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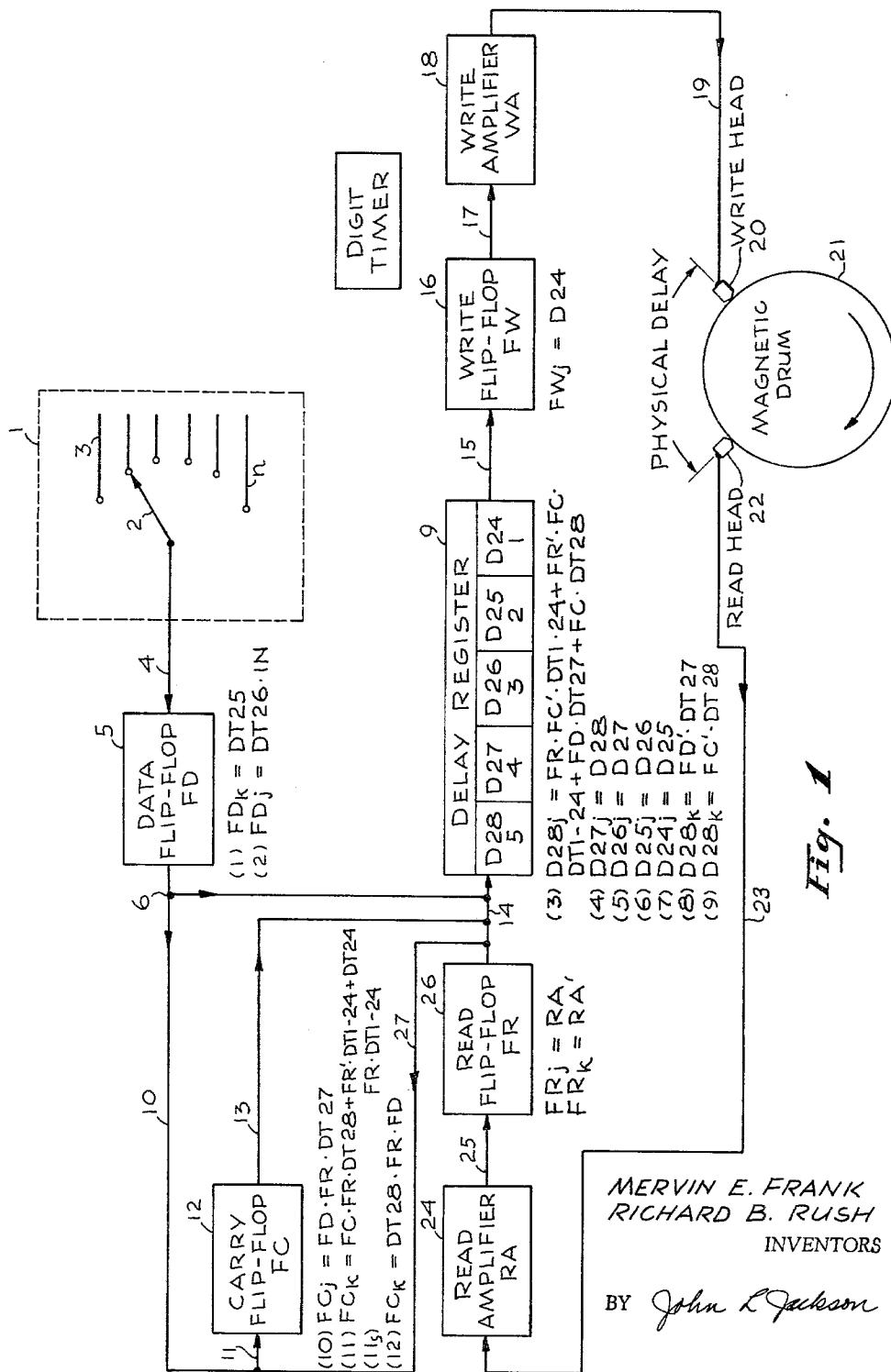
M. E. FRANK ETAL

