Dec. 10, 1940. W. F. FRIEDMAN ET AL 2,224,646

ELECTRIC CONTROL SYSTEM FOR TABULATING CARDS, DOCUMENTS, AND THE LIKE

Filed April 22, 1937 2 Sheets-Sheet 1

FIG. 1.

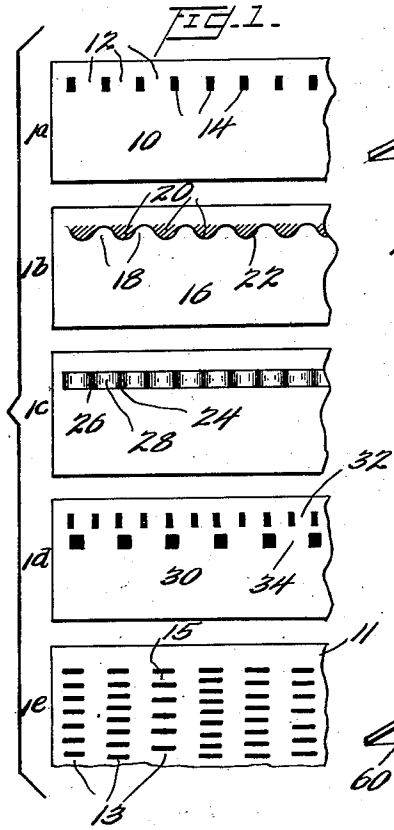


FIG. 2.

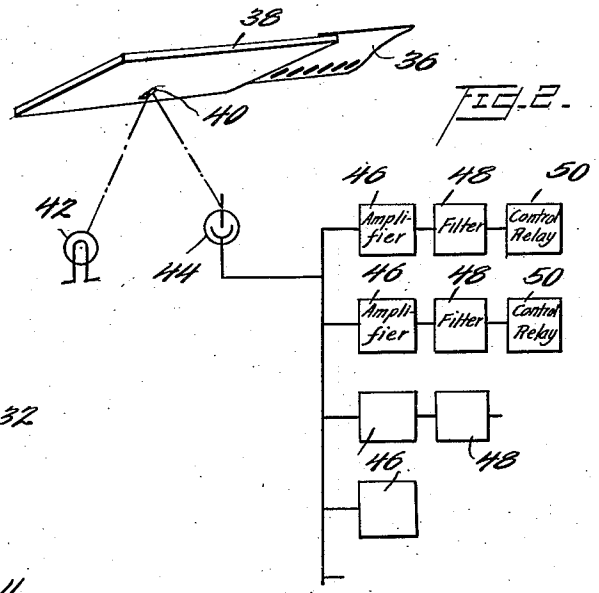


FIG. 4.

