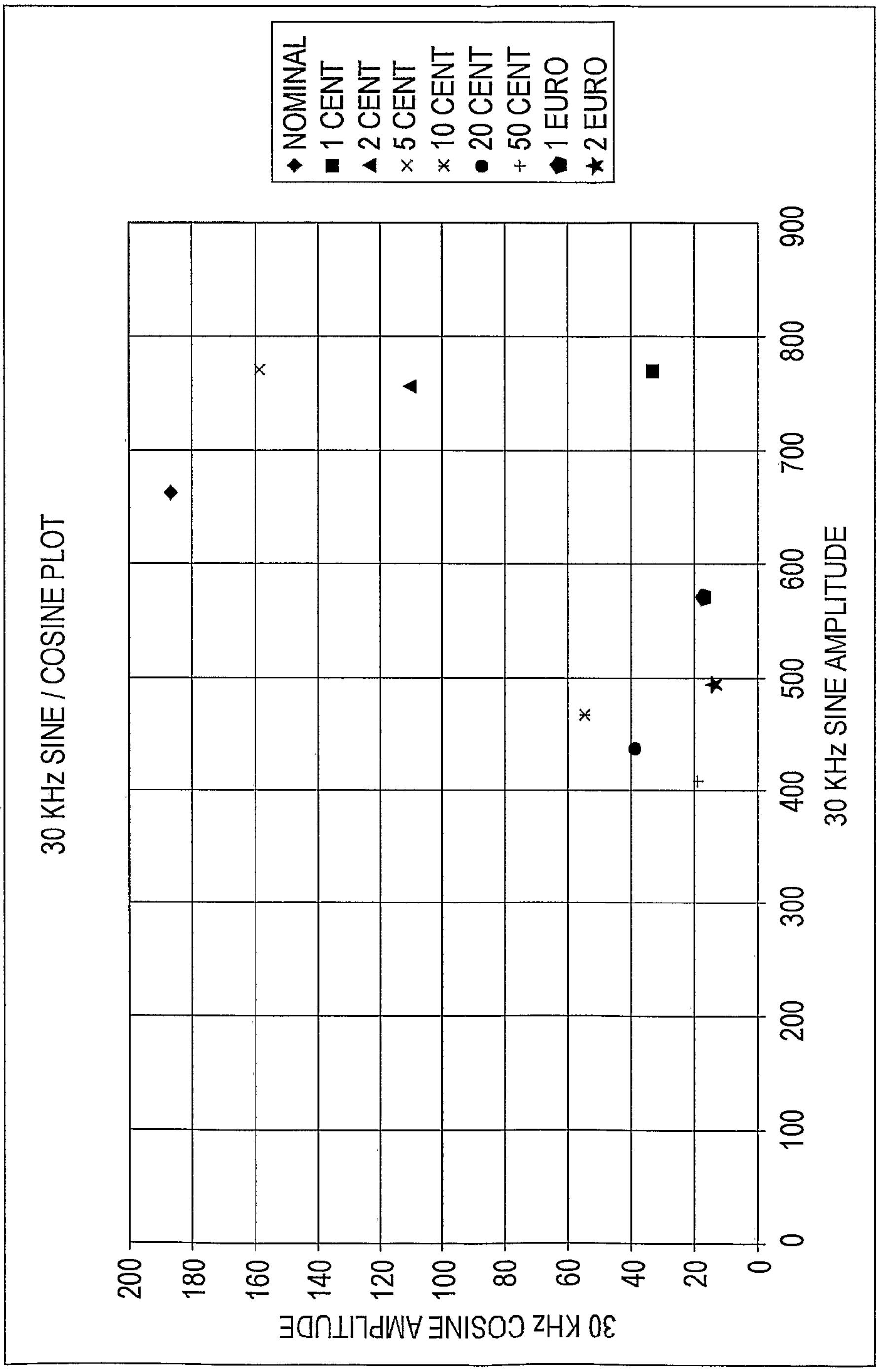

30 KHz SINE / COSINE PLOT
NOMINAL
1 CENT
2 CENT
5 CENT
10 CENT
20 CENT
50 CENT
1 EURO
2 EURO
30 KHz COSINE AMPLITUDE
200
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
30 KHz SINE AMPLITUDE

