

[54] SYSTEM FOR COUNTING PILLS AND THE LIKE

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235/92 PK; 235/92 NT; 235/98 C; 235/183[51] Int. Cl.² **G06M 7/02; G06G 7/18**[58] Field of Search 235/183, 150.51, 92 PK,
235/92 PC, 98 C

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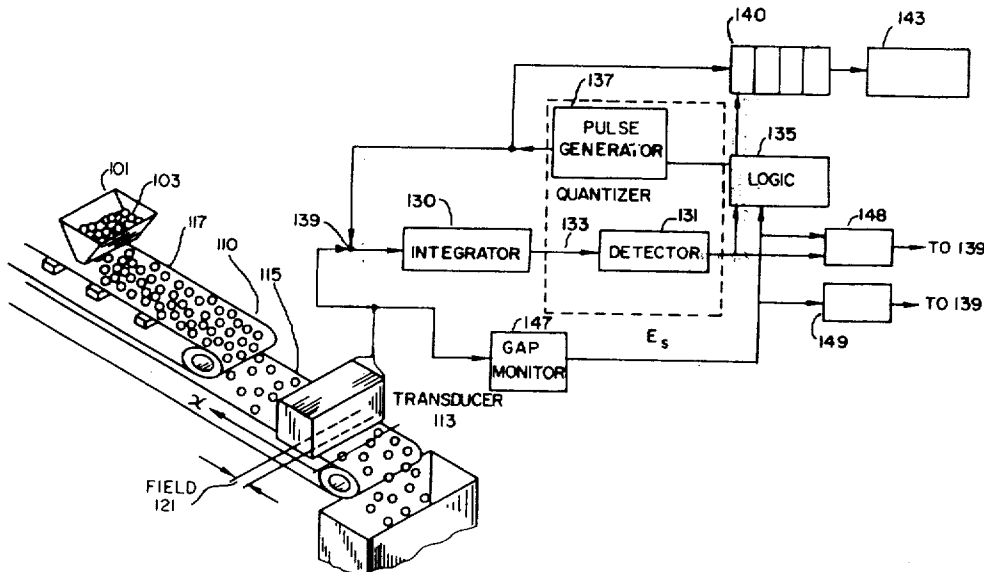
Attorney, Agent, or Firm—Killion & Larsen