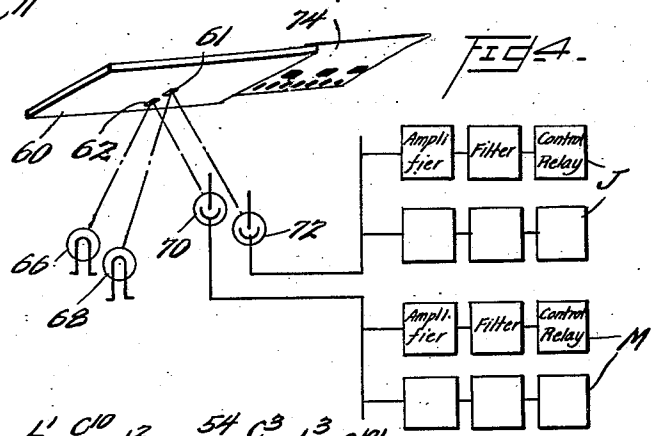
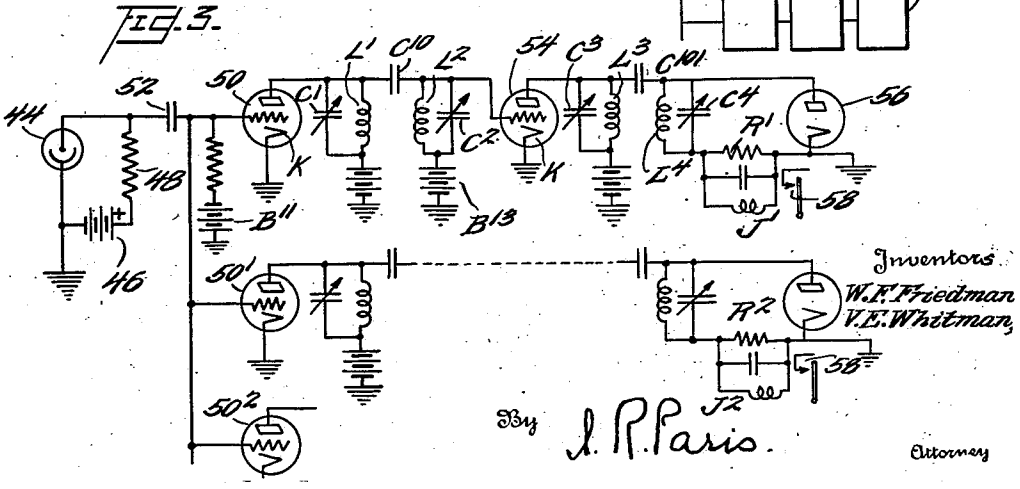


FIG. 3.



Inventors
W. F. Friedman
V. E. Whitman,

By I. P. Paris.

Attorney

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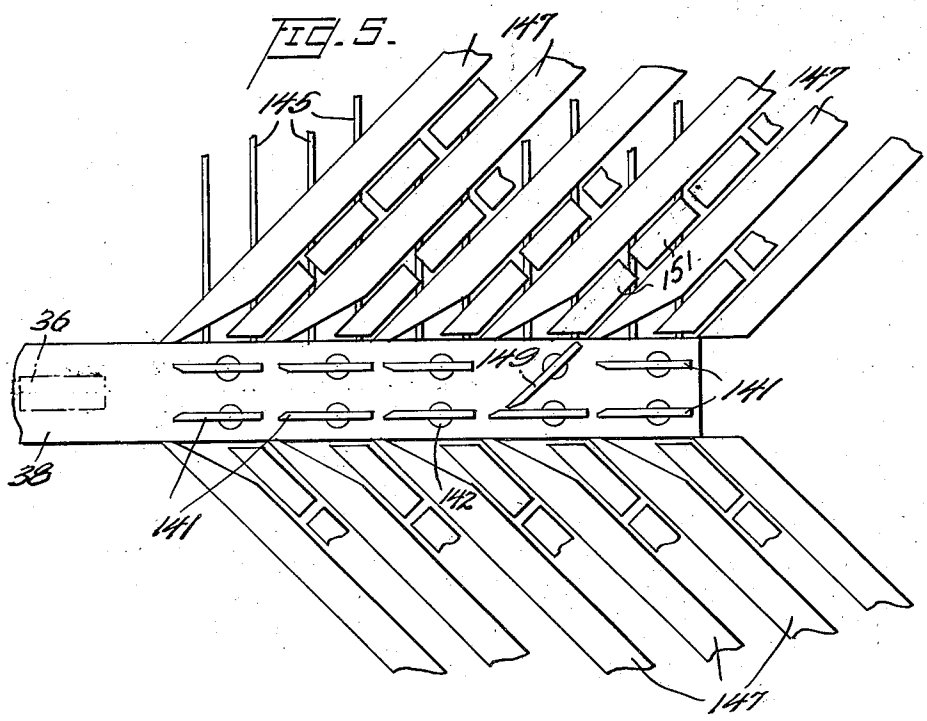
ELECTRIC CONTROL SYSTEM FOR TABULATING CARDS, DOCUMENTS, AND THE LIKE

Filed April 22, 1937 2 Sheets-Sheet 2

FIG. 5.