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MULTIPLE INPUT COUNTER UTILIZING MAGNETIC DRUM STORAGE

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2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 2

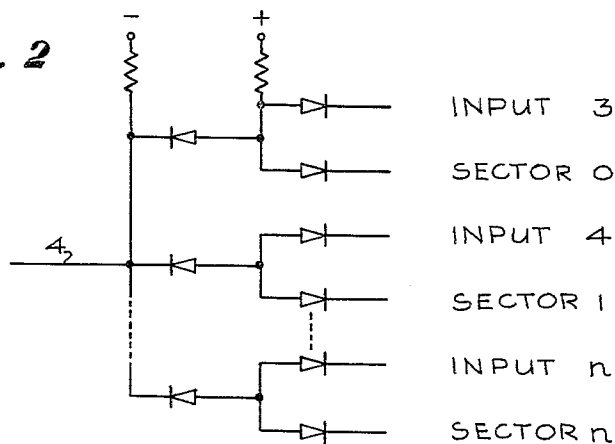
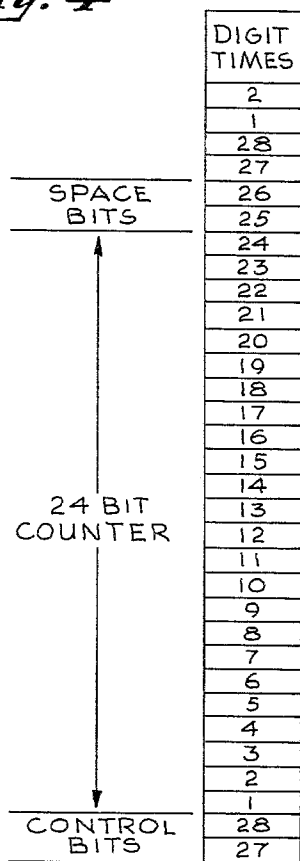


Fig. 4



8 _s	4 _s	2 _s	1 _s	DECIMAL
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9

Fig. 3

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MULTIPLE INPUT COUNTER UTILIZING MAGNETIC DRUM STORAGE

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4 Claims. (Cl. 235-92)

This invention relates to counting systems in general and more particularly to a multiple input electronic counting system utilizing a moving magnetic memory for count storage.

In many industrial and commercial environments, there is a need for counting. For instance, in a manufacturing plant, a count must often be maintained of manufactured parts as they flow through a production system. In warehousing, a count must ideally be kept of each individual item as stock is added or subtracted in inventory. In a steel strip mill, an accumulated count is normally maintained for each of several defects measured in a moving steel strip. In an automobile traffic control system, a count normally must be maintained of traffic flow on several streets. In atomic energy facilities, counters continuously monitor radiation at different points in a process or at different locations in the plant. In the collecting of tolls on toll roads, bridges and tunnels, a count of several different types of vehicles in each of several lanes must be maintained. It is therefore apparent that there is hardly an area in which things are manufactured, moved or handled where counting is not a requisite part of the system.

In many of these applications, it is desirable to obtain a cross total of some of the counters or to sort the accumulated counts of the counters into various categories. For example, an automobile production plant may turn out automobiles of ten different models. Fenders may be on one line, hoods on another, wheels on the third, etc. For purposes of production control the number of items produced in a specified period of time on any particular line must be known. Information as to the type of fender, hood, etc. being produced is also necessary. If a production control manager has immediate access to all of this data, he can better exercise control over the various phases of the operation. Thus, even in this simplified example, there may be twenty different parts being manufactured, each in five different types, requiring, for instance, counts of one hundred categories.