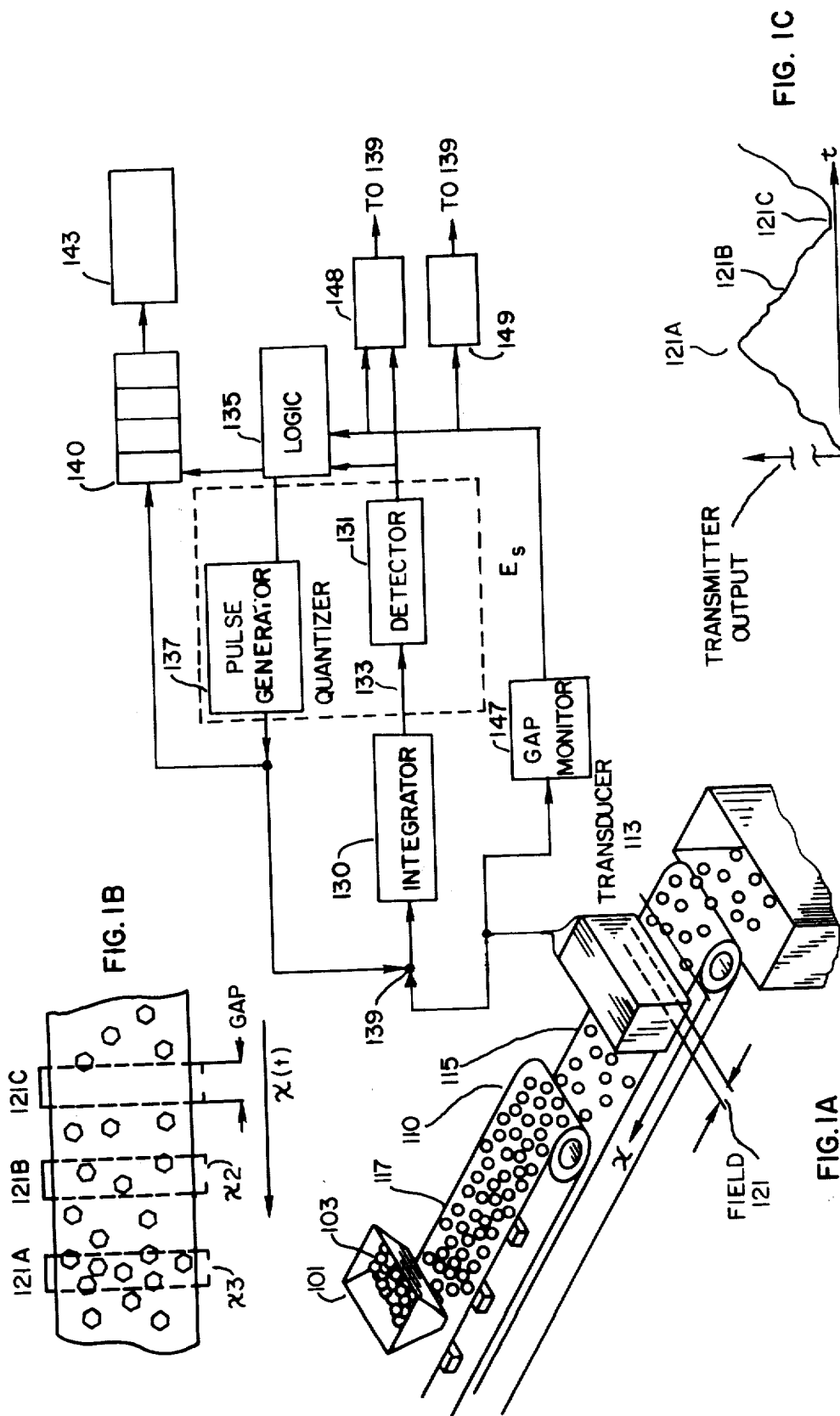
[57] ABSTRACT

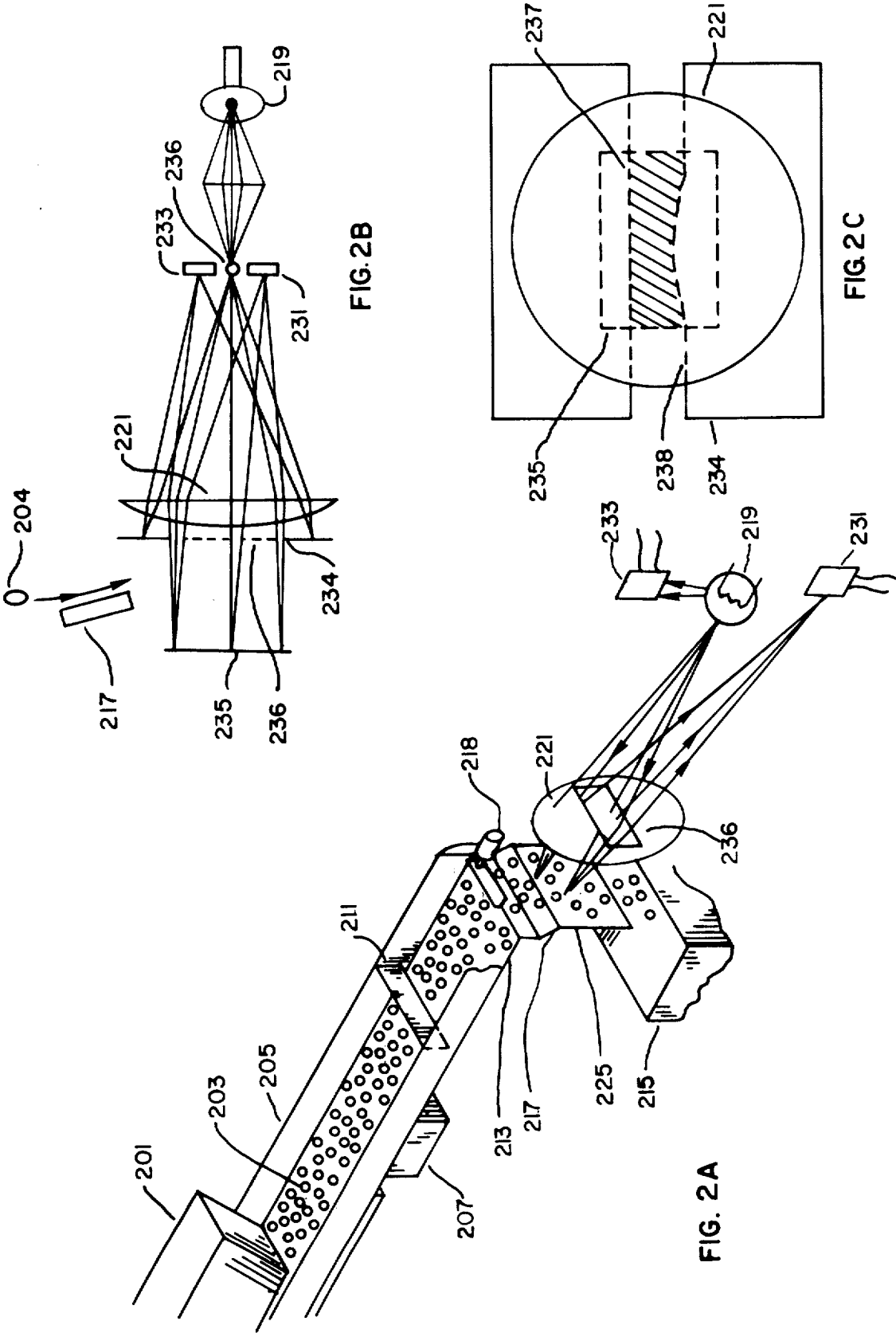
This invention provides a means for counting small articles, in which the items are not constrained to pass in single file through a count-sensing element, but instead may be permitted to pass in crowds and bunches, yet it provides an exact numerical count to a high degree of certainty.

The system is based on the a priori information that the measured property, area, weight, etc. for each item is the same. A continuous measurement is made of mass flow rate, amount of light obscured, etc. The output of the measuring transducer is integrated and represented by an electric charge held in a capacitor. The capacitor is periodically discharged by increments of charge, the number of which is counted by a digital counter. Adjustments are provided so that on the average the number of such increments is a fixed multiple (such as 16) of the number of items. Then the small remaining error is eliminated by resetting the integrator whenever a gap is observed in the flow of articles since a gap must represent the passage of an exact integral number of items.

