Sept. 13, 1966 F. H. SHEPARD, JR 3,273,013

ELECTRIC SWITCH ARRANGEMENT

Filed May 19, 1960 3 Sheets-Sheet 1

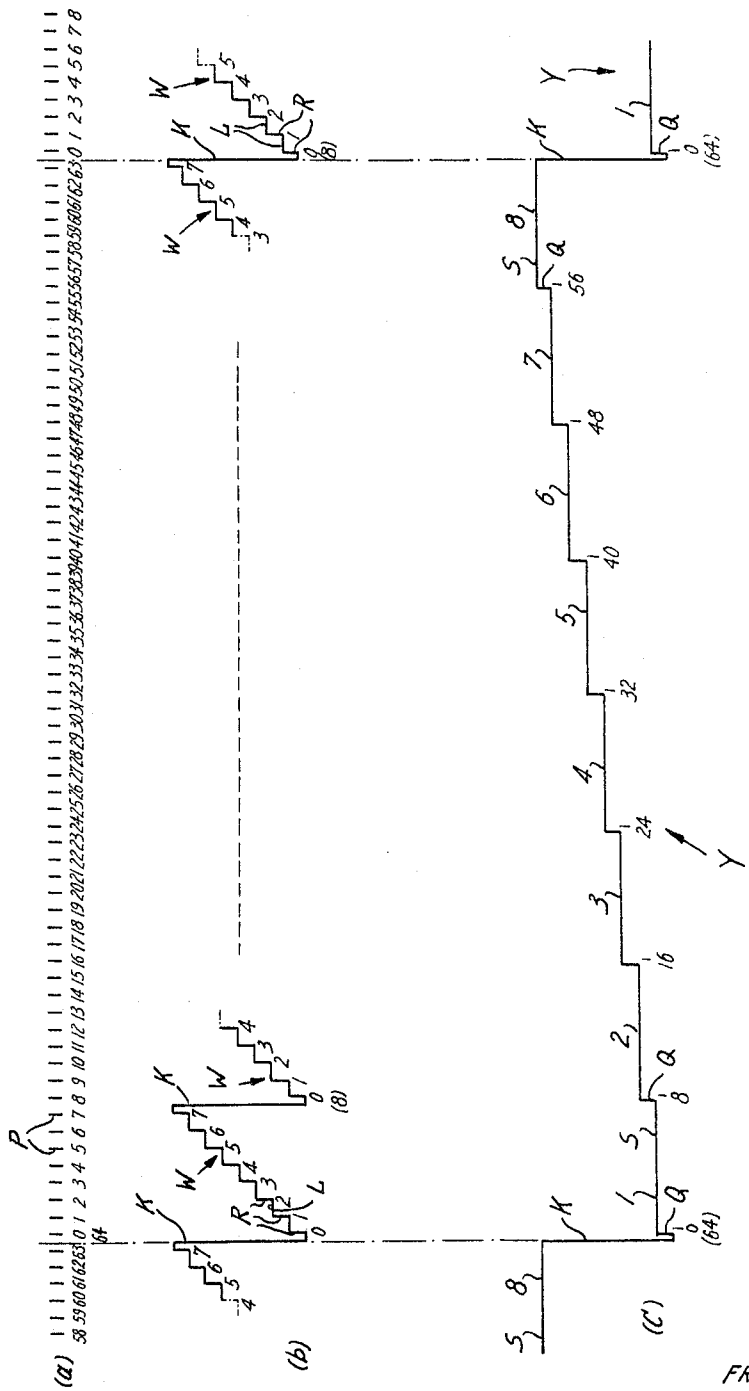

FIG. 1

INVENTOR.
FRANCIS H. SHEPARD Jr.