Inventors

W. F. Friedman

V. E. Whitman,

By J. R. Paris. Attorney

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ELECTRIC CONTROL SYSTEM FOR TABULATING CARDS, DOCUMENTS, AND THE LIKE

William F. Friedman, Washington, D. C., and Vernon E. Whitman, Bayside, Long Island, N. Y.

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4 Claims. (Cl. 209—111)

The present invention relates to a code system and to an electric control system cooperating with such code system for a variety of purposes.

The present invention employs a regularly recurring variation in a physical property of a series of objects for the purpose of controlling a variety of operations that may be sought to be performed upon the objects. The operation that may be controlled by the present system may be of a wide variety and for the purpose of illustrating the invention, we may mention the use of the present code system and electric control system for sorting a large variety of objects. Thus, it may be employed for sorting cards bearing items of information, represented by the present code system or for reproducing the information appearing on such cards or for translating such information. The present system may also be employed for sorting checks or other documents upon which the sort to which each check or document or card belongs is represented by a code of the present code system. The present electrical system may also be employed for sorting or for otherwise operating upon objects which are already so constructed that they possess a regularly recurring physical quality in accordance with the present code.

Among the physical properties that may be employed in the present code system and in the present electric control system are light reflectivity, light transmissivity, electrical conductivity, magnetic permeability, and the dielectric constant.

Other objects such as checks, documents, or tabulating cards, or packages, or the wrappers therefor, which do not already possess a regularly recurring variation in any one of these properties may have such variation imparted to them by a variety of means. For example, a relatively long and narrow zone on a surface of each of such cards, documents, or the like may be imprinted with series of markings which will impart to said zone a periodic variation in the reflectivity to such zone. It will be appreciated that this variation in reflectivity can be imparted to the surface of the document in a number of ways. The variation may be secured by printing or engraving with ordinary or special inks of any desired color, or even with the use of inks ordinarily invisible to the human eye. Or, the color of the document may be left unchanged, and the mattness or gloss of the surface varied by calendering or other processes well known in the paper making industry.

The remainder of the present specification will deal primarily with a code system which employs regularly recurring variations in light reflectivity and with an electric control system which is operable by such variations; it will be understood, however, that regularly recurring variations of other physical qualities or properties, such as set forth above, may be employed in the present code system and may also be employed to cooperate with the electric control system so as to control the operations which are to be performed upon the objects or articles.

The electric system is designed to scan the code by means of a suitable photoelectric device or by means of some other device responsive to variations in the particular physical property employed, and as a result of such scanning operation, alternating currents of frequencies predetermined by such codes are generated in the circuit of the scanning device and in the circuits associated therewith. The code system of the present invention permits of a large number of codes or markings, each peculiar to itself, and each having the property of inducing in the electric system a frequency or a set of frequencies peculiar to itself. The electrical system, which may have one or more photoelectric cells or similar scanning devices, has a plurality of control circuits each of which is tuned to a predetermined frequency that corresponds to a specific code marking while the frequencies that may be induced by other code markings are filtered out or attenuated. Each circuit is, therefore, made to control the operation of a suitable device, such as a magnet or a relay, or the like, and the latter, hereinafter called the control relay, may be made to control the operation of any type of mechanism desired, and to perform any desired operation. Thus, the relays associated with these circuits may be made to control the operation of a sorting mechanism so that a large number of objects, such as checks or other documents, record cards, or the like, or packages, may be passed over the scanning devices, be scanned thereby, and then sorted into groups, classes, or sorts.

When the present code system is employed for recording data on tabulating cards, the same photoelectric system may be employed to control the operation of a sorting mechanism which will sort the cards in groups or sorts corresponding to one or more items of information appearing on the card in code form. If desired, the same cards may be passed through the photoelectric system and the relays associated therewith may control the operation of a printing

mechanism which serves to translate one or more items of information appearing on these cards in coded form. The same system may also be employed, if desired, for operating a reproducing mechanism so that one or more items of information appearing on these tabulating cards may be reproduced in coded form.