13 Claims, 7 Drawing Figures







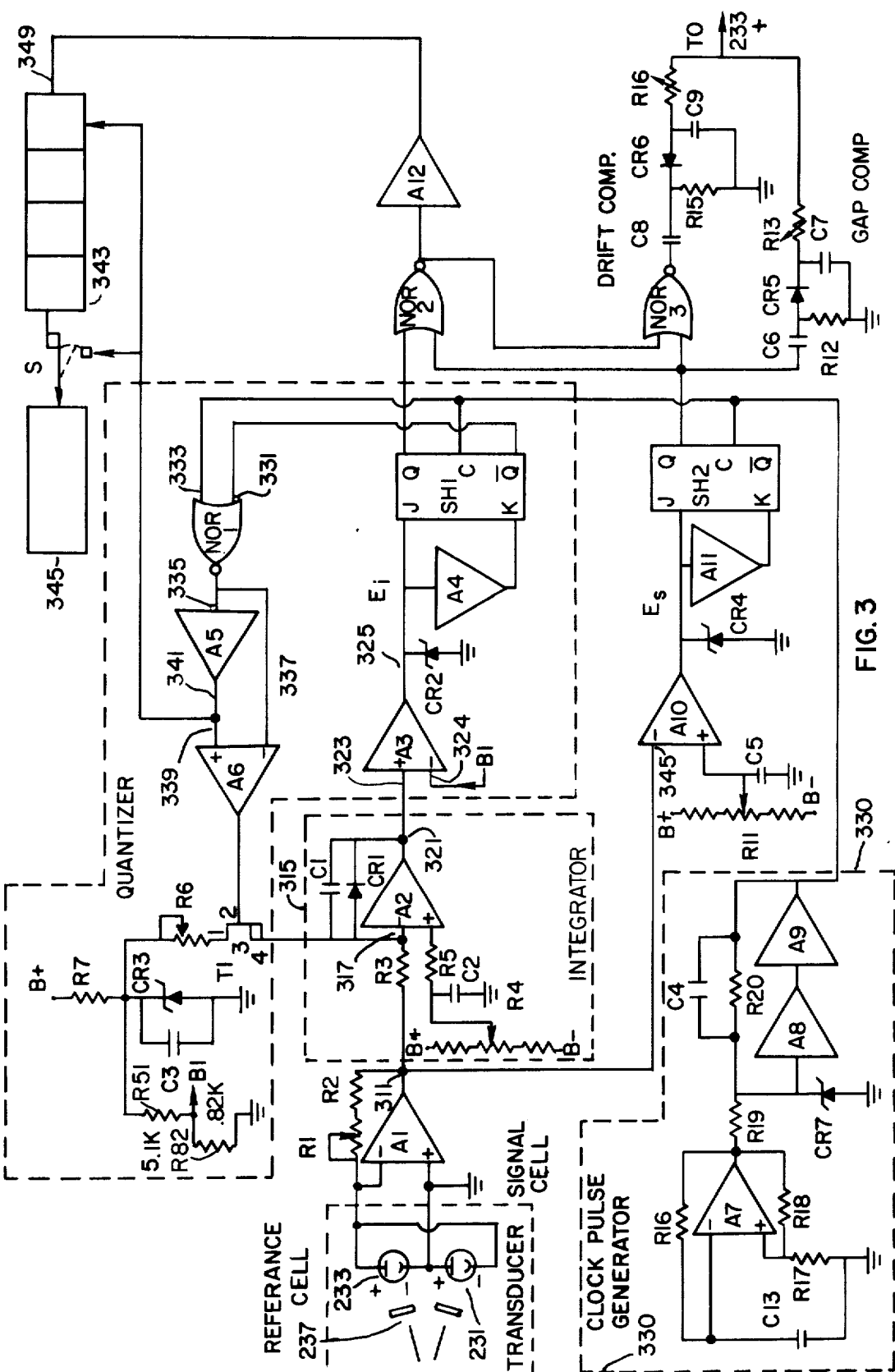


FIG. 3

SYSTEM FOR COUNTING PILLS AND THE LIKE

This invention relates generally to apparatus for counting items or parts, and particularly to high-speed counting of small parts distributed in groups.

The availability of high-speed electronic counting circuits has made it possible to count such items one-after-the other. The items are serially guided to pass or fall past a suitable transducer, such as a photoelectric cell. It is, in these cases, necessary to provide the necessary material-handling equipment to guide the parts into a single file with spacings between the parts. These limitations, the need to maintain spacing and single-file orientation, are overcome in the present invention by making use of a-priori information that the successive items to be counted are substantially equal in some measurable property. In consequence, the contribution of that property of a group of such parts to a measurable parameter is a-priori an integral multiple of the contribution of one part.

Accordingly it is an object of the present invention to provide means for the digital counting of groups of items, particularly when the number of items in the groups counted vary randomly from group to group.

It is a further object of this invention to provide apparatus with means for eliminating accumulated errors in counting arising from measurement errors and drift.

A feature by which the foregoing objects are achieved is a digital accumulator in which the total response of a transducer to the measured property of an item is made up of a number (such as sixteen) of partial outputs, which accumulator is "cleared", when a gap occurs in the flow of items, indicating the passage of an integral number of items.

Other objects and features of the invention will, in part, be obvious and in part be apprehended from the following specification and annexed drawings of which:

FIG. 1A is a schematic representation of a feed mechanism, transducer, and logic of the invention;

FIG. 1B is a detail symbolic diagram of the arrangements of parts at the transducer;

FIG. 1C is a graph of a typical wave form resulting from the arrangement of FIG. 1B;

FIG. 2A is a schematic representation of the preferred embodiment of the invention;

FIG. 2B is an alternate representation of portions of FIG. 2A;

FIG. 2C is a view of the counting field as seen from the photo cells, and

FIG. 3 is a logic block diagram of the circuitry of the preferred embodiment.