BY

Curtis, Morris & Safford

ATTORNEYS

Sept. 13, 1966 F. H. SHEPARD, JR 3,273,013

ELECTRIC SWITCH ARRANGEMENT

Filed May 19, 1960 3 Sheets-Sheet 2

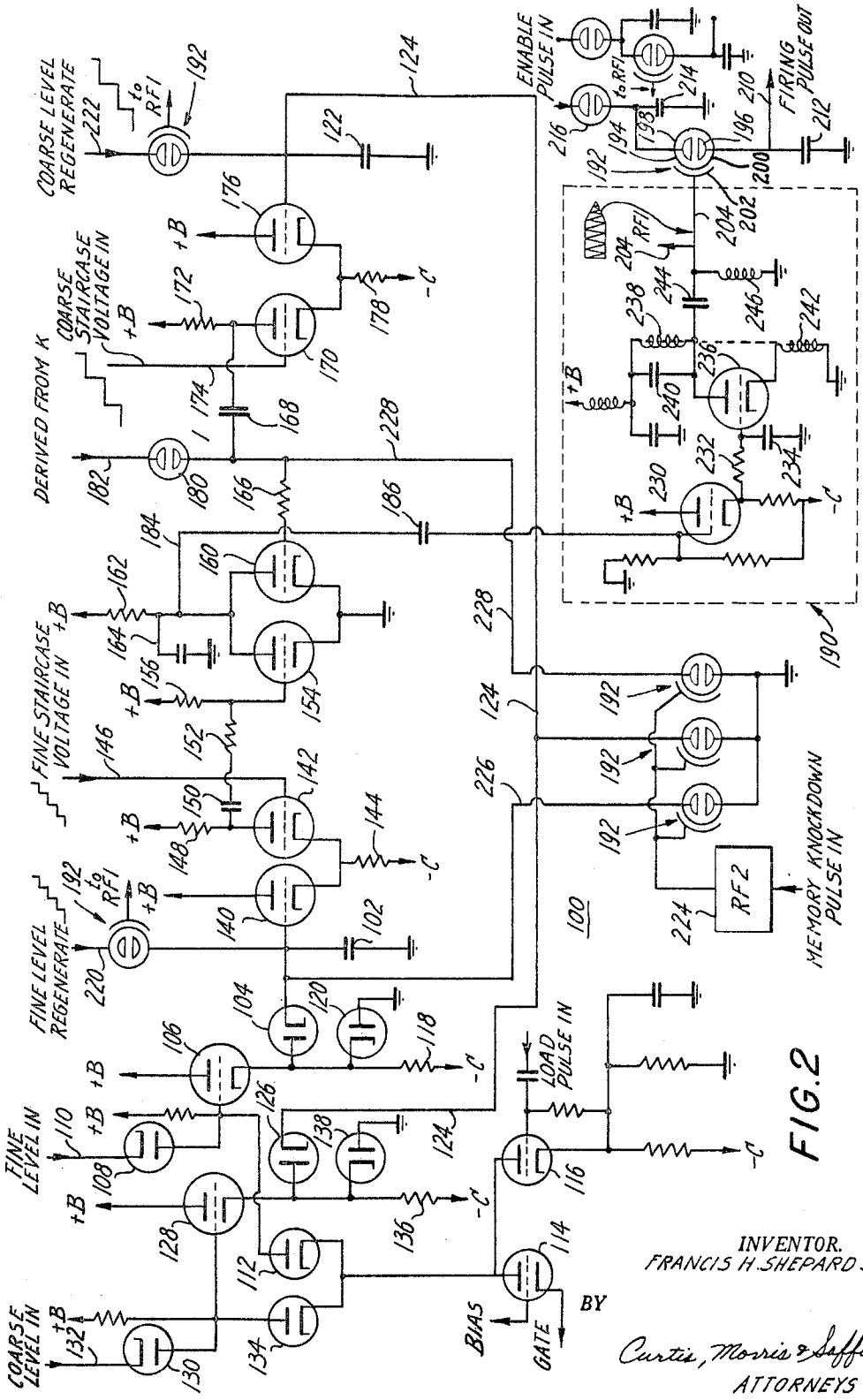

FIG. 2

INVENTOR.
FRANCIS H. SHEPARD Jr.