The code may take one of several forms as will be described in greater detail in a later portion of the present specification. The basic principle underlying the several forms of the printed code resides in providing upon a surface of the check, document, card, wrapper, or package, or any other article, an elongated and relatively narrow zone bearing printed marks thereon which are so distributed that alternate relatively light and relatively dark spaces are obtained, these being arranged in accordance with a predetermined frequency or frequencies for each code. When such a zone is scanned by a photoelectric device, the current induced in the photoelectric device and in the circuits associated therewith will vary in accordance with such markings and generate an alternating current having frequency components characteristic of such markings. With a given code marking, therefore, the control relay or relays which are specifically responsive to the frequency or frequencies included by such marking will be put into operative condition and the same will then set into operation the mechanism under its control, whether it be a sorting, a printing, or reproducing mechanism, or the like.

A clearer and more detailed understanding of the present invention may be had from the accompanying drawing and the following specification, which illustrates several embodiments of the present invention but does not serve to limit the scope of the invention.

In the drawing—

Fig. 1 illustrates several code systems;

Fig. 2 is a schematic showing of the control system;

Fig. 3 shows one form of the electric system; and

Fig. 4 shows another form of the electric system.

Fig. 5 constitutes a diagrammatic illustration of a sorting apparatus that may be employed herein and operated by the present electrical system.

The several types of code markings illustrating the present code system are shown in Fig. 1 of the drawing. One form of code marking comprises a series of spaced printed bars or stripes, applied preferably near one edge of the document or card or the like 10, as shown in Fig. 1*a*. The unprinted or light spaces 12 will reflect incident light, whereas the dark or printed stripes or bars 14 will absorb incident light. In the code shown in Fig. 1*a* the light spaces 12 are all of the same width and the printed bars 14 are all of the same width. The basic or fundamental periodicity of this marking is determined by the sum of these two dimensions and by the rate of scanning; i. e., the velocity with which the document is caused to pass the photocell. The sum of the two dimensions just referred to is equal to the distance between the centers of adjacent black, or white bars. Other codes in the same system are obtained by varying the fundamental frequency by varying the sum of these two dimensions, and this may be done either by varying the width of the printed bar while maintaining the width of the light space 12 constant or vice versa or by varying both the width of the light space 12 and of the printed bar 14. While for many purposes the code system as just described will yield a sufficient number of frequencies, substantially the same system may be employed to yield a still greater number of frequencies by providing an additional variation in which the sum of the width of adjacent light and dark spaces 12 and 14 is maintained constant but in which the ratio of the width of the light space with relation to the dark space is varied. Such markings or codes will all yield the same fundamental frequency but the harmonic content of one such code differs from the harmonic content of another such code by reason of the fact that the amplitudes of harmonic frequencies depend upon this ratio. Moreover, with a given ratio one or more of the harmonic frequencies drop out, while with another ratio, another harmonic frequency or another group of harmonic frequencies drop out. These zero amplitude harmonics may be employed to cooperate with a fundamental frequency for the control of a desired operation. The code system shown in Fig. 1*a* may, therefore, for some purposes rely for differentiation merely upon the fundamental frequency, and for this purpose will merely employ a system of codes in which the sum of the width of adjacent light and dark spaces vary from one code to the next; and for other purposes where a larger number of frequencies is desired for the purpose of controlling a greater variation in the operation of sorting, printing, or reproducing mechanisms, both the fundamental and selected harmonic frequencies are utilized, and in such cases the codes differ from each other either in the sum of the widths of the adjacent light and dark spaces or in the ratio of the adjacent light and dark spaces or in the ratio of the adjacent light and dark spaces, or in both respects.