The broad principles of the invention are next discussed with the aid of a hypothetical parts counting system illustrated in FIGS. 1A, 1B, and 1C. Shown in FIG. 1A is hopper 101 containing small parts 103 in bulk quantities dropping them on conveyor system 110. The conveyors present the parts to a suitable transducer 113 before the parts are transported to packaging equipment and the like. Means are provided for increasing the separation between parts, for example, in FIG. 1A, the conveyor belt 115 is made to travel at a faster rate than the belt 117 from which it receives the parts, while in the preferred embodiment the parts are separated as they accelerate in free fall from the feed belt.

The transducer 113 detects some property of each part, which property is selected so that the transducer

responds in like amount to that property in each of the parts to be counted. The property may be related to the fact that all the parts are of the same shape, the same weight, same luminosity, same area or such, and the transducer response substantially linearly, that is, the response for two items is twice that for one item, and the response for 10 items is substantially 10 times that for one. The total contribution from each item is the product of the strength of the influence multiplied by the duration of its exposure to the detector, in mathematical terms the integral of the influence over the time the part takes to transit the transducer. Integration is also effected across the width of the transducer field 121.

15 An enlarged view of the field 121 of the transducer 113 is depicted as 121a, 121b, and 121c in FIG. 1B for three successive instants as the parts, irregularly distributed, pass the transducer. The corresponding response characteristics of the transducer over the interval may be as illustrated in FIG. 1C. It is seen from FIGS. 1B and 1C that the output signal of the transducer falls to a minimum when no parts or only a negligible fraction thereof fall within the effective field, as indicated for 121c. A gap is then said to exist between groups of parts. Due to the above-stated uniformity in a detected property of the parts coupled with the knowledge that the number of parts presented to the transducer between gaps is an integer, the appearance of gaps presents opportunities for clearing fractional counting errors that accumulate in the apparatus. It is significant to the satisfactory performance of the apparatus. If the inherent irregularity of delivery of the parts does not insure, to any desired statistical degree of confidence, that gaps will occur frequently enough, then positive means are provided to interrupt the flow periodically, since the probability of an incorrect round-off increases with the number of parts in the group of parts between two gaps.

Referring again to FIG. 1A, the integrator 130 is connected to the transducer 113 and operates on the output of the transducer and upon the pulses (described below) inserted by the Pulse Generator 137. In the beginning the time integral of the transducer's output is generated in the integrator 130 and is quantized by decrementing, that is, approximately measured by determining the number of fractional measures having a constant integral into which it may be divided. Quantizing, may be achieved by more than one method; however, decrementing the remainder of the exact integral by a determinable number of such fractional measures until the remainder of the integral is approximately zero provides the preferred method. Accordingly, a detector 131 is provided for determining when the remainder at the output 133 of the integrator falls below a suitable threshold level amounting approximately to that resulting from one fractional unit of a part. A logic unit 135, responsive to the detector 131 activates a pulse generator 137 a decrementing pulse of a size scaled to equal that fraction (such as 1/16th) of the output of the integrator 130 for the passage of one item. Successive pulses are decremented from the remainder at the summing point 139 at the input of the integrator until the detector 131 senses a negative remainder at the output 133 of the integrator 130. With each decrementing pulse from the generator 137, a pulse is sent to the fractional counter 140. The fractional counter 140 is provided to register the number

of fractional measures required to reduce the integral remainder to the threshold level. This counter is designed also to round off the total fractional count to the nearest whole part and to increment a second counter 143 by one unit for each such whole part determined.

ROUND-OFF

Round-off to the nearest half-unit by the fraction counter 140 is accomplished by incrementing the unit counter 143 every time the fraction counter reaches a value which is an odd multiple of one half, which is to say, for the four-bit counter 140 as shown, whenever the number of input counts to the fraction counter reaches a value of $8N$, where N is an odd integer. Thus, if the integrator detector 131 is "off", indicating the integrator has a threshold level under one fractional unit ($1/16$ th part), and a value of 7 (i.e., $7/16$ th part) is in the fractional counter, this represents a total of less than $8/16$ th or half of a part. Any further increase in the integrator which causes the threshold level of $1/16$ th to be exceeded results in a count of 8 in the fractional counter. Thereupon, the units counter is duly incremented as the most significant bit in the fractional counter goes to "one." When this bit goes to zero as a count of 16 is reached, the unit counter 143 is not indexed, since this is an even multiple of 8. (An alternate way to reach the same result would be to "clear" the counter 140 to an initial count of 8, and thereafter to increment the counter 143 whenever the most significant bit of the counter 140 goes to zero).

As long as no gap occurs as determined by the gap monitor 147, the fractional counter continues to count and increments the unit counter 143 with each odd multiple of 8 counts.

Other functions of the system are to clear out residual measurement errors in the fractional counter and in drift and scale factor.

Measurement errors are represented by the contents of the fraction counter remaining after a group has passed, and the integrator has been discharged to a value less than the threshold ($1/16$ th). A priori, the passage of an integral number of whole parts should leave no residue in the fractional counter. The residue which remains represents error. In order that this error be not accumulated with the next group of parts, the fraction counter is cleared whenever the presence of both a gap and a sub-threshold level in the integrator indicates that a whole number of parts have passed.

The logic also serves to clear fractional counts that may tend to accumulate during a long gap. A constant drift in the continuous input signals and integrator is manifested in a low frequency train of incrementing pulses, but the fractional counter 140 is by each of them then immediately cleared by operation of the logic, eliminating any buildup of error from such sources.