BY

Curtis, Morris & Safford
ATTORNEYS

Sept. 13, 1966 F. H. SHEPARD, JR 3,273,013

ELECTRIC SWITCH ARRANGEMENT

Filed May 19, 1960 3 Sheets-Sheet 3

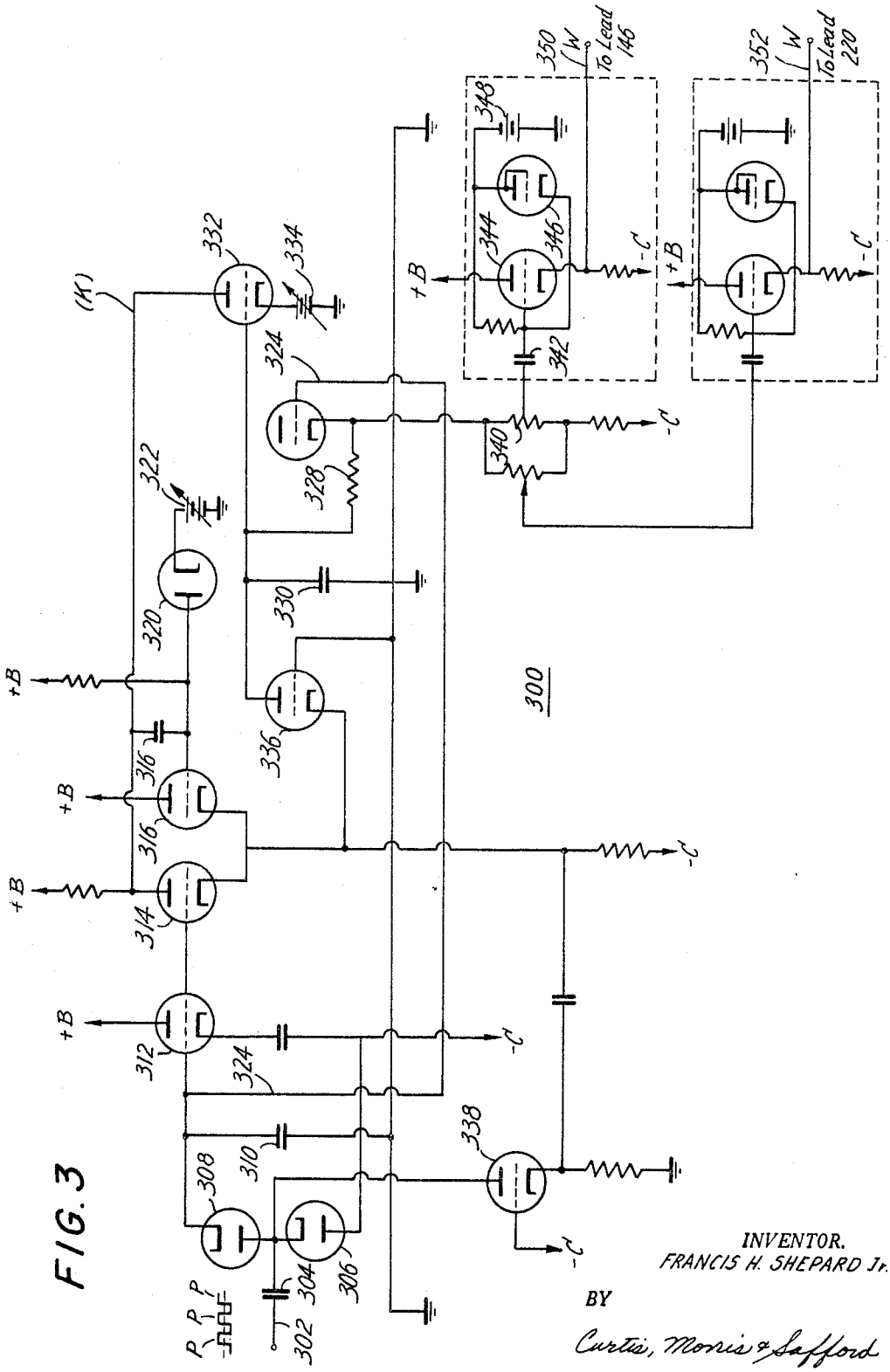

FIG. 3

INVENTOR.
FRANCIS H. SHEPARD Jr.

BY

Curtis, Morris & Safford
ATTORNEYS

United States Patent Office 3,273,013 Patented Sept. 13, 1966

3,273,013

ELECTRIC SWITCH ARRANGEMENT

Francis H. Shepard, Jr., Lee Lane, Berkley Heights, N.J.

Filed May 19, 1960, Ser. No. 30,216
4 Claims. (Cl. 315—168)

This application is a continuation-in-part of copending application, Serial No. 641,653, filed February 21, 1957, now Patent No. 2,947,910.

This invention relates to an improved technique and apparatus for identifying and remembering a number, more particularly it relates to an electronic memory and system for representing a long series of numbers or characters in electrical form and for remembering and easily identifying any chosen number of the series.

An object of this invention is to provide a high speed memory which has the relative simplicity and tremendous range of an electric voltage capacitor memory, but with effectively the permanance or information retaining ability of a magnetic core memory.

Another object is to provide a system of counting which is compatible with practical electrical circuits.

Still another object is to provide a numbering and memory system which can be built inexpensively and compactly and which will operate with an extremely high degree of reliability.

These and other objects will in part be pointed out in and in part understood from the description of the invention given hereinafter.