As an illustration of the above-mentioned dependence of harmonic content upon the ratio of light to dark area widths, the following examples are stated without proof. (The proof involves a branch of higher mathematics known as "Fourier analysis" and is omitted in the interest of simplification.) If the width of the dark band equals that of the light one, all even harmonics have zero amplitude. This means that if the document having such markings was passed over a photocell (covered by a table with a slit 40 in Fig. 2 narrow with respect to the dimensions of the markings) at the rate of 100 black bars per second, that a voltage would be generated in the output of the photocell having 100, 300, 500, and 700 cycle components. The frequencies of 200, 400, and 600 cycles would have practically no voltage. Furthermore, if the sensitivity of the system was such that the amplitude of the 100 cycle component was 4 volts, then the 300 cycle amplitude would be approximately 1.3 volts, and the 500 cycle component 0.8 volt. If, on the other hand, the dark bar had been 50% wider than the light one, the voltages at the various frequencies would have been as follows: 4.0 volts of 100 cycles; 1.2 volts of 200 cycles; 0.8 volt of 300 cycles; 1.0 volt of 400 cycles, and 0.8 volt of 500 cycles. The distinctions between the two examples are obvious: it is the purpose of the electrical elements in the system to allow such distinctions to cause different operations to be performed on the corresponding documents. It is obvious from the above analysis that code markings may be resolved into their spectra and that these spectra contain characteristic ele-

ments in addition to the fundamental frequency involved.

Fig. 1*b* shows a document **16** having on the edge thereof another type of imprinted code marking. In this type of imprinted code marking, the light spaces **18** are divided from the dark spaces **20** by a sinusoidal line **22**. The fundamental frequency of this type of marking is determined by the distance between the peaks of a pair of adjacent dark spaces or light spaces which distance is varied from code to code.

Fig. 1*c* shows another check or card or other document or package employing variable density type of marking. In this case the frequency is determined by the distance between the points **24** and **26** which are adjacent lines of maximum density, the printing upon the space between these points becoming less and less dense until the point **28**, half way between **24** and **26**, is reached, where there may not be any marking at all, and constitutes the point of maximum reflectivity.

While, as shown here, these markings are disposed at or near the edge of the document, it will be understood that such markings may be disposed along any suitable line, provided that in each case, the code zone contains a sufficient number of cycles. The number of cycles required depends upon the refinements of the system. In general, it may be said that for practical operation a minimum of ten cycles is desirable.

Fig. 1*d* shows a check, card, or similar article **30** bearing two code zones **32** and **34**. Each of these zones may be of any of the types shown in Fig. 1*a*, Fig. 1*b*, or Fig. 1*c*. These two zones differ from each other, however, in the fundamental frequency, and they cooperate with each other and with the photoelectric system in order to determine the nature of the operation of the controlled sorting, tabulating, printing, or reproducing mechanism.

In the case of tabulating cards, each of which carries several items of information, each item of information will be represented thereon by a columnar zone bearing the imprinted code marking thereon, and these zones may be adjacent to each other.

Fig. 1*e* shows a portion of a tabulating card **11** having the columnar zones **13**, some of which bear the markings **15** representing in coded form the desired items of information.

When multiple code zones exist, as shown in Figs. 1*d* and 1*e*, the information contained therein can be secured from all zones simultaneously by simultaneous scanning with the required number of scanning systems; or, a single scanning system may be employed, and the different zones scanned successively.

While in the preferred form of the invention as thus far described, the code zone is designed to reflect incident light from a constant source of light onto a photoelectric cell or similar sensitive device, it will be understood that the same invention may be employed in connection with transparent or translucent articles, and the present code will vary the amount of light transmitted therethrough.

The electric system and its manner of cooperation with the documents bearing the codes are schematically illustrated in Fig. 2. The document or other coded article **36** is passed over the scanning platform **38** which is provided with a slot **40**. Light from the source **42** is directed upon the slot and is reflected from the document passing thereover onto the scanning device, diagrammatically represented by the photoelectric cell **44**. The cell is electrically connected in any suitable manner to a plurality of control circuits, each comprising an amplifier **46**, a frequency selector or filter **48**, and a control relay **50**. The actuation or energization of the control relay **50** then serves to control the operation of any desired mechanism as set forth hereinabove. The frequency selectors or filter circuits **48** in each control circuit is adjusted to a preselected frequency, differing from the frequency of the remaining selectors or filters in the system.