These same sources of drift which are completely eliminated during gaps, may be assumed to continue at substantially the same rate during non-gap times. To compensate in large measure the drift rate signal generated during gaps is smoothed in a long time-constant low-pass filter drift compensator 148 which in turn produces negative feedback of the summing point 139 in proportion to the drift detected during gaps.

A second compensation circuit 149 provides feedback proportional to the number of gaps to account for the first or last item in a group being partly cut-off.

PREFERRED EMBODIMENT

A preferred embodiment of the transducer portion of the invention adapted for counting opaque parts in illustrated in FIGS. 2A, 2B, and 2C. Shown in FIG. 2A is hopper 201 feeding parts 203 of approximately equal cross-section, such as pills, coins, and the like, into chute 205. A vibrator 207 induces movement of the parts past a wiper 211 and toward the lower edge 213 of the chute where they fall toward a pin 215. The steep portion 217 of the chute serves to stop the pitch and roll rotations of the parts before they enter the transducer field. Gate mechanism 218 introduces gaps are needed.

A photo-electric transducer is provided utilizing lamp 219 emitting light passing through a lens 221 reflected back from a tilted mirror 225 toward "signal" photo cell 231. A portion of the light from the lamp 219 impinges on a "reference" photo cell 233. Shutter means (not shown) are provided to balance the signal and reference response when the field is clear.

FIG. 2B indicates in somewhat clearer outline the optical arrangement for a pill counter. The pills 204 are dropped to graze the guideplate 217 then drop between two mirror plates 234 and 235 which are nearly parallel and perpendicular to the beam of light colimated by the lens 221. Light from the lamp 219 is condensed to form an image of the filament and a virtual source 236 between the signal and reference photo cells 231 and 233. The reference cell receives its light from the first mirror plate 234 which has a clear portion 236 defining the sensing field and allowing light to pass through to the second mirror across which the pills drop.

The lower limit of the field is defined by a contoured mask 238. This makes it unnecessary that the beam be of uniform intensity across the sensing field 237. Ordinarily the beam turns out to be somewhat more intense at the center than at the edges; but since it is desired that each pill contribute the same integrated output, it is possible to compensate for greater intensity by a shorter duration of exposure. Accordingly, an edge of the field 237 is modified by the contoured mask 238. Using a vertical wire to simulate a falling pill, the signal may be measured as a function of horizontal position in the field, and the needed correction calculated and the mask cut therefrom, accounting for gravitational acceleration if required.

Reference is now made to the schematic diagram of FIG. 3 disclosing electronic circuiting for the parts-counting apparatus of the preferred embodiment. Standard logic symbols correspond to integrated or micro-electronic circuit modules which are identified in the text by manufacture and part designation. Catalog references are listed below. In the family of modules preferred the nominal level for logical ZERO is 0.2v. (0.8 v. max.) and the level for a logical ONE is 3.3 v. (2.0v. min.).

In FIG. 3, signal and reference photo cells 231 and 233 are connected in parallel opposition and the net, or differential, cell signal current is coupled to a high-gain d.c. amplifier A1. The amplifier is provided with differential inputs as indicated plus and minus with feedback resistances R_1 and R_2 , potentiometer R_1 being provided to maintain the amplifier within its linear dynamic range over a variety of part sizes detected by the signal cell 231. The output terminal 311 of the amplifier A1 is coupled through resistor R_4 to an integrator 315 utilizing inverting amplifier A2 with integrating ca-

capacitor C1 and clamping diode CR1 parallel connected between the input and output terminals 317, 321 respectively of the amplifier A2. The diode CR1 prevents the amplifier output from drifting too far negative during calibration, which is detailed below. After calibration, drift is to be positive only and CR1 inoperative. Biasing is supplied from a potentiometer R₁ part of a voltage divider between positive and negative supply voltages B+ and B-. A capacitor C2 and resistor R₂ serve to filter the bias voltage. The integrator output signal at 321 is amplified by non-inverting amplifier A3 the positive output of which is limited by a zener diode CR2 to protect from under or overvoltage on the logic inputs.

When no integrated signal is presented to the input 323 of the amplifier A3, above a threshold level corresponding to one fractional unit (e.g. 1/16th) its output E_i is maintained at the binary zero level (zero volts) by the forward action of the zener diode CR2. On the other hand, the output voltage E_i of the amplifier A3 is at the binary "1" level when an integrated signal greater than the threshold level does appear across the input terminals 323, 324 of the amplifier A3. The inverting input 323 has a bias B1 developed by resistors R51 and R82 of 5.1 and 0.82 ohms nominally respectively and Zener diode CR3.

The output terminal 325 of amplifier A3 is coupled to a sample-and-hold unit SH1, directly to the terminal J of the unit SH1 and also through inverter logic A4 to the terminal K, the inverted input signal being provided to eliminate input signal ambiguity. The unit SH1 has complementing outputs at terminals Q and $\bar{Q}$. Internally, as explained in the supplier's catalog, there are "master" and "slave" sections responsive to the rise and fall of clock pulses from a clock pulse generator 330 coupled to terminal C of the unit SH1. On the rise of the clock pulse, the master and slave sections are first isolated, then the input terminals J and K are coupled to the master section. On the fall of the clock pulse, the inputs are disconnected from the master section and then the up-dated state of the master section is coupled to the slave section with its outputs Q and $\bar{Q}$. Thus, the binary state of signal E_i is periodically sampled during the fall of each clock pulse and held until the fall of the following clock pulse.