At the present time, the most widely used counters in industry are of the mechanical or electromechanical type wherein an accumulated count is visually presented. These units are simple, rugged and reliable. This type of counter is usually capable of registering approximately ten counts per second while some extremely specialized units currently available can register up to sixty counts per second with fairly good reliability. For higher counting speeds, in the range of one hundred to one million counts per second, wide use is made of electronic counters such as an electronic scaler. Originally, these electronic scalars were developed for use in atomic energy applications. However, they are now utilized in many other industrial applications. Another type of counter which has been developed for ultra-high speed counting applications at, for instance, rates up to a megacycle employs a multiple element vacuum tube known as a beam switching tube.

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For applications which lie in the area between the relatively slow speed applications which are implemented by electromechanical counters and the ultra-high speed counting applications which are implemented by electronic scalars, a number of ingenious devices have been developed. One such example is a glow transfer tube which has a single envelope containing ten anodes, an arrangement whereby an electron beam from a common cathode is sequentially stepped from anode to anode, thus forming the basis for a counting device. The counting range of this type device is usually from zero to two thousand cycles. However, they are most often utilized in applications of from one hundred to several thousand cycles per second. Additionally, this type of counting device provides an electrical readout.

With the recent advent of "automation," a need has arisen for electrical readout of the various counters utilized in the particular process being automated. This facility is necessary for efficient utilization of the associated computing device in the automated process in that valuable computer time is wasted where the various counters are visually read and their counts punched or otherwise manually entered into the computing device.

Electronic counters provide electrical readout in that the digital quantity stored in the counter can be read out electrically to an external printer, tape or card punch or computing device. Since most of the counter applications in industry are in areas requiring relatively slow counting, an attempt has been made by several manufacturers of the mechanical and electromechanical type counters to fill the need for electrical readout by equipping the counter wheels of the counters with individual commutator discs which provide an electrical code equivalent of the count in the particular counter wheel involved to associated brushes which are electrically connected to an associated printer, tape record punch, etc.

However, none of the above-mentioned type counters have proved to be entirely satisfactory for use in applications where electrical readout is necessary. For instance, in those applications where relatively slow counting speed of the mechanical or electromechanical type counter can be tolerated, the associated commutator and brush arrangement which is necessary for electrical readout reduces the otherwise high reliability of the counter since the brush and commutator arrangement, because of the large number of sliding contacts, is not only subject to mechanical and electromechanical wear, but, in addition, is prone to malfunction due to the large amount of air impurities which are often found in many industrial facilities. Until recently, most electronic counters or scalars have used vacuum tubes, four vacuum tubes being required per decade. A typical counter of this type would, therefore, have twenty-four vacuum tubes exclusive of those in the power supply and miscellaneous circuits. Reliability of these devices is limited, therefore, by the finite life characteristics of the vacuum tubes. Recently, counters of this type using transistors have become available; very recently, the advent of high speed transistors has permitted construction of completely solid state counters with far longer life and greater reliability than was heretofore possible. The cost of these solid state counters has tended to be quite excessive.

Another problem encountered when electromechanical counters are utilized along with an electrical readout capability is that of the ambiguity which exists in the counter output during the moment of transfer from one number to the next. In the case of most electromechanical counters, this transfer occupies an appreciable por-

tion of the count cycle. Since the counter cannot be read out during this transition, a suitable signal gate must, therefore, be provided to inactivate the output during this time. Although the electromechanical visual readout counters are themselves inexpensive, provision of readout commutators adds considerably to their cost. Thus, often where electrical readout is provided, the cost of the counter is eight times the cost of an identical counter without the electrical readout capability. In addition to the cost of the counter, the cost of wiring ten leads to each of the ten segments representing the output of a single decade is appreciable. Where large numbers of counters are required, the cost of cabling can be a significant item.

Electronic counters are quite expensive. However, where only a few different items are to be counted, the cost of these units can be readily justified. However, where large numbers of counters are required, the cost often becomes staggering. For instance, a typical strip mill operation may require fifteen or twenty counters capable of counting at a rate of about 100 counts per second. A warehouse inventory system might require several thousand counters capable of counting at a rate of one count per second. In a toll bridge data collecting system 1,000 to 2,000 counters are required. Each counter, however, can be quite slow since vehicles cannot pass the toll booth much faster than one every three seconds.