It will now be understood that with a predetermined and constant rate of travel of the documents, cards, or the like, successively over the slot, the fundamental and harmonic content of the code markings on each document will determine the frequencies and amplitudes of the components of the current flowing in the circuit of the photocell and thereby the selected control relay or combination of control relays will be energized and the desired operation determined by the code markings on the document will be performed. As a specific example of the action of such a system, let us consider the electrical differentiation between checks which have been so marked that they are to be sorted into groups "EA," "EB," "DA," and "DB." In accordance with any practical embodiment of this invention, all checks will be assumed to be scanned at a constant rate, irrespective of the markings they may have. In our specific example it will be assumed that checks EA and EB have been marked with coding bars whose distances between centers is equal in the two cases, giving rise therefore to equal fundamental frequencies when scanned, and that these spacings are such that this fundamental frequency will be 100 cycles in each case. 100 cycles may, therefore, be said to be characteristic of all checks which are to be filed or sorted under the letter E. All checks for sorting under D, however, will be given a code marking which will have a fundamental of 110 cycles, whether the checks are intended for sub-sort A or sub-sort B. The differentiation between the sub-sorts A and B either in case E or in case D will be made on the basis of the harmonic content of the markings. Let it be further assumed that all checks intended for sub-sort A are marked with bars in which the width of the dark bar is always equal to that of the light one. In accordance with the analysis of this case given in a paragraph above, the amplitude of all even harmonics will be zero. Checks intended for sub-sort B may be given markings in which the dark bar is 50% wider than the light one: the harmonic content of such a marking was also given in the paragraph referred to above. In order to simplify this illustration as much as possible, all elements not essential to the sorting of the four checks under consideration will be dispensed with; the extension of this example to more complicated cases will be obvious. In order to differentiate between the four checks under consideration, only four relays and their associated tuned circuits and amplifiers are necessary. Two of these will be tuned to 100 and 110 cycles respectively and will be referred to as the "master relays" of sort E and D respectively. Any check which passes the scanning mechanism so as to generate a voltage or current with a 100 cycle component will energize the E master relay and be directed toward primary sort E, irrespective of the higher

harmonic contents. Whether the check will subsequently be passed on to sub-sort A or B will be determined by the harmonic content of the voltage generated in the scanning circuit as will be illustrated below. Two of the four necessary relays have been mentioned; the others are tuned to 200 and 220 cycles and are associated with the 100 and 110 cycle master relays, respectively. These additional relays will be recognized as being tuned to the second harmonics of master relays E and D. Let us assume now that check EA passes the scanning mechanism; master relay E is energized because of the 100 cycle voltage present; there is, however, no 200 cycle component available to actuate the relay tuned to this harmonic; the check will, therefore, pass on to a place corresponding to that particular relay combination. If, on the other hand, check EB had passed, a voltage of 200 cycles would have been present in addition to the 100 cycle one, and the check will pass on to a place corresponding to the combined action of master relay E and sub-relay B. A similar analysis will show how the relay energizing is unique for each of the check markings considered. Mechanisms by which these different relay actions may be made to actuate corresponding sorting operations are well known in the art and constitute no part of the present invention. Suffice it to say that the essentials for distinguishing between checks EA, EB, DA, and DB have been derived above, and they may, therefore, be sorted into classifications EA, EB, DA, or DB, as the case may be.

The length of the slot **40** should preferably be equal to the width of the markings. The slot should, however, be as narrow as is consistent with sufficient light reaching the photocell.