There are many applications where to obtain high speed operation it is necessary to represent a series of numbers in terms of electrical impulses. Thus, in a high speed printer, such as shown in the inventor's U.S. Patent No. 2,787,210, information, for example in the form of binary digits, is read off of a magnetic tape and typed out on paper at the rate of about 40,000 words per minute. This compares with a typing speed of about 70 words per minute for a good secretary. In this printer, 64 alphanumeric characters, corresponding to the keyboard characters of an ordinary office typewriter, are arranged around each of 190 closely-spaced circular type-wheels. These are rotated in unison at high speed and paper to be printed on is moved stepwise tangentially beneath them. During each step-by-step pause of the paper, a row of 190 hammers beneath the paper and wheels are selectively fired upward and drive the paper against an inked ribbon and any chosen print character on each wheel to print an entire line of words across the paper. Now, it takes at least one revolution of the print wheels for every one of the 64 characters on each wheel to rotate opposite the type hammers. Moreover, each hammer must be actuated at the precise instant (within a few microseconds) that the desired character moves opposite it. This then requires a highly accurate way of counting the characters to identify them as they rotate past the hammers. Furthermore, because it takes a finite time, i.e. one revolution of the type wheel, for all 64 characters to pass a hammer, it is necessary to remember, at least for this long, what character is to be printed until this particular character is in printing position. Thus, for each of the 190 hammers and type wheels it is necessary to provide a high speed way of counting or numbering the positions of the type characters, and of remembering the characters to be printed after they have been read from the tape and until they have actually been printed. The present invention provides a highly successful and advantageous system for doing this.

One previously known type of memory uses an array of small saturable magnetic cores or toroids in which information in the form of binary numbers is stored according to whether each core is magnetized in one direction or the other. Because the information is stored as a relatively permanent magnetic flux, a memory device of this kind is effectively perfect in its ability to remember any given number indefinitely and until told to remember a different one. Unfortunately, because a magnetic core normally has only one of two states, that is, magnetized in one direction or the other, to be able to remember a large number, e.g. a number as large as 64, a great number of individual cores must be used in a rather intricate array. This is a serious drawback from the standpoint of cost where a multitude of large number series must be remembered.

A second kind of memory generally known before uses simply a capacitor in which an electrical charge corresponding to a number can be stored. Here, the number which can be remembered can be any one of a large plurality of them depending upon the sensitivity and resolving ability of associated equipment used to read the memory. Thus, for example, it is an easy matter with inexpensive, existing equipment to charge a capacitor with a voltage corresponding to any digit from 0 to 10 and thereafter accurately read the voltage to determine the number. Unfortunately, this kind of memory tends to "forget" the information stored in it since the electrical charge on a capacitor leaks off in time. This has been so serious a defect that until now capacitor memories have had only very limited practical use. The present invention eliminates this difficulty and makes possible a capacitor memory having wide range, extreme reliability and remembering ability, and low cost.

In accordance with one aspect of the present invention, a series of numbers is represented as a voltage which increases step-by-step like a staircase, each step representing a separate and distinct number. Now, for practical considerations such as the ability of associated equipment to distinguish between voltage levels, and for high reliability it is desirable to provide a rise of several volts or so for each level of the staircase. Thus, in a memory system for use with above described high speed printer having 64 characters around the type wheels, two voltage staircases are used. Each staircase has eight levels, the first or fine staircase having a rise or step corresponding to each character, the other or coarse staircase having a respective step corresponding to each successive group of eight characters. By determining first the particular level or step of the coarse staircase, and then the level of the fine, any one of the 64 characters to be printed can be chosen. If there were 100 characters, then a coarse and a fine staircase of 10 steps each could be used and counting would be analogous to conventional decimal arithmetic.

In accordance with a principal aspect of the invention, a number is remembered by charging a capacitor to a corresponding voltage level. Then, by comparing this remembered voltage to a voltage staircase representing a series of numbers, for example one to eight, a coincidence pulse marking the instant the staircase voltage equals the remembered voltage is obtained. This pulse, which identifies the number being remembered, in turn is used to actuate momentarily a unique electronic switch provided as part of the system to apply to the memory capacitor a voltage derived from the staircase voltage and equal to the voltage which should be remembered. In this way the remembered voltage on the capacitor is continuously regenerated. Thus the difficulty with previous capacitor memories of gradually losing the information stored is eliminated. This new memory can retain the information read into it indefinitely, but, as will be explained in detail later on, can be reset to remember a new number almost instantaneously. Readout of information is easily accomplished without losing the informa-

tion stored. A single capacitor memory can easily remember any of 10 different numbers and this is of far reaching importance in the field of electronic computing.