It is evident that for an application requiring a large number of counters, the use of individual commercially available counters will result in an expensive system. It is, therefore, an object of the present invention to provide a novel counting system which is capable of accepting a plurality of count inputs.

Another object of the present invention is to provide a relatively high speed counter which is extremely reliable and entirely solid state.

Another object of the present invention is to provide a counting system wherein additional count inputs can be added at a minimum cost.

Another object of the present invention is to provide a novel method of counting which is particularly suited for use with moving magnetic memory type digital computers.

Other and further objects and advantages of the present invention will become apparent to one skilled in the art from a consideration of the following detailed description when read in light of the accompanying drawings, in which:

FIG. 1 is a block diagram of the novel counting system herein-described;

FIG. 2 is an "AND-OR" gate combination which may be used for input selection; and

FIG. 3 is a chart showing the binary equivalents of the decimal numbers 0 through 9.

FIG. 4 is a chart showing the digit format of a drum sector.

Briefly, an input system is utilized which sequentially samples a plurality of inputs. A counter register recorded on a magnetic drum holds the accumulated count associated with each input. The content of each of the counter registers is continuously read and circulated through associated "add one" circuitry wherein a one is added to the contents of the particular register if its associated input is true. The output of the add one circuit is re-recorded in the exact memory location that the register occupied prior to reading.

Refer first to FIG. 1. In FIG. 1 is generically shown input means 1 having a stepping arm 2 which is capable of sequentially stepping from input 3 through input n . Each of the inputs 3 through n is connected to sensing means (not shown) which provide an electrical impulse on lines 3 through n concurrently with the detection by each sensing means of a count. The form of the sensing means, which may be a photocell, an infra-

red detector, a mechanical feeler, etc., is not important for the purpose of the present invention, the particular form depending upon the particular application involved.

While the input means 1 is shown in the form of a stepping switch arrangement, this is for convenience only and it should be understood that the input means may be of any form, the speed of which is compatible with the hereindescribed counting system. For instance, the input means may take the form of the AND-OR arrangement of FIG. 2 wherein a plurality of diode-resistor AND gates drive a diode-resistor OR gate. The AND gates have two input terms which are connected to the count sensor and a timing signal identifying the particular sector of the drum which is passing under the read head, as will hereinafter be more fully explained. The OR gate will have an output at any time that either of the plurality of AND gates is true.

The output of the input means 1 is fed along line 4 to a data flip-flop 5 (FD). The output of the data flip-flop FD is fed along line 6 to the input D28 of a delay register 9. The output of FD is also fed along lines 10 and 11 to the input of a carry flip-flop 12 (FC). The output of the carry flip-flop FC is fed along line 13 to the input D28 of the delay register 9. The input stage D28 of the delay register 9 has its output connected to the input of the next succeeding stage D27 which in turn has its output connected to the input of the next succeeding stage D26, etc. The output stage D24 has its output connected along line 15 to the input of the write flip-flop 16 (FW). The output of FW is fed along line 17 into the write amplifier 18. The output of the write amplifier 18 (WA) is fed along line 19 to the write head 20 which is in magnetic association with the magnetic drum 21. Also in magnetic association with magnetic drum 21 is a read head 22 which is physically separated from the write head 20 seven binary digits. The write and read heads are preferably contained in a single housing. One such head is the subject of a copending application entitled, "Electromagnetic Delay Head," Serial No. 115,537, assigned to the same assignee as the assignee of the present invention. A read amplifier 24 has its input connected to the read line 23 which in turn is connected to the read head 22. The output of the read amplifier (RA) is fed along line 25 to the input of the read flip-flop 26 (FR). The output of FR is fed along line 14 to the input D28 of the delay register 9. The output of FR is also fed along line 27 to line 11 and thence to the input of FC.