FIG. 24

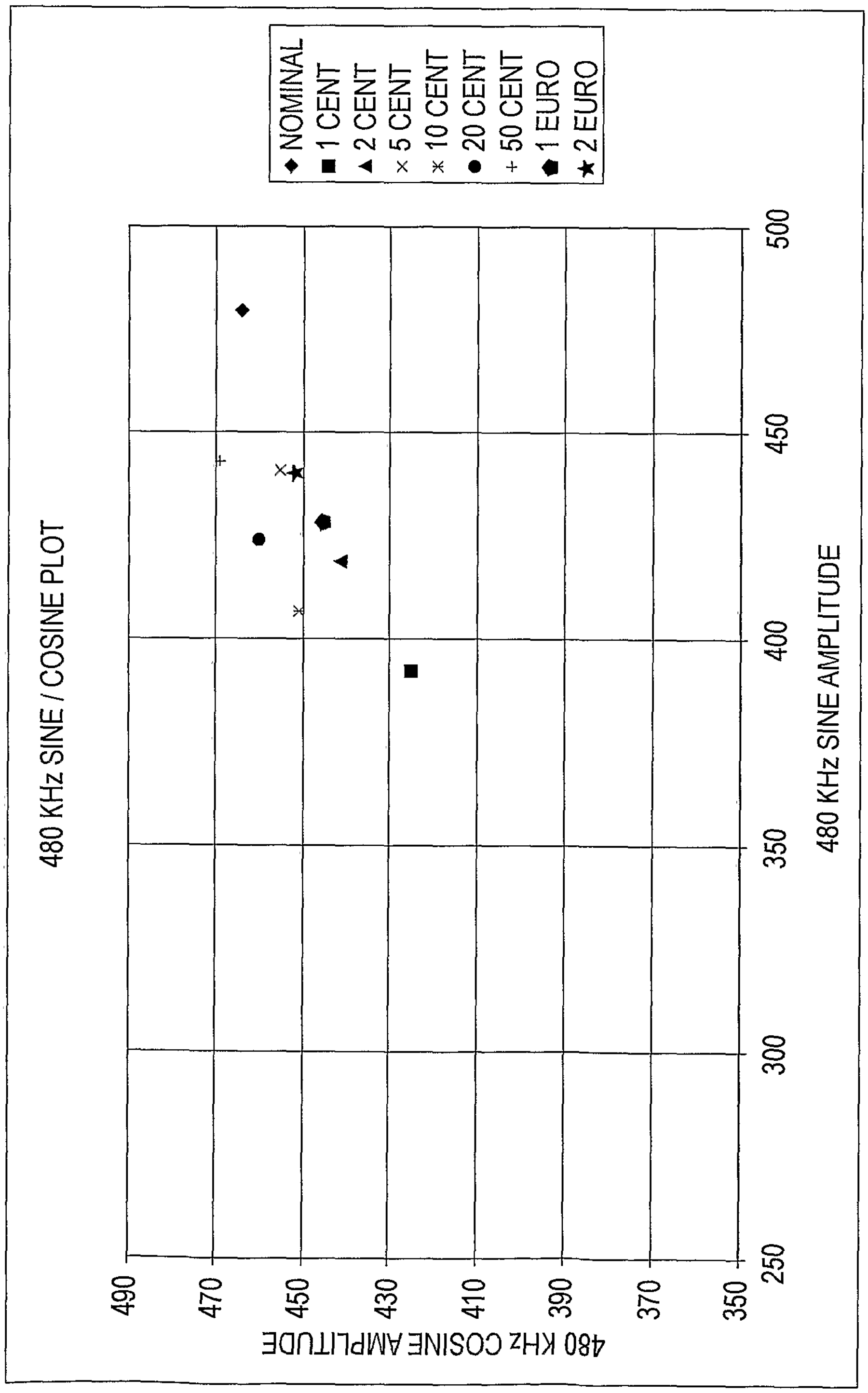

480 KHz SINE / COSINE PLOT
480 KHz COSINE AMPLITUDE
490
470
450
430
410
390
370
350
250
300
350
400
450
500
480 KHz SINE AMPLITUDE
NOMINAL
1 CENT
2 CENT
5 CENT
10 CENT
20 CENT
50 CENT
1 EURO
2 EURO