A better understanding of the invention together with a fuller appreciation of its many advantages will best be gained from the following description given in connection with the accompanying drawings wherein:

FIGURE 1 illustrates a method of counting according to the invention; line (*a*) representing a repetitive sequence of 64 pulses evenly spaced in time; each corresponding to a number from 1 to 64 as indicated, line (*b*) showing a series of fine staircase waveforms having vertical steps or risers on the occurrence of each pulse in line (*a*) up to eight, then repeating for the next eight and so on; and line (*c*) showing a coarse staircase having a step for each group of eight pulses, and so on.

FIGURE 2 shows a capacitor memory system embodying features of the invention; and

FIGURE 3 shows a fine staircase voltage generator used with the system shown in FIGURE 2.

Line (*a*) of FIGURE 1 represents by short vertical lines P, which in practice are narow voltage pulses, a sequence of 64 numbers. Assuming that these correspond to the print characters in the above described high speed printer, the entire sequence will be repeated upon each revolution of the print wheels. Each pulse in the sequence of line (*a*) identifies in time a particular character on a print wheel, and the characters or numbers are evenly spaced in time. Knowing at what instant a particular number occurs (by counting and remembering as described below) it is then possible to actuate a type hammer and print the corresponding character.

Lines (*b*) of FIGURE 1 shows a fine staircase voltage waveform having a vertical riser R at the instant of occurrence of each pulse P in line (*a*) and having a horizontal level L for the time between pulses. The first waveform W represents eight pulses, namely, 0 to 7. Approximately midway between numbers 7 and 8 the waveform returns or is knocked down as indicated at K to zero level and then at number 8 a second waveform W repeats, and so on.

Line (*c*) of FIGURE 1 shows a coarse staircase voltage waveform Y having a vertical riser Q occurring just before every eighth pulse P up to 64, and then repeating in a second waveform Y, etc. This coarse staircase Y is generated synchronously with the fine staircase W, each knockdown K serving as a timing pulse to initiate as a suitable delay each riser Q of the coarse staircase. The latter has a corresponding step or level S to identify each octal group in line (*a*), fine staircase W serving to identify each pulse in each octal group. Thus, for example, pulse number 11 will occur during the second step of the coarse staircase and exactly at the fourth riser of the fine staircase. In this way, by "remembering" the particular levels of the coarse and fine staircases, any one of the 64 numbers is identified in time.

FIGURE 2 is a schematic diagram of an electronic memory circuit **100** provided according to the invention. Near the left center of the drawing is shown a fine memory capacitor **102** which is adapted to be charged to a level corresponding (but differing by a fixed amount) to a level L of a fine staircase W in line (*b*) in FIGURE 1. This capacitor need not be large or specially made, it should however be free of "hysteresis." A 1000 micromicro-farad (1000) mmf.) Mylar tubular capacitor has been found very satisfactory in this particular circuit.

Capacitor **102** is adapted to be charged to a desired level through a de-coupling diode **104** from the cathode of a buffer tube **106**. The grid of this tube is connected through a de-coupling diode **108** to a fine level input lead **110** to which is applied the desired voltage level. This voltage is derived, for example, from binary digits recorded on a magnetic tape, these digits being read from the tape and then translated in a suitable decoder circuit (not shown, but known in the art) to a voltage of given

level. However, as will be explained later, before this voltage can be applied to memory capacitor **102**, tube **106** must be unblocked, this being accomplished by unclamping its grid. The grid of tube **106** is normally biased to cut off by means of a diode **112** whose cathode is connected to the plate of a gating tube **114** and a "load pulse" input tube **116**. When either of the latter is conducting, the grid of tube **106** is held sufficiently negative so that it cannot conduct. When both are off, the D.C. level on lead **110** is applied through tube **106** and diode **104** to memory capacitor **102**. To insure that the proper D.C. level is transmitted through tube **106**, its cathode is biased to —C by a load resistor **118** and it is also clamped to —B by a diode **120**. Tube **106** need only be energized briefly (tube **114** being gated open and tube **116** being momentarily pulsed off) to charge memory capacitor **102** to a desired level, thereafter the tube is turned off and the capacitor is held at this voltage (for as long as desired, as will be explained) until another voltage is fed in through tube **106**.

On the right in FIGURE 2 is a coarse memory capacitor **122** which is adapted to remember a voltage corresponding (but differing by a fixed amount) to a level S of a coarse staircase Y in line (*c*) of FIGURE 2. This capacitor, which is identical to fine memory capacitor **102**, is connected via a lead **124** through a de-coupling diode **126** to the cathode of a buffer tube **128**. This tube is connected and operated the same way as buffer tube **106**, the grid of tube **128** being connected through a diode **130** to a coarse level input lead **132**. This grid of tube **128** is normally biased off by a diode **134** whose cathode is connected in common with the cathode of diode **112** to the plates of tubes **114** and **116**. The cathode of buffer tube **128** is connected through a resistor **136** to —C and is clamped by a diode **138** connected to —B.