Refer next to the chart of FIG. 3 wherein is shown the binary equivalents of the decimal numbers 0 through 9. From a close consideration, it can be seen that a simple rule for adding one to a number can be devised. For instance, it is seen that in considering the binary number 0010, it can be incremented by one by inverting the 0 contained in the 1's column and copying the 1 contained in the 2's column and the 0 contained in the 4's and 8's columns. Considering binary number 0011, it can be seen that it can be incremented by a 1 by inverting the 1 in the 1's column, inverting the 1 in the 2's column, inverting the 0 shown in the 4's column and copying the 0 contained in the 8's column. Thus the rule for adding one may be stated as follows: Considering sequentially the number to be incremented by 1 beginning with its least significant digit, invert all digits through and including the first 0 and thereafter copy each digit as is. This rule is implemented along with a method of digital filtering to prevent the counting of random or spurious noise pulses as hereinafter described.

The logical terminology hereinafter employed is as follows: A j subscript means that if the conditions on the right of the equality marks are met, the left-hand term is set in its true or "one" state during the following digit time while a subscript k implies the false or "zero" state; DT designates timing, thus "DT1-24" signifies digit times 1-24; capitol letters such as FC imply a true or

one condition while capital letters primed as RA' imply a false or zero condition.

Consider again FIG. 1. For the purpose of illustration of operation, the description of the operation involved in adding one to a drum register as well as digital filtering will be described. In the present example it will be assumed that each of the drum sectors is 28 bits in length and that 24 of the 28 digits are used for the counter and two of the four space bits are used as control bits to accomplish the hereinafter described digital filtering. Thus each sector may be broken down as shown in FIG. 4. It is, of course, apparent that this operation is the same for any of the drum registers. Assume, therefore, that there is an input along line 4 which corresponds in voltage to the logical level of a binary one utilized in the system which is indicative of the sensing of one of whatever article is being counted.

From a consideration of FIG. 4, it can be seen that the control bits associated with each counter register occur at DT27, 28 preceding the reading of the particular register by the read head. Thus, in accordance with the digital filtering method, FD is set to 0 each DT25(1) preceding the entry of the particular sector involved and FD is set true at each DT26(2) in the event that there is a one on the input line 4.

FC is utilized in both the add one operation whereby the contents of a particular drum register are increased by one and the digital filtering whereby spurious noise pulses are digitally filtered and prevented from being registered as a count on the input line 4.

Considering first the add one operation in accordance with the logical Equation 3 associated with the delay register 9 which is merely a shift register (4)-(7), it can be seen that FC controls the add one operation. If FC is true at DT1, the input stage D28_j of the delay register 9 copies FR' until the first one occurs (3). Upon the occurrence of the first one, FC, as will hereinafter be described, is reset and D28_j copies FR through DT24(3). Thus one is added to the contents of the selected sector if FC is true at DT1.

A measure of noise filtering is accomplished by imposing the requirement that any input along line 4 must be present for two drum revolutions. Assume that FD is false for several drum revolutions at DT25 preceding the selector sector. Zeros are copied by D28_j at DT27 from FD(8) and at D28 from FC(9). The first revolution that FD is true at DT26, a one is copied at DT27 from FD by D28_j(3) and a zero is copied by D28_i from FC at DT 28(9). Thus FC is false at DT1 and the contents of the selected sector are not incremented by one. During the second revolution that FD is true at DT26, a one is copied by D28_j at DT27 from FD(3) and FC is set true at DT27(10). D28_j then copies a one from FC at DT28(3) and since FC is true at DT1, the contents of the selected sector are increased by one during the interval DT1 through 24(3), (11). On subsequent revolutions, if FD is still true. FC is set true at DT27 and FC is reset at DT28(12). A one is copied by D28_j at DT27 from FD and a zero is copied at D28 from FC(3). During the first revolution that FD is false, a zero is copied by D28_j at DT27 and FC is not set true at DT27(10). Thus a zero is copied by D28_j at D28 from FC. During the second revolution that FD is false, the cycle described above may be repeated. Line 4 must, therefore, be true for at least two drum revolutions before the counter contents can be changed. Random noise pulses thus tend to be rejected.

