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Greene

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[54] **APPARATUS FOR IDENTIFYING COINS**

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[51] **Int. Cl.**^{2}... **G06K 7/14;** G07D 5/00; G07F 1/04

[58] **Field of Search**........ 194/97 A, 97 R, 4 G, 4 R; 250/222, 223, 556, 557, 224, 567, 568; 356/71; 340/146.3 AC; 235/61.11 E, 61.11 F, 61.11 K

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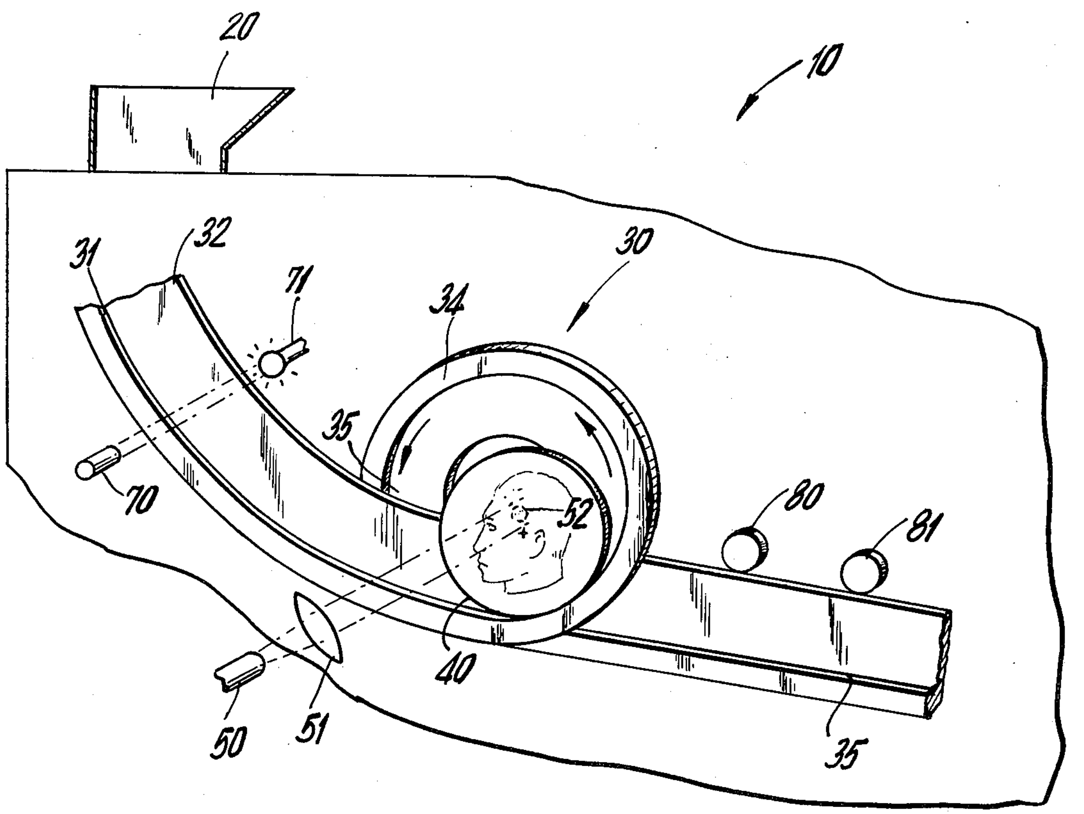
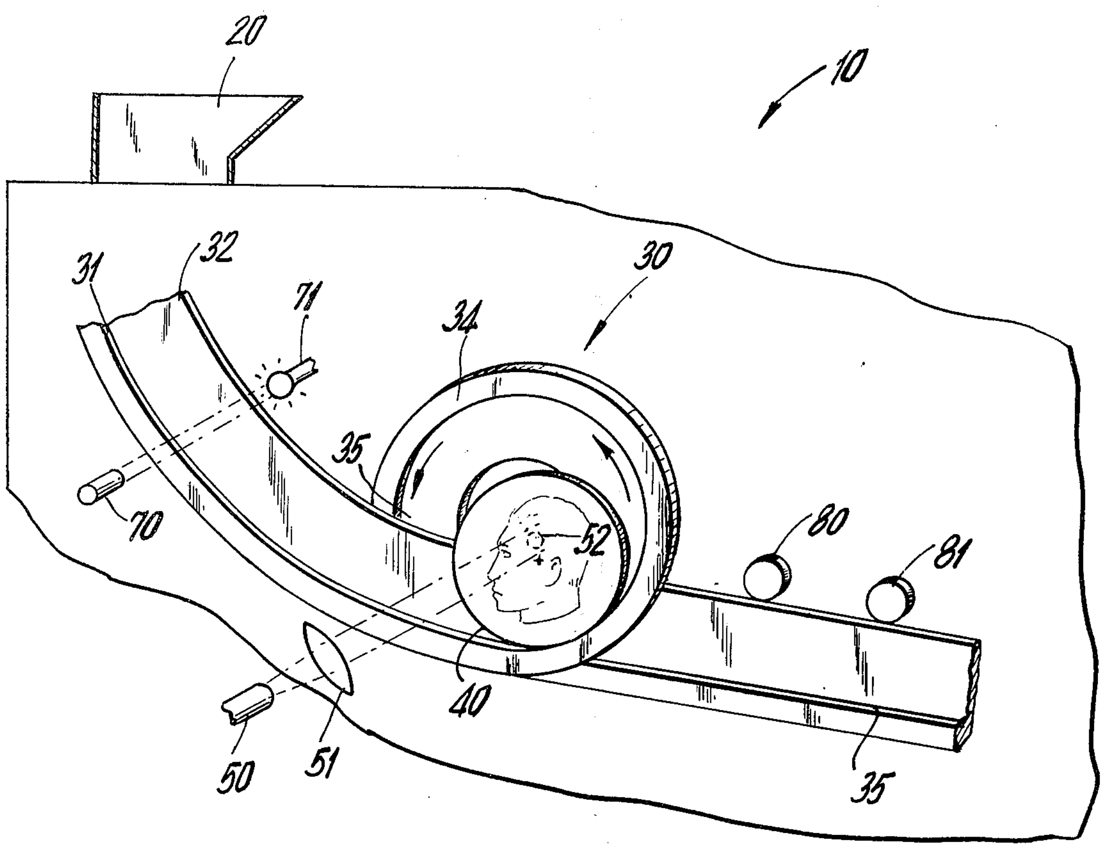
[57] **ABSTRACT**