Assuming that the desired voltage levels to be applied to the memory capacitors **102** and **122** exist respectively on leads **110** and **132**, and that tube **114** has previously been placed in open gate condition, then a momentary negative pulse applied to tube **116** will cause both memory capacitors to be loaded to the desired levels, respectively. As soon as the loading pulse applied to tube **116** disappears, the tube again conducts and blocks both buffer tubes **106** and **128** thereby disconnecting them, through the action of diodes **104** and **126**, from their respective memory capacitors.

Fine memory capacitor is connected via the grid of a cathode follower tube **140** to the cathode of a "fine level coincidence" tube **142**, the common cathodes of these tubes being connected to a load resistor **144** and —C. The grid of coincidence tube **142** is connected to a lead **146** to which is applied a fine staircase voltage W, cyclically repeated, as illustrated by line (*b*) of FIGURE 1. Whenever this voltage rises above the voltage level then at memory capacitor **102**, a negative pulse appears at the plate of tube **142** across its load resistor **148**. This negative pulse is coupled through a small capacitor **150** and a decoupling resistor **152** to the grid of a tube **154**. This latter tube is normally biased on through a grid resistor **156** connected to +B. The tube is connected in parallel with a similar tube **160**, also normally on and which, as will appear, is gated off by the coarse staircase waveform Y in conjunction with coarse memory capacitor **122**.

To determine precisely the timing of the negative pulse appearing at the plate of tube **142**, the voltage on fine memory capacitor **102** is set approximately midway between two successive voltage levels L of waveform W. Thus precisely at the riser R between these levels, the fine staircase voltage W will become greater than the voltage on fine memory capacitor **102**, and thereupon, as explained above, a negative pulse will appear at the plate of tube **142** and momentarily turn tube **154** off. Now, when tube **160** is at the same time also off, a positive voltage pulse will appear at the plates of these tubes across

their load resistor **162**. A small RF (radio frequency) capacitor **164** bypasses this resistor to ground. Unless tube **160** is off, there effectively cannot be a positive voltage pulse at the plate of the tube and tube **154**.

The grid of tube **160** is normally positive and is coupled through a resistor **166** and a capacitor **168** to the plate of a tube **170**, a load resistor **172** connecting this plate to +B. The grid of the latter tube receives via a lead **174** the coarse staircase voltage waveform Y. Tube **170** operates in conjunction with a tube **176**, these tubes having a common cathode resistor **178** connected to —C. When the coarse staircase Y exceeds the voltage set on coarse memory capacitor **122**, a negative voltage appears at the plate of tube **170**. This voltage has a duration approximately equal to the duration of the remaining coarse staircase (i.e. until the resetting of the coarse staircase level K on the coarse staircase in FIGURE 1) and is applied to the grid of tube **160** to turn it off during one coarse level during this interval. At the knockdown K of the fine staircase W corresponding to the particular coarse staircase level S in question, a positive voltage pulse is applied to the grid of tube **160** through a cold gas diode **180** via a lead **182**. This puts a voltage charge on capacitor **168** and holds tube **160** on through the end of the present coarse staircase waveform Y and until the interval in the next waveform Y when the coarse staircase voltage again rises above the level set on coarse memory capacitor **122**. Because the risers Q of coarse staircase waveform Y occur just slightly before the corresponding risers R of fine staircase waveforms W, tube **160** will, at the selected eight pulse interval, be turned off for a time long enough to encompass all eight risers R of the thus selected waveform W. As with the voltage set on the fine memory capacitor, the voltage set on coarse memory capacitor **122** is set at a value between two successive steps S of waveform Y. Thus the point at which a coarse staircase Y exceeds the voltage set on coarse memory capacitor **122** is marked by a riser Q of the coarse staircase.

The positive voltage pulse appearing at the plates of tubes **154** and **160** when there is a dual coincidence between the fine and coarse staircase voltages respectively, and the corresponding voltages set on the fine and coarse memory capacitors, is applied via a lead **184** and a coupling capacitor **186** to an RF generator indicated at **190**. The momentary voltage applied to the input of the generator produces a momentary but somewhat longer burst of RF voltage, as indicated by the waveform at the right of the generator, which dies exponentially, rather than suddenly, to zero.

This burst of RF voltage is used to control a unique switch, now to be described. One such switch is indicated, to the right of generator **190**, at **192**. This comprises a gas diode **194**, such as a neon NE–2, having two electrodes **196** and **198** in a gas filled envelope **200**. Surrounding this envelope is a conductive tubular sleeve **202**. The latter is connected to the output lead **204** (RF1) of generator **190**.