As is obvious from a consideration of the logical equations associated with FC, it can be seen that FC is set true at DT27 only if FD and FR are true (10), FR, of course, being true only if a one is entered in D28_j during DT27 of the previous revolution. FC is reset at DT28 if FC and FR are true (11), which indicates that one has already been added to the contents of the particular register due to the presence of the input signal

on line 4. Likewise FC is set to zero at DT1 through 24 in FR' is true or at DT24 in the special case that the counter fills and FR' does not go true (11). The remaining logical elements in the system simply copy their preceding element as indicated by the logical equations associated with FR, FW, and the delay register 9.

In some applications, it may be desirable to count through use of subtraction rather than by addition. The logic at D28_i is unchanged but one FC_k input term changes from: FR'.DT1-24 to FR.DT1-24(11's. D28_i, thus copies FR' until the first zero occurs and then FC is reset. D28_i then copies FR. Thus the contents of the counter are decreased by one if FC is true at DT1. While the present description has been made through utilization of only one drum sector, it is, of course, apparent that a plurality of sectors could be utilized. Each track on a computer contains a plurality of sectors, the number of which depends upon the length of the sector. The sector selection means involving magnetic drums are old in the art as well as track selection means. Thus it should be understood that the present invention is not limited to one sector or a plurality of sectors upon the same track.

Likewise, the particular digit timing means involved in the present invention has not been described since digit timing means are well known in the art and are readily available. Thus timing means are always present in a computer and it is a simple matter to provide such a timing means in the event that the counter is employed in non-computer type applications.

In the above described manner we have presented a novel counting system which is capable of accepting a plurality of count inputs. Furthermore, I have provided a novel counting system which not only can be designed to function independent of computer applications but which is highly compatible in computer applications to provide a counting system of extremely low additional cost beyond the cost of the computer system.

While there has been described what is at present considered to be a preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A counting system for counting and separately maintaining the individual counts from a plurality of input sensors comprising: a moving magnetic medium having associated therewith in magnetic association at least one read head and one write head, read amplification means and write amplification means attached to said read and write heads, delay means connected between said read and write amplification means, said delay means comprising a read flip-flop connected to said read amplification means, a delay register having an input stage and an output stage having its input stage connected to said read flip-flop, a write flip-flop, the output stage of said delay register being connected to said write flip-flop, the output of said write flip-flop being connected to said write amplification means, input means for selecting from among said plurality of count sensors, adding means connected between said input means and said delay means for adding one to the contents of said delay means in the event that an input is received from the selected count sensor, said adding means comprising a data flip-flop having an input and an output, and a carry flip-flop, the output of said data flip-flop being connected to the input of said carry flip-flop, the output of said read flip-flop being connected to the input of said carry flip-flop and the output of said carry flip-flop being connected to the input stage of said delay register.

2. A counting system for counting and separately maintaining the individual counts from a plurality of input sensors comprising: a moving magnetic medium having

associated therewith in magnetic association at least one read head and one write head, read amplification means and write amplification means attached to said read and write heads, delay means connected between said read and write amplification means, said delay means comprising a read flip-flop connected to said read amplification means, a delay register having an input stage and an output stage having its input stage connected to said read flip-flop, a write flip-flop, the output stage of said delay register being connected to said write flip-flop, the output of said write flip-flop being connected to said write amplification means, input means for selecting from among said plurality of count sensors, adding means connected between said input means and said delay means for adding one to the contents of said delay means in the event that an input is received from the selected count sensor, the electrical delay provided by said delay means being equal to the physical delay provided by said read and write heads whereby information read from a particular sector of the moving magnetic medium is re-recorded in exactly the same sector, and said adding means comprising a data flip-flop having an input and an output, and a carry flip-flop, the output of said data flip-flop being connected to the input of said carry flip-flop, the output of said read flip-flop being connected to the input of said carry flip-flop and the output of said carry flip-flop being connected to the input stage of said delay register.