Fig. 3 shows the detail of one electric system that may be employed herein, it being understood, however, that such circuits may be varied as desired so long as it embodies a photoelectric device and a suitable number of control circuits, each containing amplifying means, frequency selecting means, and a control relay, as shown in Fig. 2. In Fig. 3, the variable current induced by the scanning operation is made to flow through the photocell **44** by means of the battery **46**. The resulting current causes a voltage drop across the resistor **48**, which drop is impressed on the grids of amplifying tubes **50**, 50^1, 50^2, etc. These tubes are disposed in a series of parallel control circuits which receive the alternating current components fed through the condenser **52** which also serves to isolate the grids of these tubes from the battery **46**. Each of these circuits comprises suitable amplifying devices and suitable filtering or frequency selecting devices, and a control relay. If desired, any type of rectifying device may be interposed between the control relay and the remainder of the circuit.

More particularly, the circuit shown at the top of Fig. 3 which is illustrative of the remaining circuits, comprises multi-electrode tubes **50** and **54** and interposed between them are the tuned coupling circuits C^1, L^1, C^{10}, L^2, C^2, tuned to a predetermined frequency corresponding to the fundamental frequency of a selected code. The rectifier is illustrated by the two electrode tube **56**, it being understood that this is merely illustrative of any suitable rectifier, it being further understood that A. C. relays may be employed and the rectifier may then be omitted. The control relay is indicated at J^1 which is actuated in response to the frequency determined by its circuit and by making or breaking contact **58**, it serves to control the nature of the operation of the printing, sorting, or reproducing mechanism with which the system is employed. An additional tuned circuit C^3, L^3, C^{101}, L^4, C^4 is also interposed between tube **54** and the rectifier **56**. The cathodes K of all tubes are shown as grounded and suitable operating points on the tube characteristics are insured by the grid bias batteries B^{11}, B^{13}, etc. The tubes together with the coupling system act as amplifiers. The coupling condensers C^{10}, C^{101}, should be chosen so that the tuned circuits will be coupled slightly less than optimum as this insures the maximum transfer of energy (amplification) with the maximum sharpness at the tuned circuits. With the coupling system shown in Fig. 3, no inductive coupling is intended between the coils. It will be understood, however, that any other suitable type of tuned coupling may be employed.

What has just been said regarding the control circuit beginning with tube **50** which is tuned to a frequency $f1$ is equally applicable to the remaining control circuits which are indicated by tubes 50^1, 50^2, etc., except that the circuits following tube 50^1 are tuned to $f2$, etc. Relays J^1, J^2, etc., constitute the control relays, each responsive to a preselected frequency.

To further illustrate the action of the device considered so far, let us assume that the relays J are normally open. This is the condition when the voltage drop across R^1, R^2, etc., is zero, which condition will automatically be met when the light entering **44** is not varying, as when no bars are passing slot **40** in Fig. 1. Suppose, now, that a check or other document **10** is caused to pass the slot at such a rate that the light is varied from maximum to minimum back to maximum (one complete cycle) $f1$ times per second. This will cause a voltage of frequency $f1$ to be impressed on the grids of tubes **50**, 50^1, 50^2, etc. This voltage will be further amplified as it passes through the tuned circuits and tubes tuned to its frequency, and a rectified voltage appearing across R^1 will cause J^1 to close its contact **58**, thus starting the chain of mechanical events which will cause the check or other document to be deposited in the selected receptacle or to have other operations performed.

The voltage of frequency $f1$ appearing on the grids of tubes 50^1, 50^2, etc., will be attenuated so as to be substantially zero upon reaching R^2, etc., and, therefore, relays J^2, etc., will remain open.

Fig. 3 also illustrates the manner in which a similar electric control system operates when codes differing from each other in their harmonic content are employed. In this case the first control circuit of the control relay J^1 is tuned to the fundamental frequency, while the remaining control circuits are each tuned to a selected harmonic frequency. The relay J^1 is a master relay and the other relays are auxiliary relays. The operation sought to be performed is then controlled by the cooperation of a master relay and one or more auxiliary relays. If desired the auxiliary relays may be such that they function only when deenergized. The number of control circuits as shown in Fig. 3 may be multiplied so that they fall into groups, each comprising a master relay responsive to a predetermined fundamental frequency and auxiliary relays responsive to the selected harmonics.