An apparatus for identifying acceptable coins, including a coin track assembly having a circular coin track loop around which coins can roll, sensor means focused at the center of the circular coin track loop for generating a signal in response to the coin surface pattern as the coin rolls around the circular coin track loop and means for monitoring the signal output from the sensor means to identify acceptable coins.

10 Claims, 3 Drawing Figures

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80
81
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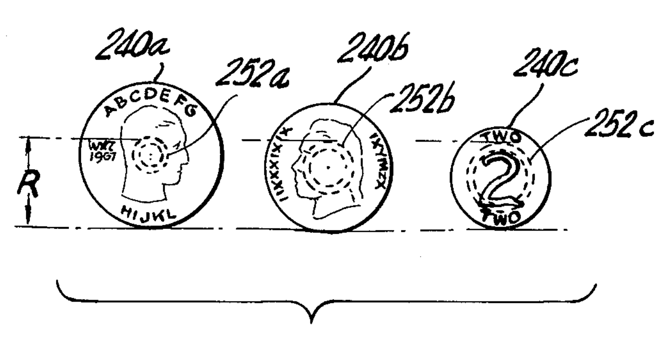
FIG. 1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252a
240b
252b
240c
252c
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ABCDEFG
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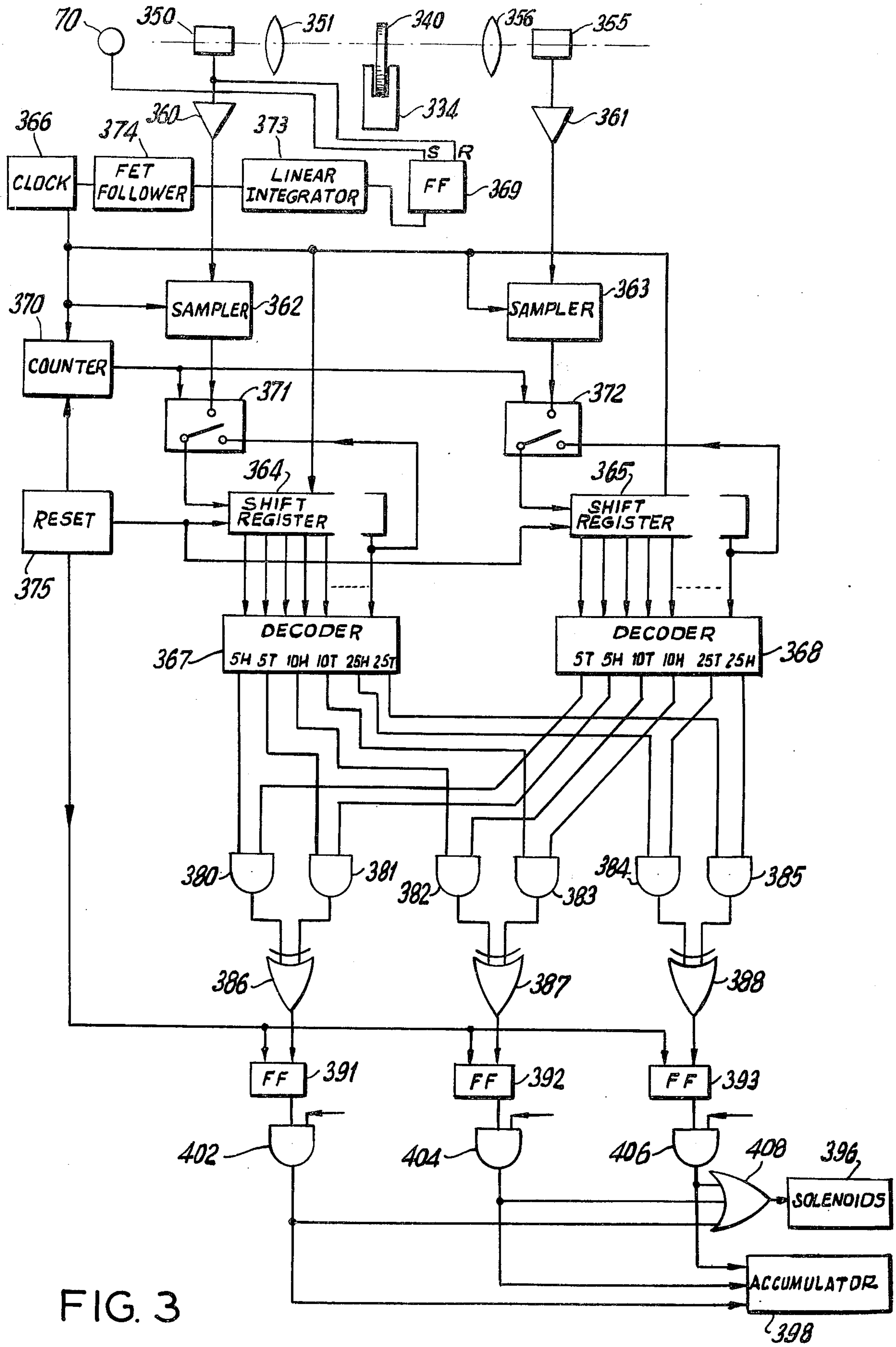
TWO
2
TWO

FIG. 2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350
351
340
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366
374
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CLOCK
FET FOLLOWER
LINEAR INTEGRATOR
FF
369
370
SAMPLER
362
SAMPLER
363
COUNTER
371
372
364
SHIFT REGISTER
365
SHIFT REGISTER
RESET
375
DECODER
367
5H 5T 10H 10T 25H 25T
DECODER
5T 5H 10T 10H 25T 25H
368
380
381
382
383
384
385
386
387
388
FF
391
FF
392
FF
393
402
404
406
408
396
SOLENOIDS
ACCUMULATOR
398

FIG. 3

APPARATUS FOR IDENTIFYING COINS

SUMMARY

This invention relates to coin discriminators and, more particularly, to a method and apparatus for determining the denomination of coins and for rejecting undesired and counterfeit coins.