When the RF voltage burst described above appears on shield **202**, the gas inside tube **194** is ionized and the tube becomes a good conductor, hence a closed switch. When the RF voltage dies out the gas de-ionizes (assuming the potential across electrodes **196** and **198** is less than the glow voltage) and the tube ceases altogether to conduct. It then becomes an open switch. Because the RF voltage is controlled to die out gradually, the tendency of self-rectification of the gas diode is eliminated. This is most important. If the RF voltage were turned off suddenly, there would on the average be a volt or so drop across electrodes **196** and **198** at the instant of cutoff. Now, where a switch **192** is being used to charge a capacitor (such as fine memory capacitor **102**) to exactly a given voltage, there cannot be tolerated any voltage drop across the switch at the instant of turnoff. Accordingly, the use of a gradually dying-out RF voltage pulse to actuate such a switch is essential. This switch is broadly shown and claimed in co-pending application Serial No. 641,653, filed February 21, 1957, now Patent No. 2,947,910, of which the present is in this respect a continuation-in-part.

The output signal from circuit **100** is obtained at its lower right from a lead **210** which is bypassed to ground by a small capacitor **212** and is connected to one side of a switch **192**. When this switch is turned on, there is established a conductive path to a storage capacitor **214**. The latter is adapted to be charged to a suitable voltage through a gas diode **216** and thereafter left in charged condition until switch **192** is closed. An important advantage of this arrangement is that an output signal is obtained only if capacitor **214** has been charged, moreover, this output signal can have a sizeable magnitude at low impedance even though the signal actuating RF generator **190** is small. Further, as many separate output signal leads as desired can be provided simply by providing additional elements, as indicated.

The RF lead **204** is also connected to another switch **192** one side of which is connected to fine memory capacitor **102** and the other side of which is connected to a lead **220**. The latter is energized with a voltage having a waveform identical to fine staircase W but suitably shifted down in D.C. level. Thus for a given level L of staircase W, the corresponding level of the voltage on lead **220** will be approximately midway between this level L and the one below or preceding it, The voltage on lead **220** is in fact derived from the fine staircase voltage by taking the latter and shifting its absolute or D.C. level down by an appropriate fixed amount.

Now when RF lead **204** is energized, the switch **192** in series with fine memory capacitor **102** and lead **220** will be closed for a short instant. But the voltage at this instant on lead **220** will be precisely equal to the voltage which is being remembered by capacitor **102**. Accordingly, even though some of the voltage previously set on capacitor **102** (through tube **106** or from lead **220**) has since leaked off, the voltage will now be re-set from lead **220** to the exact value it should have. Once set to a given voltage, fine memory capacitor will continue to be re-set in this manner until intentionally set to a different voltage (through tube **106**).

Simultaneously with the continual regeneration of the voltage on fine memory capacitor **102**, coarse memory capacitor **122** is re-set to the desired voltage through a switch **192** and a lead **222**. The latter has applied to it a voltage derived from the coarse staircase Y but shifted down in D.C. level an appropriate fixed amount.

Near the lower center of FIGURE 2 is a cluster of three switches **192**, one side of each being grounded. They are controlled in unison by an RF generator **224** similar to generator **190** but independently actuated. When turned on, the first of these switches through a lead **226** discharge fine memory capacitor **102**. The second switch grounds lead **124** and discharges coarse memory capacitor **122**. The third switch through a lead **228** grounds one side of capacitor **168** and insures that tube **160** is turned on. Thereafter, when these three switches are opened, the fine and coarse memory capacitors can be set to whatever new levels are desired. The setting of new voltages to be remembered can be accomplished very quickly.

RF generator **190** includes an input buffer tube **230** which is connected via a pulse stretching network consisting of a resistor **232** and a capacitor **234** to an oscillator tube **236**. Network **232**, **234** keeps the oscillator turned on for longer than the duration of the pulse applied to buffer tube **230** and this network also gradually turns the oscillator off so that the burst of RF voltage on lead **204** does not die out suddenly. Tube **236** in conjunction with a high-Q coil **238**, a resonant capacitor **240** and a feedback coil **242** functions as a Hartley type oscil-

lator. Its output is applied through a coupling capacitor **244** to lead **204**. A choke coil **246** grounds lead **204** to D.C. In an actual unit the RF pulse applied to lead **204** had an amplitude of about 100 to 200 volts, a frequency of about 2 megacycles, a duration of 30 to 40 microseconds, and a die-out of 10 to 15 microseconds. The interval between pulses P was about 800 microseconds, and the peak-to-peak amplitude of a waveform W or Y, about 70 volts.