When the code system shown in Fig. 1*d* is employed the electrical system shown in Fig. 2 is made in duplicate as shown in Fig. 4. The scanning table **60** now has two slots **62** and **61** and which are individually illuminated by the

sources 66 and 68, the two code zones being individually scanned by the photocells 70 and 72. The electrical system associated with each cell is the same as that shown in Figs. 2 and 3. Each article, document, or the like, now energizes a selected control relay J in one system and a selected control relay M in the second system. These two relays may now control the operation of the sorting, printing, or the like in a manner peculiar to their combination.

The two code zones shown in document 74 in Fig. 4 may be disposed successively if desired so that the relays operated thereby come into successive operation, and thus when this is employed for sorting into a large number of sorts the first relay may direct the travel of the document into a predetermined direction common to a group of sorts, and the second relay will direct the document or card into the selected sort.

Fig. 5 is a diagrammatic showing of a sorting mechanism such as that shown in patent numbered 2,020,925 and which may be employed herein in cooperation with the present electrical system. The platform 38 is shown extended and is provided with pivotal gates 141 secured to the heads of rotating pins 142. The lower end of each pin 142 may be rotated by links 145 which in turn are operated by electro-magnets. Thus when the corresponding electro-magnet is energized the corresponding gate is deflected as shown at 149 thereby deflecting and directing the card or article 36 into the channel defined by the guides 147. Compartments 151 are disposed between and below the guides 147, the compartments having trap doors which are also operated by electro-magnets under the control of the control relays.

Having thus described our invention, we claim:

1. Apparatus for sorting documents into classes, comprising a support for moving documents, photo-electric scanning devices operating in response to imprinted code markings on said documents to generate persistent electrical impulses having frequency characteristics corresponding to said markings; the documents belonging to one class bearing code markings which cooperate with said scanning devices to give rise to persistent electrical impulses having one frequency characteristic distinguishing said class from some classes and another frequency characteristic distinguishing said class from the remaining classes; a plurality of tuned circuits connected to said scanning devices, each circuit being tuned to a different frequency characteristic, and means operable by such circuits to direct the documents belonging to each class into a compartment.

2. Apparatus for sorting documents into classes, comprising a support for moving documents, photo-electric scanning devices operating in response to imprinted code markings on said documents to generate persistent electrical impulses having frequency characteristics corresponding to said markings; the documents belonging to one class bearing code markings which cooperate with said scanning devices to give rise to persistent electrical impulses having one frequency characteristic distinguishing said class from some classes and another frequency characteristic distinguishing said class from the remaining classes; a plurality of tuned circuits, each circuit being tuned to a different frequency characteristic and means selectively operable by a selective pair of such circuits to direct the documents belonging to each class in a path distinctive to each class.

3. Apparatus of the class described comprising scanning mechanism responsive to recurrent impulses having variable frequency characteristics, means for passing before said scanning means tabulating cards or the like having code markings thereon and causing said scanning mechanism to generate persistent electrical impulses having various frequency spectra; the tabulating cards belonging to one class bearing code markings which give rise to a spectrum characteristic of said class and different from the spectra produced by the code markings borne by the tabulating cards belonging to other classes; and means responsive to the joint operation of a plurality of spectrum components of a selected spectrum for performing a selected machine operation.

4. Apparatus of the class described comprising a support for moving tabulating cards or the like, photo-electric scanning devices operating in response to imprinted code markings on said cards to generate persistent electrical impulses having frequency characteristics corresponding to said markings, the cards belonging to one class bearing code markings which cooperate with said scanning devices to give rise to persistent electrical impulses having one frequency characteristic distinguishing said class from some classes and another frequency characteristic distinguishing said class from the remaining classes; a plurality of tuned circuits connected to said scanning device, each circuit being tuned to a different frequency characteristic, and means responsive to the joint operation of a plurality of such circuits to perform a selected machine operation.

WILLIAM F. FRIEDMAN.
VERNON E. WHITMAN.