Complementing output terminal $\bar{Q}$ of SH1 is coupled to one input terminal 331 of NOR gate NOR1, its other input terminal 333 receiving clock pulses from the clock generator. The output signal of the gate NOR 1 is fed to the input terminal 335 of the inverting amplifier A5 and to the inverting input terminal 337 of amplifier A6, while the output signal at 341 of the amplifier A5 is connected to the positive terminal 339 of the amplifier A6. The output signal of the amplifier A6 is received by gate terminal 2 of a p-channel-enhancement MOS field-effect transistor T1 that serves as a switch for pulses of current for decrementing the output level of the integrator 315. Decrementing is "on" when the output of A6 is "low". The "source" terminal 4 of the switch T1 is connected to the input terminal 317 of the integrating amplifier A2. The current pulses, regulated in amplitude by a zener diode CR3 and potentiometer R6 are applied to the integrator 315 in polarity opposite to the signal current from the amplifier A1. Thus switch T1 allows a predetermined quantum of charge to be subtracted from the integral when its gate 2 is pulsed as the output of the am-

plifier A6 is switched from the binary "one" level to the binary "zero" level for the duration of a clock pulse. This switching is coincident with a binary zero on both inputs of the gate NOR 1, one zero from negative clock pulse from the clock generator 330, the other responsive to the integrated output of amplifier A2 being above the threshold level. The output at 341 of the amplifier A5 is also fed to the Fractional Counter 343 (illustrated as having four binary stages, but more or less may be appropriate). The selected preferred counter module is one that increments upon the fall of input voltage from binary "1" to binary zero, these changes coinciding with the end of each current pulse through the switch T1. The fractional counters 343, in turn increments the decimal counter 345. The selected preferred decimal counter modules happen to increment upon the rise of the input voltage from a zero to a 1. This happens when the fractional counter 343 reaches half of its full count. The desired round-off as described above is the result. By means of the calibration switch S, the pulses from the amplifier A5 may be fed directly to the decimal counter rather than to the fractional counter. This provides a higher output counting rate for calibration purposes as detailed below.

Clock pulses to trigger the various switching operations and to control the width of the decrementing current pulses are supplied by the clock pulse generator 330. It is illustrated as comprising a free-running relaxation oscillator comprising an amplifier A7 with a 5,100 ohm resistor R16 from the output terminal to the inverting input terminal and shunt capacitor C13 to control the frequency and a shunt resistor R17 and positive feedback resistor R18 both of 10,000 ohms and connected to the other input terminal. The oscillator output is carried through a 750 ohm resistor R19 to amplifiers A8 and A9. With positive feedback 510 ohm resistor R20 and 91 picofarad capacitor C4 in parallel and shunt zener diode CR7 these amplifiers, square and limit the resulting clock pulse, eliminating spurious spikes, as required to meet the level and sharpness specifications of the logic integrated circuits of the system.

The introduction of parts into the counting field unbalances the input and results in a negative-going output signal from amplifier A1. When gaps are present in the photocell field, the output voltage of the amplifier A1 presents a quiescent level to an amplifier A10 in addition to the integrator 315. This amplifier and the associated sample-and-hold unit SH2 generate an output pulse whenever a gap is detected. The operation of the unit SH2, the amplifier A11 between its J and K inputs, the zener diode CR4 and bias network R11, C5 operates in the manner above-described for the unit SH-1 and associated circuits. The output level E_s of the amplifier A10 is adjusted with R11 such that this output level E_s goes positive only when at least a part of an article to be counted is in the field. The minimum size of this part is governed by the noise and drift levels of the system.

The output terminal Q of unit SH2 holds the value of the signal E_s sampled until the fall of the next clock pulse.

The terminals Q of the units SH1 and SH2 are coupled through nor gate NOR2 and inverter A12 to the clearing terminal 349 of the fractional counter 343 to reset that counter than both E_i and E_s reach zero. This condition corresponds to the coincidence of a fully-

decremented integral and a gap. This condition provides the opportunity to clear out errors that accumulate in the counters while storing the integer values of parts counted in the decimal counter, as explained above.

COMPENSATION

Two forms of compensation are provided in the circuit of FIG. 3. The first is to compensate for incomplete counts, i.e., where portions of the first and last parts of a group are below a signal level so as to be neglected (as in FIG. 1B) by the circuitry. To compensate for this a current is fed back to add an input proportional to the number of gaps detected. The second compensation is for drift. Drift in the system is indicated by number of counts in the fractional counter which are dumped on the average when a gap is encountered. By feeding back at the beginning of each group counted a quantity which will subtract from the next group the observed error of the previous group, drift is substantially eliminated as a factor. It should be noted that this compensation completely eliminates the accumulation of counts during long standby periods. In such cases, gradual drift will cause an occasional pulse to go to the fractional counter; but will immediately be followed by a gap and cleared. At the same time the input is urged negative so that the time required to generate the next drifts pulse is increased.

The pulse which appears at the output Q of the unit SH2 is differentiated by a differentiating circuit C6, R22, rectified by diode CR5, and integrated by capacitor C7 and variable resistor R23. The resulting current, proportional to the number of gaps is fed back to the positive terminal of the reference cell 233.

To generate the drift compensation signal, the outputs of the gate NOR2 and of unit SH2 are applied through the nor gate NOR3 to a differentiating circuit C8, R25, rectified by diode CR6 (oppositely poled to diode CR5) and integrated by capacitor C9, and variable resistor R26, to the same terminal of the reference cell.