Throughout this specification and in the appended claims, the term "coin" is intended to mean genuine coins, tokens, counterfeit coins, slugs, washers, and any other item which may be used by persons in an attempt to actuate a coin-operated device. An "acceptable" coin is an authentic coin of the monetary system in which the device is intended to operate and of a denomination which the device is intended selectively to receive for value.

The apparatus and method of the present invention provides a means for examining characteristics of the surface of selected areas of coins in a coin selector. This invention has utility with a coin set of several denominations of varying diameters, as well as with coins of a single diameter. This invention is also suitable for use in conjunction with other coin examining techniques.

IN THE DRAWINGS:

FIG. 1 is a perspective view of a simplified coin track assembly plus a schematic representation of other elements of a coin selector formed in accordance with this invention.

FIG. 2 is a front elevational view of the three coins of a hypothetical coin set which includes a general indication with respect to each coin of the surface area of the coin which would be scanned by one embodiment of this invention.

FIG. 3 is a schematic block diagram of a coin discriminator formed in accordance with this invention.

DETAILED DESCRIPTION

A coin discriminator **10** constructed in accordance with the principles of this invention is shown in FIG. **1.** Any of a number of various types of coins (acceptable or otherwise) may be introduced into the coin discriminator **10** through a coin slot **20.** The coin **40** falls under the influence of gravity into a coin retarder (not shown). The coin retarder may be any of a variety of mechanical or electro-mechanical arrangements for stopping a coin and then releasing it, e.g., a passageway obstructed by a pin which is mechanically or electromagnetically retracted when a coin comes to rest thereagainst. The coin retarder momentarily brings the coin to rest and then releases it into a coin track assembly indicated generally at **30.** All coins, no matter how inserted into coin slot **20,** enter coin track assembly **30** under the same initial conditions.

Once in the coin track assembly **30,** the edge of the coin **40** bears upon initial track section **31** which is sloped downwardly in a direction away from coin slot **20** and the coin retarder. Coin track assembly **30** may take any of a variety of forms which will hold the coin **40** in a substantially vertical orientation and allow it to roll downward on its edge under the influence of gravity. As shown in FIG. **1,** for example, track **30** has a slotted or channel-shaped cross section just wide enough to admit the thickest of the acceptable coins. Further, the upstanding portion **32** of the cross section of track **30** should be high enough to prevent the largest diameter coin, for which the coin discriminator is designed, from falling out of the track; one half of the diameter of such a coin is a suitable height for this purpose.

Advantageously, one form of the initial track section **31** has a large radius of curvature from the start of the initial track section **31** to the beginning of a circular track loop section **34** as shown in FIG. **1.** This configuration of initial track section **31** permits a coin to rapidly gather the momentum required to carry it around the circular track loop section **34** and at the same time tends to convert the initial vertical motion of the coin to rolling motion along track **30** with a minimum of coin bouncing. Initially the motion of a coin may be a combination of sliding and rolling. When the coin enters track loop section **34,** however, the predominant form of motion will be rolling.

As will be apparent from FIG. **1,** a coin **40** rolling down coin track section **31** enters track loop section **34,** and if it possesses sufficient momentum rolls up and around circular track loop section **34,** and then emerges on a final track section **35.** Coins of all acceptable denominations must have sufficient momentum when they enter circular track loop section **34** to maintain firm rolling contact with the coin track of the circular track loop section **34.** The physical principles governing motion of this type are discussed, for example, in *University Physics* by W. F. Sears et al. (Addison-Wesley Publishing Co., Inc., Cambridge, Mass., second Ed. (**1955**), pp. **107–110**). As stated generally therein, an object rolling around a circular track will remain in contact with the circle if its velocity at the top of the circle is at least equal to $\sqrt{gR}$, where g is the acceleration due to gravity and R is the radius of the circle.