3. A counting system for counting and separately maintaining the total individual counts from a plurality of count sensors comprising: a moving magnetic medium having at least one read head and at least one write head associated in magnetic association therewith, read amplification means having an input and an output, the input of said read amplification means being connected to said read head, a read flip-flop having an input and an output, the output of said read amplification means being connected to said read flip-flop, a delay register having an input and an output stage, the output of said read flip-flop being connected to said input stage, a write flip-flop having an input and an output, the output stage of said delay register being connected to the input of said write flip-flop, a write amplification means having an input and an output, the output of said write flip-flop being connected to the input of said write amplification means, the output of said write amplification means being connected to said write head, input means capable of selecting from among said plurality of count sensors, digital filtering and adding means connected to said input means comprising a data flip-flop having an input and an output, the input of said data flip-flop being connected to the input of said carry flip-flop having an input and an output, the output of said data flip-flop being connected to the input of said carry flip-flop and the input stage of said delay register, the output of said carry flip-flop also being connected to the input stage of said delay register, and the output of said read flip-flop being connected to the input of said carry flip-flop whereby the contents of the delay register are imple-

mented by one and the data from the count sensor is filtered in accordance with the logical equations:

$$\begin{aligned} FD_j &= DT26.IN; FD_k = DT25; FC_j = FD.FR.DT27 \\ FC_k &= FC.FR.DT28 + FR'.DT1-24 + DT24 \\ D28_j &= FR.FC'.DT1-24 + FR'.FC.DT1-24 \\ &\quad + FD.DT27 + FC.DT28 \end{aligned}$$

4. A counting system for counting and separately maintaining the total individual counts from a plurality of count sensors comprising: a moving magnetic medium having at least one read head and at least one write head associated in magnetic association therewith, read amplification means having an input and an output, the input of said read amplification means being connected to said read head, a read flip-flop having an input and an output, the output of said read amplification means being connected to said read flip-flop, a delay register having an input and an output stage, the output of said read flip-flop being connected to said input stage, a write flip-flop having an input and an output, the output stage of said delay register being connected to the input of said write flip-flop, a write amplification means having an input and an output, the output of said write flip-flop being connected to the input of said write amplification means, the output of said write amplification means being connected to said write head, the total electrical delay encountered in said read amplifier, read flip-flop, delay register, write flip-flop and write amplifier being equal to the total physical delay presented by said read and write heads, input means capable of selecting from among said plurality of count sensors, digital filtering and adding means connected to said input means comprising a data flip-flop having an input and an output, the input of said data flip-flop being connected to said input means, a carry flip-flop having an input and an output, the output of said data flip-flop being connected to the input of said carry flip-flop and the input stage of said delay register, the output of said carry flip-flop also being connected to the input stage of said delay register, and the output of said read flip-flop being connected to the input of said carry flip-flop whereby the contents of the delay register are implemented by one and the data from the count sensor is filtered in accordance with the logical equations:

$$\begin{aligned} FD_j &= DT26.IN; FD_k = DT25; FC_j = FD.FR.DT27 \\ FC_k &= FC.FR.DT28 + FR'.DT1-24 + DT24 \\ D28_j &= FR.FC'.DT1-24 + FR'.FC.DT1-24 \\ &\quad + FD.DT27 + FC.DT28 \end{aligned}$$

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,219,802

November 23, 196

Mervin E. Frank et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 58, for "an" read -- and --; line 71, for "D28_i" read -- D28_j --; column 6, line 2, for "in", first occurrence, read -- if --; line 9, for "D28_i" read -- D28_j --; line 10, for "D28" read -- D28_j --; line 12, for "D28_i" read -- D28_j --; column 7, line 50, for "the input of said" read -- said input means, a --.

Signed and sealed this 19th day of September 1967.

(SEAL)

Attest:

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Attesting Officer

EDWARD J. BRENNE

Commissioner of Patents