The preferred parts for the assembly of the system of FIG. 3 are as set forth in Table I.

TABLE I

A1, National Semiconductor Corp., Operational Amplifier, Circuit Type LM 207
A2, National Semiconductor Corp., Operational Amplifier Circuit Type, LM 308
A3, A6, A7 and A10, Signetics Corp., operational Amplifier Circuit Type N5741V.
A4, A5, A8, A9, A11, A12, each 1/6 of International Telephone and Telegraph Corp., Circuit Type ITT 7404 Inverters. ITT Product Catalog 1972/73
NOR1, NOR2, NOR3, each one-fourth of Texas Instrument Corp., Positive Nor Gates, Circuit LT/Type SN7402
SH1, SH2, each one-half of Texas Instruemnt Corp., MasterSlave Flip Flops, Circuit Type SN7473
T1, Solitron Devices Corporation, P-Channel Enhancement, MOS-FET, Type 3N-172
Fractional Counter, SN 74197
Decimal Counter, Computer Measurements Co., Model 912
Supply voltages, B+, B- each 15 volts

CALIBRATION

To calibrate the system initially, input to the input decimal counter 345 is connected by switch S to bypass the fractional counter 343 and be incremented directly by the decrementing pulses. In this mode the unit counter 345 is incremented each time that the integrated signal is decremented. Thus the counter output simply represents the quantized value of the integrated input plus drift accumulating with time. The potentiometer R11 is set to its upper end to block the amplifier A10 with positive output, thereby to disable the compensation circuits.

The bias potentiometer R4 for the integrating amplifier A2 is then adjusted to eliminate integrator drift. With the light source off, or covered, the potentiometer R4 is adjusted so that the counter indicates a small positive counting rate, e.g., one count per second. This value is chosen to be small enough to contribute insignificantly to the errors, and large enough to stay positive in value.

Next, the light source is made operative and the counter rate will be observed to increase or decrease because of slight imbalance in the optical paths. The light paths are then brought into balance by adjusting a shutter, or mirror (not shown). During these drift-rate adjustments, the diode CR1 serves its function in limiting the negative value to which the integrator may be driven. If the diode were not present, and the integrator drifts to its negative extremity, a long delay is required to return the integrator level to its positive operating range where the drift rate will again be reflected in a counting rate.

If the calibrataion is for a part which differs in size significantly from the parts last counted by the system, or if it be an initial setup of the system, the output of the amplifier A1 should be checked to see that it operates within its linear range when the maximum expected number of parts are in the field of the sensor.

To check this, the maximum number of parts, (or a mask of equivalent area) is held in the beam while a voltmeter (not shown) measures the output of the amplifier A1. The potentiometer R1 is then adjusted, if necessary, so that the voltage is between 25 and 100 percent of the specified linear range of the amplifier.

To calibrate the quantizer, so that each article applied to the field contributes its proper number (e.g. 16) of counts, and equivalently its proper amount of decrementing current to the integrator, a fixed number (e.g. 100) of articles are run through the field repeatedly in the operating manner, and the accumulated counts noted. If drift has been properly adjusted, the statistical variation in the number of counts from run to run will be less than about 2 percent. The resistor R6 is then adjusted so that the observed count is the correct one, (e.g., 1,600 counts for 100 items). Since statistical fluctuations will occur, this adjustment cannot (and need not) be made exact. Once this setting causes counts both above and below the correct count, the quantizer is said to be calibrated.

The gap monitor threshold level is calibrated with the input of the unit counter reconnected by switch S to the output of the fraction counter. The drift should then cause counting in the unit counter at only the fraction (1/16th) of the previous observed rate. A single article is suspended at the edges of the field to create a photo-cell signal of something less than half its maximum (e.g.

1/15th) and potentiometer R11 is then adjusted just enough that the drift counting rate is stopped. Caution must be taken to avoid setting the threshold too low since drift or noise could prevent the monitor from detecting the gaps.

The gap compensator sensitivity may also be adjusted by returning the switch S to the "calibration" position and running a number (e.g. 100) of articles through the system at a maximum speed to obtain a minimum number of gaps and then at a lesser speed to obtain a significantly greater number of gaps (up to one gap per article). If the latter count is consistently low then the former, this indicates that the integral of the initial and final articles of each group are being detectably reduced by the level of the threshold setting. To compensate properly for this, the resistor R13 is decreased to provide extra current to the integrated signal at the start of each group in order that this added signal equals that lost by the first (and last) article of the group.

Should the latter count be lower, this indicates that the resistor R13 is too low in value. It is increased to obtain the desired equality.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained. Since certain changes may be made in carrying out the above method and in the constructions set forth without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

In particular it will be understood that the terms "transducer", "integrator", and "counter" comprehend —means for converting a measurable parameter to an integrable quantity—, —means for integrating—, and —means for counting— respectively, and comprehend not only the electronic means preferred, but equivalents as well, which may be electromechanical, for example.