When coin **40** enters track loop section **34,** one or both of its surfaces are advantageously illuminated (to the extent permitted by the presence of circular track loop section **34**) by light from a light source or sources (not shown). Considering, for example, only the face of the coin visible in FIG. **1**, an optical sensing device **50** is aligned with the axis through the center of the circular track loop section **34.** Light reflected from the surface of the coin at a point **52** coincident with the center of the circle defined by the circular track loop section **34** is focused by lens **51** onto the optical sensing device **50.** The optical sensing device **50** may be any photosensitive transducer device, e.g., a phototransistor, which produces an electrical output in proportion to the intensity of the light focused on it. It should be appreciated that other types of coin surface characteristic sensors which do not require light may be employed, e.g., high frequency inductors focused at the center of the circular track loop section **34.**

In order for a coin to roll around circular track loop section **34,** the diameter of the circle measured from the bottom of the channel must be larger than the diameter of the largest acceptable coin. To prevent coins larger than the loop from becoming lodged in track loop section **34,** such coins may be excluded from the apparatus **10** by appropriate dimensions of the coin slot **20.**

It is evident from geometrical considerations that any coin smaller in diameter than one half the diameter of the circular track loop section **34** will reflect no light from the center of the circular track loop section **34** to sensor **50.** Accordingly, the ratio of the diameter of the largest acceptable coin to the diameter of the smallest acceptable coin cannot exceed 2 to 1. This ratio can be extended in accordance with the principles of this invention by including two or more progressively smaller loops arranged in series. Large coins can then be identified in the first loop and removed from the coin track while smaller coins pass through the first loop for subsequent identification in a smaller loop. For most coinage, however, a single loop will be sufficient.

FIG. 2 illustrates three hypothetical coins **240***a*, *b*, and *c* each having a distinctive diameter. The diameter *d* of each of these coins is such that $D > d > ½D$ where *D* is the diameter of the circular track loop section **34**. Accordingly, any of these coins will pass through track loop section **34** and all are large enough to reflect light from the center of the circular loop **34** to sensor **50**. Moreover, it is evident from geometrical considerations that each coin will make between one and two complete revolutions in rolling around track loop section **34**, the largest coin making slightly more than one revolution and the smallest coin making almost two revolutions.

Since sensor **50** is focused on the center of the circle defined by circular track loop section **34**, sensor **50** scans the surface of these coins at a uniform distance from the edge of the coin as the coin rolls around the circular track loop section **34**. Since the focus of the sensor **50** is off the center of any coin and since each coin makes at least one complete revolution in traveling around the circular track loop section **34**, sensor **50** scans at least one complete circle on the surface of each coin concentric with the center of the coin. The circles scanned on each of coins **240***a*, *b*, and *c* in FIG. 2 are represented by broken lines **252***a*, *b*, and *c*, respectively. As is evident from FIG. 2, the locus of points scanned on a larger coin **240***a* defines a circle smaller in diameter than the circle defined by the locus of points scanned on the smaller coin **240***c*.

The face and denomination of any coin of a denomination accepted by the apparatus can be identified by sampling the output of the sensor **50** during the scanning of a face of a coin searching the samples generated for corresponding "key" samples associated with each face of all coins of that denomination. If no subset of samples is found to match the key for any acceptable coin, the coin scanned is determined to be unacceptable.

Some extraneous scanning will occur as the coin enters and leaves the circular track loop section **34** (i.e., two lines connecting the edge of the coin with the scanning circle **252***a*, *b*, or *c* will be scanned). This extraneous scanning can be prevented by enabling sensor **50** only while a coin is actually in the circular track loop section **34** or this extraneous scanning information can be ignored in the signal processing, as discussed below. The presence of a coin at any point along the coin track assembly **30** can, of course, be determined, for example, by shining a light through an aperture in the coin track assembly **30** onto a photoelectric device so that occlusion of this light by a coin produces a change in the signal produced by the photoelectric device.