FIGURE 3 shows a fine staircase generator **300** which is adapted to supply the requisite voltage to leads **146** and **220** in FIGURE 2. Also, a pulse K is derived from generator **300** which after suitable amplification and shaping is applied to lead **182** in FIGURE 2. The operation of circuit **300** is for the most part conventional and will be understood by those skilled in the art. Accordingly, only a brief description of the circuit will be given. It is to be understood that a closely similar circuit can be used to generate the coarse staircase voltages needed in FIGURE 2 (leads **174**, **222**).

Circuit **300** at the left has an input terminal **302** adapted to be energized by a symmetrical square wave, derived from pulses P in FIGURE 1 and having the same repetition rate or frequency. This square wave is applied through a capacitor **304** to a pair of clamping diodes **306** and **308** to charge a capacitor **310** step-by-step. To the right of the latter is connected a tube **312** which serves as a cathode follower to keep the charging of the capacitor linear. The ratio of capacitor **310** to capacitor **304** determines the amount of each step of waveform W.

To the right of tube **312** is connected a tube **314**, which in conjunction with a tube **316**, a capacitor **318**, a clamping diode **320** and an adjustable battery **322** determine the number of steps in a waveform W.

Also connected to the same potential as the grid of tube **312** through a lead **324** is a cathode follower tube **326**. This through a resistor **328** is adapted to charge a capacitor **330**. The latter when sufficiently charged raises the potential on the grid of a tube **332** adjustably biased through a battery **334** to cause the knockdown of waveform W as indicated at K in FIGURE 1. Battery **334** can be adjusted to locate knockdown K where desired. A tube **336** discharge capacitor **330**. To insure that capacitor **310** returns to its consistent zero position the cathode of tube **336** is used as a negative clamp or excursion limit for the cathode of **316** and **314** which discharges capacitor **310** through the grid-cathode current of tube **312**. To insure that capacitor **304** returns to its zero condition upon knockdown a tube **338** is provided.

One output of circuit **300** is obtained through a gain adjusting resistor **340** in the cathode of tube **326**. This is coupled via a capacitor **342** to a cathode follower tube **344** and a D.C. level adjusting diode **346** and battery **348**. Waveform W is obtained at terminal **350**. A similar waveform but shifted in level (for lead **220** in FIGURE 1) is obtained at terminal **352** from an identical arrangement.

It is to be understood that a single generator **300** can supply a number of memory circuits **100**. Also, where a smaller capacity memory is desired, the coarse staircase portion, for example, of circuit **100** can be dispensed with. The above description of the invention is intended in illustration and not in limitation. Various changes or modifications in the embodiment set forth may occur to those skilled in the art and can be made without departing from the spirit or scope of the invention as set forth.

What is claimed is:

1. An electric switch arrangement comprising an electric circuit adapted to be switched on and off whenever desired, a gas tube connected in series with said circuit, said tube being ionizable and acting substantially as a short-circuit when ionized and as an open-circuit when de-ionized, and generator means for applying to said tube an ionizing high frequency field, said generator means supplying a substantially continuous ionizing field when on and being substantially independent of said electric circuit, said generator means giving a gradually decreasing field when turned off so that voltage drop across said tube at the instant of de-ionization is substantially zero.

2. The circuit in claim **1** wherein said generator means is turned on and kept on by the presence of an external signal, said generator means gradually turning off over a number of cycles of oscillation of said generator means when said signal is removed.

3. The circuit in claim **1** wherein said gas tube is a cold cathode gas filled tube such as an NE–2 diode.

4. The circuit of claim **3** wherein said generator means operates at roughly two megacycles frequency and a hundred volts.

References Cited by the Examiner

UNITED STATES PATENTS

2,658,142	11/1953	St. John	315—248 X
2,696,566	12/1954	Lion et al.	313—201 X
2,741,756	4/1956	Stocker	340—173
2,771,575	11/1956	Hampton	320—1
2,785,342	3/1957	Carley	315—168
2,872,662	2/1959	Dufour	340—173
2,887,619	5/1959	Hussey et al.	315—168
2,947,913	8/1960	Trostler	313—201 X
3,071,730	1/1963	Piepenburg	315—176

JOHN W. HUCKERT, *Primary Examiner.*

IRVING L. SRAGOW, JAMES D. KALLAM,
Examiners.

R. M. JENNINGS, R. F. POLISSACK,
Assistant Examiners.