FIG. 25

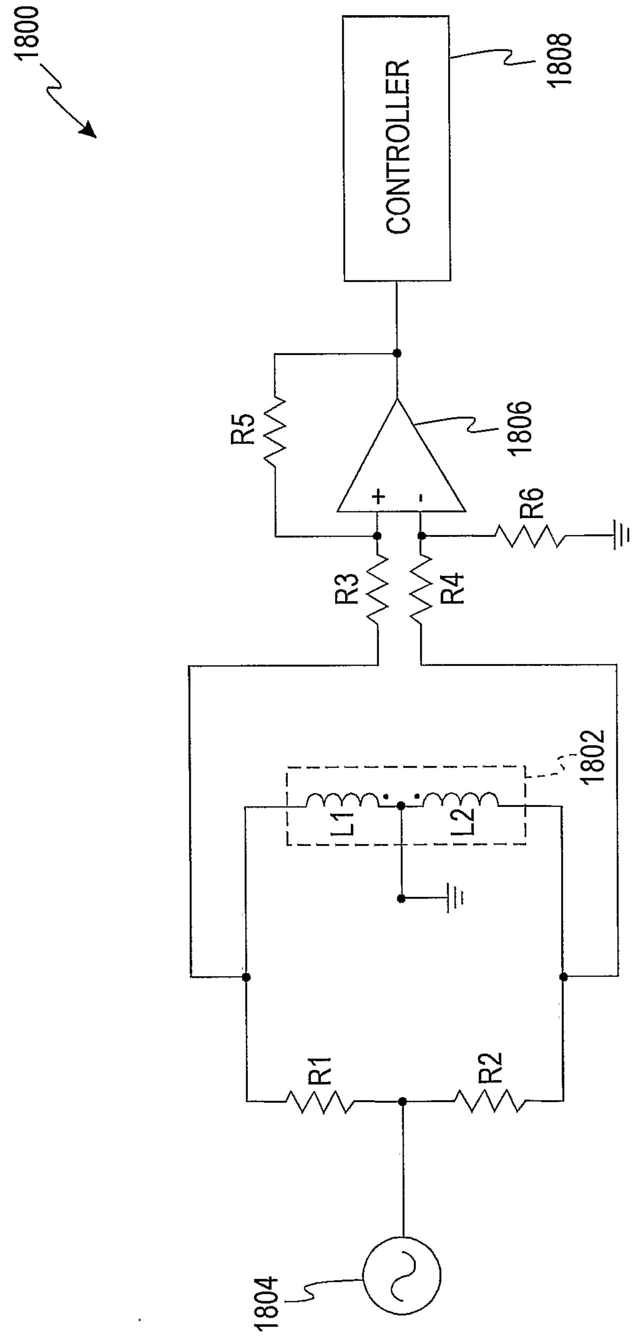


FIG. 26

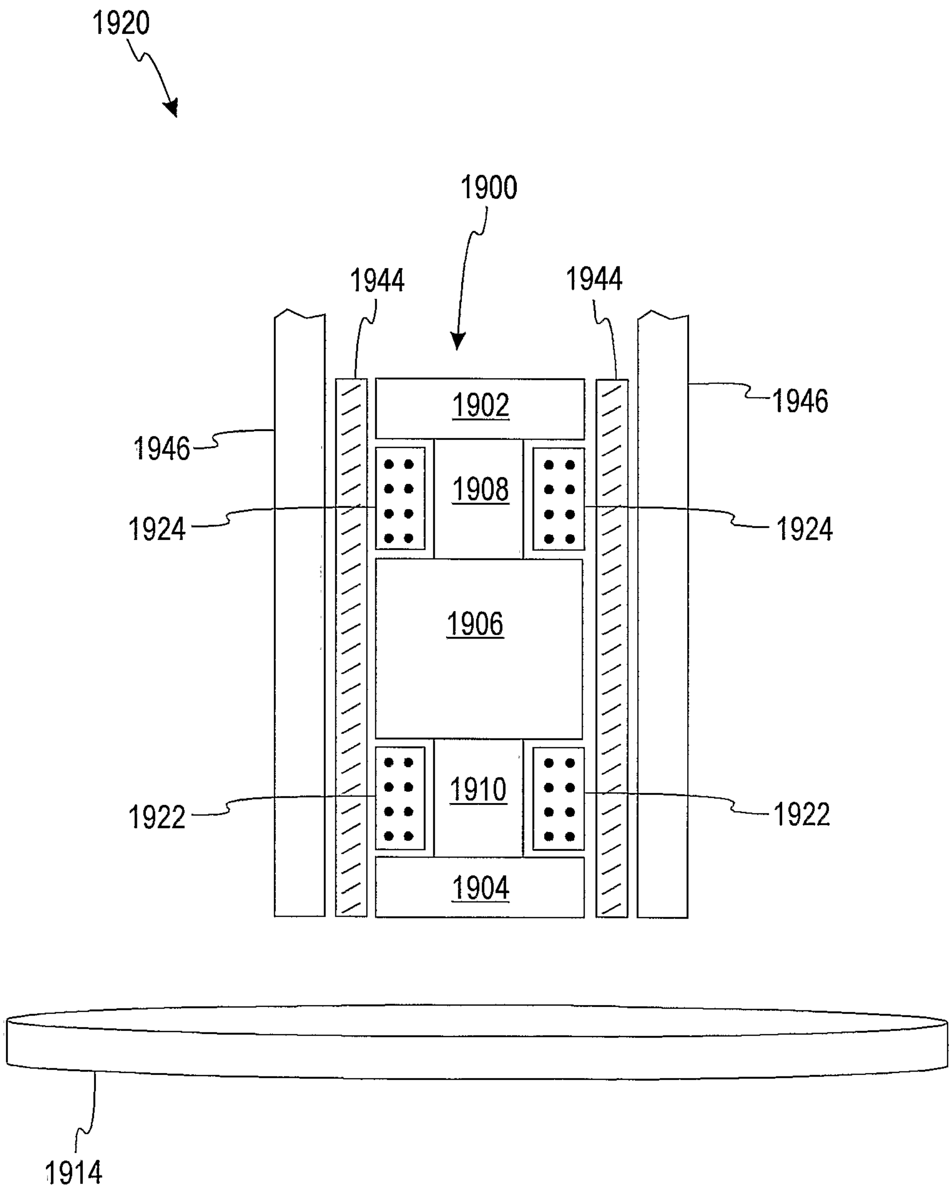

1920
1900
1944
1944
1902
1946
1946
1908
1924
1924
1906
1910
1922
1922
1904
1914

FIG. 27

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/06762

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : G07D 7/00
US CL : 194/302
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 194/302

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
East

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,992,602 A (ZWIEG et al) 30 November 1999 (30.11.1999), entire document.	1-136
A, P	US 6,431,342 B1 (SCHWARTZ) 13 August 2002 (13.08.2002), entire document.	1-136
A, P	US 6,503,138 B2 (SPOEHR et al) 07 January 2003 (07.01.2003), entire document.	1-136
A	US 4,681,128 A (RISTVEDT et al) 21 July 1987 (21.07.1987), entire document.	1-136
A	US 4,753,625 A (OKADA) 28 June 1988 (28.06.1988), entire document.	1-136

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 May 2003 (02.05.2003)	23 MAY 2003

Name and mailing address of the ISA/US	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703)305-3230	Donald P. Walsh Telephone No. (703)308-1113