Apparatus for identifying coins from the optical information received by scanning their surface features is shown in FIG. 3. As the coin **340** rolls around the circular track loop section **334** in the manner discussed above in connection with FIG. 1, sensor **350** in conjunction with lens **351** scans a circular region on one face of the coin while sensor **355** in conjunction with lens **356** scans a similar region on the opposite face of the coin. Each of sensors **350** and **355** therefore produces an output signal progressively representative of the intensity of light reflected by successive points on the scanning circle on the adjacent surfaces of the coin **340**. It will be evident that depending on the orientation of coin **340** in track **334**, either face of the coin may be presented to either sensor **350** or **355**.

The scanning signals produced by sensors **350** and **355** are amplified by amplifiers **360** and **361** and the amplified signals applied to samplers **362** and **363**, respectively. Each sampler **362** and **363** is responsive to a periodic timing signal produced by clock **366** and produces output signals representative of successive samples of the applied scanning signal. Any of a number of well known signal sampling schemes may be employed. For purposes of illustration, however, each of samplers **362** and **363** may be assumed to be a simple threshold detector, producing an output signal having one of two levels depending on the level of the applied scanning signal relative to a predetermined threshold level and in response to each timing signal pulse from clock **366**.

The pulse rate of the clock **366** is adjusted to compensate for variations in velocity between the coins being examined, so that the same number of bits of information will be sampled for one full circular scan of a coin of a given denomination regardless of its initial velocity. A signal, the duration of which is representative of coin velocity, is obtained by initiating timing when the coin first occludes a sensor from its light source which may be located as indicated by sensor **70** and lamp **71** in FIG. **1** to the time when the coin first reflects light from the lamp (not shown) toward the sensor **350** or from the lamp (not shown) toward the sensor **355**. When sensor **70** first receives reflected light, flip-flop **369** is set causing a linear integrator **373**, which may be a feedback operational amplifier of conventional design, to begin integration. When sensor **350** first receives light from the lamp (not shown), the flip-flop **369** is reset stopping the period of integration by the integrator **373**. A FET follower **374** applies a signal representative of the stored output voltage level of the integrator **373** to the input of the clock **366**. The clock **366** is advantageously a voltage controlled oscillator in which the output frequency is dependent upon the voltage applied across its input terminals. Adjustment for the range of voltages necessary to provide the desired frequencies is accomplished by known means in the FET follower **374**. Such known means may include a voltage divider and a difference circuit.

The digitized output signals thus produced by samplers **362** and **363** are applied to the input terminals of multistage shift registers **364** and **365** by way of switches **371** and **372** which, during this portion of the operation of the apparatus of FIG. **3**, are arranged in response to the output signal from a counter **370** to connect the input terminal of each shift register **364** and **365** to the corresponding samplers **362** and **363**, respectively. Each of the multistage shift registers **364** and **365** has N stages, each stage capable of storing one scanning signal sample of the type produced by samplers **362** and **363**. In response to each timing signal pulse produced by clock **366**, each of the shift registers **364** and **365** shifts the contents of its several stages one stage to the right as viewed in FIG. **3**. Simultaneously, the most recent scanning signal sample produced by each of samplers **362** and **363** is stored in the initial stage (i.e., the leftmost stage as viewed in FIG. 3) of the corresponding shift register. Each of shift registers **364** and **365** contains a sufficient number of stages (e.g., N) to store all of the scanning signal samples produced during the scanning of the faces of any acceptable coin, including the extraneous scanning signal samples resulting from the entry and exit of the coin from the circular coin track loop section **334.**