By way of further illustration, the mass of the article may be the characterizing property. If the articles are delivered from a conveyor belt at some particular velocity, momentum becomes another such measurable property. The articles may be thrown off the end of the conveyor belt to impinge in a substantially inelastic collision with a vertical surface of a ballistic pendulum. Each such collision would add the same increment to the velocity of the pendulum, which velocity of represents the formed integral. Conveniently the suspension of the pendulum may be a d'Arsonval galvanometer movement, and the resulting motion may be sensed by induced voltage in its winding and opposed by pulses of current through its winding which represent fractional measures of incremental velocity, and which are counted as the velocity is returned to zero. Here the transducer, the integrator, and the decrementing means would all be associated with the galvanometer mechanism.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. Apparatus for counting parts presented in groups separated by gaps, said parts generally characterized by contributing substantially equally to the integral of a transducer's response thereto, said apparatus comprising:

transducing means for detecting said parts and having a response,

first means for forming an integral, connected to said transducing means to operate said response,

second means for dividing said formed integral by a number of equal fractional measures, including means for varying said measures such that on the average an integral number n of said measures are required to form a quotient of one with a single parts's contribution to said formed integral, the integer n being selected to be even,

third means for counting said measures and accumulating both the number of odd multiples of half said integer ($n/2$) and a fractional remainder,

fourth means for detecting said gaps, said fourth means having an output signal; and

fifth means responsive to said fourth means for clearing said third means of said remainder upon the detection of a gap and after said measures have been counted by said third means.

2. Apparatus for counting articles presented in groups separated by gaps, said articles generally characterized by substantial equality in some measureable property whereby each said article contributes substantially equally to the integral of a transducer's response thereto, said apparatus comprising:

transducing means for detecting said articles and having a response to said property thereof,

an integrator for forming an integral connected to said means to operate on said response,

decrementing means for diminishing said formed integral by successively taking away equal fractional measures such that on the average substantially an integral number n of said measures diminish said integral by the amount of the contribution of each of said articles,

a counter comprising fractional counting means for accumulating said number n and an integer counting means, said fractional counting means being adapted to increment said integer counting means to the next higher integer upon the decrementing of the next said number n of said measures, and means responsive to each of said gaps for clearing said fractional counting means.

3. Apparatus as defined by claim 2 wherein said number n is an even integer, and said fractional counting means comprises a binary counter.

4. Apparatus as defined by claim 3 wherein said integer counting means is a digital electronic counter, and said fractional counter increments said electronic counter whenever the number of said measures taken away is an odd multiple of half of said integral number n .

5. Apparatus as defined by claim 2 wherein said transducer comprises a photocell, a lamp, a lens, and a mirror.

6. Apparatus as defined by claim 2 in further combination with means for drift compensation comprising means for feeding back to said integrator a signal propor-

tional to the number of counts cleared from said fractional counting means during said gaps.

7. Apparatus as defined by claim 4 in further combination with

means for drift compensation comprising means for feeding back to said integrator a signal proportional to the number of counts cleared from said fractional counting means driving said gaps.

8. Apparatus for counting parts presented in groups separated by gaps, said parts generally characterized by contributing substantially equally to the time integral of the output response of a photo-electric circuit, said apparatus comprising:

a photo-electric circuit for detecting said parts and having an electrical output response,

first means receiving said output response and for forming an integral of it over time,

second means for detecting when said integral of said response differs by a threshold level from a reference level of said integral,

a source of electrical pulses substantially equal in their contributions with calibrating means for adjusting the value thereof so that on the average substantially an even integral number n of said pulses diminish said integral by the amount of the contribution of each of said parts,

third means responsive to said second means for subtracting said pulsed from said integral to bring said integral across said threshold level,

fourth means for counting said pulses required to carry said integral across said threshold level and accumulating both the of odd multiples of half said integer ($n/2$) and a fractional remainder,

fifth means for detecting said gaps, and

sixth means responsive to said second and fifth means for clearing said fractional remainder upon the detection of a gap concurrent with the reduction of said integral below said threshold value.

9. Apparatus as set forth in claim 8 wherein said pulses are of uniform voltage and width.

10. Apparatus as set forth in claim 9 wherein said pulses are uniformly spaced.

11. Apparatus as set forth in claim 8 wherein said pulses are uniformly spaced and of constant current amplitude and duration.

12. Apparatus as set forth in claim 8 wherein said second means has an output signal E_i having a first binary state when said integral exceeds said threshold level, and a second binary state when said integral falls below said threshold level, said fifth means has an output signal E_s having a first

binary state when no gap is detected, and a second binary state when a gap is detected,

said fractional remainder is accumulated in a binary counter the stages of which in number equal the logarithm to the base two of said integer n , and wherein said multiples are accumulated in a second counter, said binary counter incrementing said second counter by a unit on the count of half of said integer n ,

said source of pulses comprises a clock generator and switching means coupled to a voltage source to connect said voltage source to said first means upon coincidence of said clock pulses and said output E_i having said first binary state, and comprising also

seventh means for clearing said binary counter upon the coincidence of said second binary states of said second and fifth means.

13. A method for counting articles presented in groups separated by gaps, said articles generally characterized by substantial uniformity in some measurable property, comprising the steps of:

causing said articles to move through a defined measurement field athwart their path at a predetermined speed,

obtaining from an appropriate transducer, a continuous response proportional to the total of said property within said field,

forming the time integral of said response,

decrementing said formed integral by successively taking away equal fractional measures, whenever said integral attains a significant threshold value to diminish it below said value, said measures being of a size such that on the average substantially an integral number n of said measures diminish said integral by the amount of the contribution of each of said articles,

counting said measures until a gap occurs in the flow of articles indicated by the complete absence of articles in said field and accumulating said count,

dividing the number of thus accumulated counts by said integer n to obtain an integral quotient and a remainder,

adjusting said integrating step in proportion to the amount of drift which is a measure of system error, rounding-off the quotient to obtain the best count, clearing any residue of said integral and the remainder, and

resuming the integration and counting with a fresh start after each gap until the count is complete.

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