Assuming clock **366** to be arranged to produce N timing pulses during the passage of coin **340** through track loop section **334,** N samples of the intensity of the light reflected by each face of the coin, including that produced upon entry and exit of the coin from the track loop section **334,** will be produced and stored in shift registers **364** and **365** in the manner described above. Counter **370** counts the timing pulses produced by clock **366.** When N pulses have been counted, indicating that N samples of each scanning signal have been produced and stored in the N stages of shift registers **364** and **365,** counter **370** produces an output signal which causes switches **371** and **372** to change state. When the switches **371** and **372** change state, the last stage of each of the shift registers **364** and **365** is connected to the input terminal of that shift register forming a closed loop, so that in response to further timing pulses the contents of the last stage of each shift register is continuously shifted back to the input terminal of its corresponding shift register **364** or **365.**

Each shift register **364** and **365** has a decoder **367** and **368,** respectively, electrically connected thereto to monitor the contents of the shift registers. The decoders **367** and **368** should possess a bit capacity twice as great as that of the shift registers **364** and **365** to allow identification of a coin whose data sequence may begin or may be interrupted at random, e.g, by a foreign substance on the face of the coin. The required decoder capacity may be more fully appreciated by considering a sequence of data samples where $N=8$. If the sequence of **8** data samples has additional samples of spurious data within its sequence, (e.g., from scanning as the coin entered and left the loop), no amount of shifting will produce the proper sequence, i.e., **1, 2, 3, 5, 6, 7,** and **8** in the shift register. Therefore, unless the decoders **367** and **368** include a bit capacity twice as great as the shift registers **364** and **365,** the coin identification becomes unreliable. However, with decoders of the proper bit capacity, i.e., **16** where $N=8$, the shift registers **364** and **365** may be connected to the decoders **367** and **368,** respectively, so that corresponding data sequences will activate the decoders **367** and **368** to provide identification of the coin when there is a correspondence between subsets of data samples.

It should be understood that other forms of apparatus may be used to convert the scanned data into useful information. For example, a first shift register feeding a second shift register in series may be employed with a decoder. A switch is used to stop data sampling as the coin begins to leave the loop and to cause the data in the second shift register to be circulated until the data samples attain a correspondence with the decoder. Further, an analog shift register may be employed which sums the current output from the amplifiers **360** and **361.** To decode this information digitally, a read only memory may be employed with the appropriate logic circuitry. Further, when employing an analog shift register a Gray-code analog to digital converter may be advantageously employed.

When the contents of the shift registers **364** and **365** correspond to the predetermined data pattern for one of the faces of an acceptable denomination coin, within a predetermined tolerance, e.g., **40** percent, an output signal is produced by the decoders **367** and **368.** The output signals from the decoders **367** and **368** enable appropriate logic circuitry (not shown) when predetermined subsets of data samples in the shift registers **364** and **365** correspond with those in the decoders **367** and **368.** For example, in a coin selector in which current United States coinage in the **5**-cent, **10**-cent and **25**-cent denominations is to be accepted, the outputs from the decoders **367** and **368** and appropriate logic circuitry (not shown) have been designated in FIG. **3** as follows: **5**H, **5**T, **10**H, **10**T, **25**H and **25**T, where the numerals designate the denomination and H and T (heads and tails) designate the two faces of the coins.

The outputs from the decoders **367** and **368** and appropriate logic circuitry (not shown) are connected so that the H output for each denomination from decoder **367** is connected to the same AND gate as the T output for the same denomination from decoder **368,** and vice versa. As a result, when a coin is determined to have the characteristics of a genuine **5**-cent piece on both faces, either AND gate **380** or **381** will be activated, depending on the orientation of the coin with respect to sensors **350** and **355.** The output from the AND gates **380** and **381** is connected to an EXCLUSIVE OR gate **386** and the output from the EXCLUSIVE OR gate **386** to a flip-flop **391.** The output from the EXCLUSIVE OR gate will set flip-flot **391.** Similarly, in the case of a **10**-cent piece, AND gates **382** or **383** will be activated and flip-flop **392** will be set via EXCLUSIVE OR gate **387;** and in the case of a **25**-cent piece, AND gates **384** or **385** will be activated and flip-flop **393** will be set via EXCLUSIVE OR gate **393.** The flip-flops **391, 392** and **388,** as well as the shift registers **364** and **365** are reset by a resetting means indicated at **375** after the coin has exited from the final coin track **35.**

The transition in the signal output which occurs when the coin leaves the track **334** and sensor **350** no longer receives light from lamp (not shown) causes a pulse at the output of a capacitor (not shown) which is applied to one input of each of the AND gates **402, 404** and **406.** The other input of each of these AND gates is the output of the flip-flops **391, 382** and **393,** respectively. When the transition pulse is applied to the AND gates **402, 404** and **406,** the state of the flip-flops **391, 392** and **393** is interrogated, and, in the event that one of the flip-flops is set, the associated AND gate produces an output signal, indicative of the acceptability of a coin of the associated denomination, which passes through OR gate **408** to activate solenoid **396** causing the coin to be directed to an acceptable coin container (not shown). The output signal from the AND gates **402, 404** and **406** also passes directly to an accumulator **398** where the acceptance of the coin of the particular denomination is recorded.

In addition to the coin track loop assembly **30,** FIG. **1** also indicates, schematically, two inductors **80** and **81,** one or both of which may be used in accordance with my invention to provide more accurate discriminations against counterfeit coins, slugs and the like. A high degree of discrimination is provided by use of inductive sensing of coin material characteristics at two widely separated frequencies as disclosed in UK specifications numbers 16538/71 and 8385/72. Another variant of my invention employs a coin impeller of the type disclosed in UK specification number 43014/70 and U.S. patent application Ser. No. 120,652 of Mar. 3, 1971 to move the coin along the coin track rather than employing gravity; in which case the velocity of acceptable coins would be predictable, therefore the clock **366** could have a fixed output frequency and sensor **70** and its associated circuitry could be eliminated.

What is claimed is:

1. An apparatus for identifying acceptable coins, comprising a coin track assembly including a circular coin track loop around which coins can roll, sensor means focused at the center of the circular coin track loop for generating a signal in response to the coin surface pattern as a coin rolls around the circular coin track loop, and means for monitoring the signal output from the sensor means to identify acceptable coins.

2. The apparatus claimed in claim **1** wherein said coin track assembly includes an initial coin track section coupled to said circular coin track loop, said initial coin track section having a large radius of curvature to permit a coin to gather the momentum required to carry it around said circular coin track loop.

3. The apparatus claimed in claim **1** wherein said sensor means includes two optical sensing devices positioned on opposite sides of said circular coin track loop and focused at the center of said circular coin track loop.

4. The apparatus claimed in claim **1** wherein said sensor means produces an analog output, said monitoring means includes means for converting the analog output from said sensor means into digital information, means for sequentially storing said digital information, and means for decoding the sequentially stored digital information by comparison with predetermined data subsets representative of an acceptable coin surface pattern.

5. The apparatus claimed in claim **4** including coin velocity determining means for controlling the number of digital conversions made by said converting means.

6. An apparatus for identifying acceptable coins, comprising:

a coin track assembly including a circular coin track loop around which coins can roll, the circular track loop having a diameter greater than the diameter of the coins to be identified and less than two times as great as the diameter of the coins to be identified;

sensor means focused at the center of the circular coin track loop for generating a signal in response to the coin surface pattern as a coin rolls around the circular coin track loop; and

means for monitoring the signal output from the sensor means to identify acceptable coins.

7. The apparatus claimed in claim **6** wherein

said coin track assembly includes an initial coin track section coupled to said circular coin track loop, said initial coin track section having a large radius of curvature to permit a coin to gather the momentum required to carry it around said circular coin track loop.

8. The apparatus claimed in claim **6** wherein

said sensor means includes two optical sensing devices positioned on opposite sides of said circular coin track loop and focused at the center of said circular coin track loop.

9. The apparatus claimed in claim **6** wherein said sensor means produces an analog output, said monitoring means includes means for converting the analog output from said sensor means into digital information, means for sequentially storing said digital information, and means for decoding the sequentially stored digital information by comparison with predetermined data subsets representative of an acceptable coin surface pattern.

10. The apparatus claimed in claim **9** including

coin velocity determining means for controlling the number of digital conversions made by said converting means.

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