ELECTROSTATIC STORAGE OF INFORMATION

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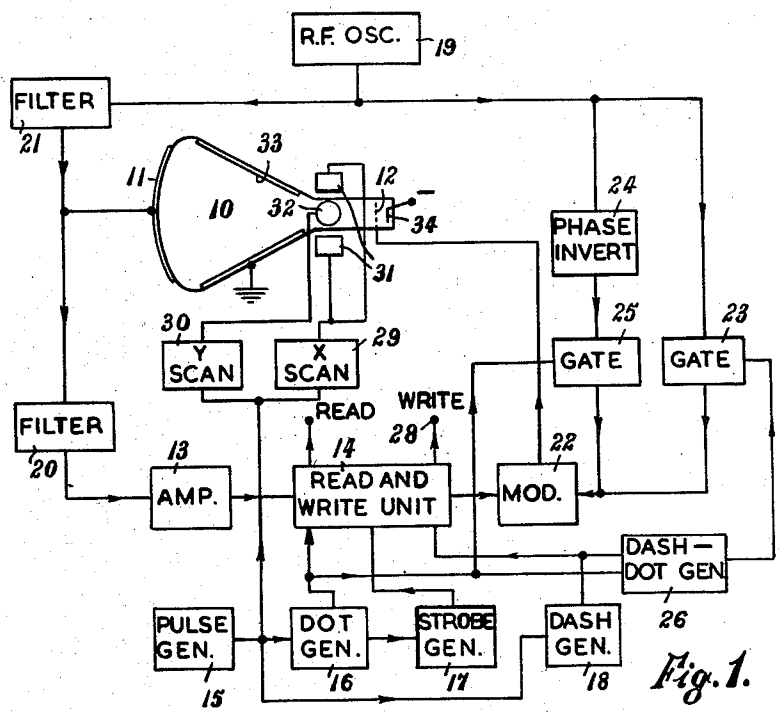

Fig. 1.

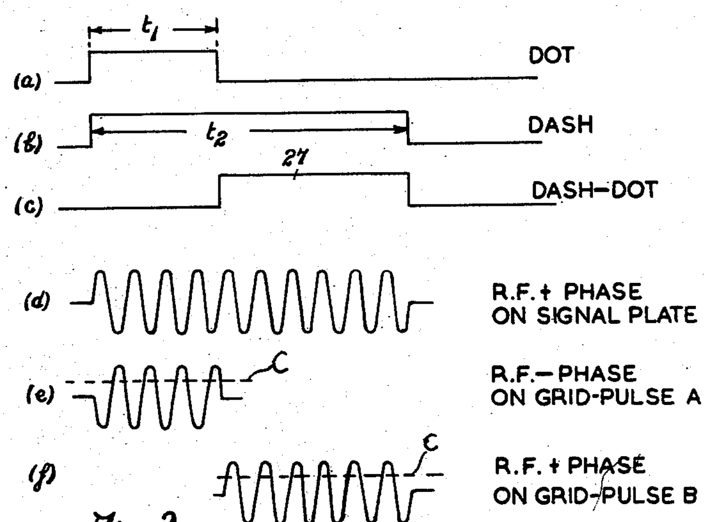

Fig. 2.

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ELECTROSTATIC STORAGE OF INFORMATION

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The present invention relates to a method of storing digital information of the type in which a cathode ray beam is caused to explore areas of a surface of an electric charge retaining screen and to liberate secondary electrons from the areas, these secondary electrons being collected by a collecting electrode, whereby the areas become charged, in which the information to be stored is applied to control the charge produced upon the respective areas, in which changes of charge produced by a subsequent exploration of the areas develop in a signal pickup plate associated with the screen voltages representative of the stored information, and in which these voltages are applied to cause regeneration of the charges upon the respective areas.

Examples of this method of storage are described, for example, in the specifications of co-pending U. S. applications Serial No. 50,136 filed September 20, 1948, 124,192 filed October 28, 1949 and 205,459 filed January 1, 1951, now Patent No. 2,642,550. The method described in the two earlier of these three specifications involves bombarding each of the areas with the cathode ray beam to produce on each area a first state of positive charge representative of one digit and, when required, to represent another digit causing, with the aid of the cathode ray beam, a further, later emission of secondary electrons to the area to decrease the positive charge on the area. The further, later emission of secondary electrons is arranged to take place either from an area outside of and near the area first bombarded or else, in the method known as "defocus-focus" from an area within that first bombarded. In the latter case the beam is first directed in a defocused condition upon a relatively large area and is subsequently focused sharply so that it bombards a relatively small area within the first area. In both cases the size of the area of the screen made use of in the process of storing each digit is substantially larger than that of the spot produced by a focused beam, even though the stored information is contained in an area not substantially larger than that of the focused spot.

The method described in U. S. application Serial No. 205,459 filed January 1, 1951 has the advantage over that described in the two earlier specifications referred to that the storage of each digit utilises only a single spot on the screen surface and that such spot may have the minimum size, namely that produced by a well-focused beam. In this method of storage two different states of charge upon a single spot are obtained by bombardment of the spot with and without a radio frequency modulation of the signal plate potential, one digit being recorded by normal bombardment of the spot and another digit being recorded by first carrying out the normal bombardment and subsequently modulating the signal plate potential at a radio frequency. The effect of the radio frequency modulation is explained in U. S. application Serial No. 205,459 filed January 1, 1951 but may be simply regarded as producing a modification of the potential of the spot whereby a net positive or negative current

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is caused to flow to the spot, with a resultant net increase or decrease in the positive charge left on the spot when the bombardment ceases. The present method of recording is an improvement upon this previous method of recording upon a single spot.

The present invention has for its object to provide a new or improved method of and means for the electrostatic storage of digital information in which, as in the method last above referred to, the area required to store each digit may be of minimum size, as above defined.

According to the present invention there is provided a method of storing digital information of the type set forth including the steps of holding the beam stationary or substantially stationary upon each said area during each digit interval (that is to say the time allotted to the storage of each digit) applying two electrical oscillations of high frequency during such interval one to switch the beam on and off at each positive or negative peak of the oscillation and the other to vary the potential difference between the said areas of the screen surface and the collecting electrode, the two oscillations having at least two different conditions in which the range of said potential difference at the times during which the beam is switched on has different values respectively, and recording one digit by the use during the said interval of only one of said conditions and recording another digit by the use during the said interval of the same one of the said conditions followed by the other.

By "high frequency" is meant a frequency sufficiently high in relation to the frequency at which digits are stored to permit adequate separation of the high frequency from the frequencies concerned in the digit storage.

The different conditions are preferably phase differences and for storing binary digits the two conditions of approximately in-phase and approximately anti-phase are preferably used.

The invention also provides apparatus for carrying out the method set forth.

The invention will be described by way of example with reference to the accompanying drawing in which

Figure 1 is a block circuit diagram of one embodiment of the invention and

Figure 2 shows waveforms of voltages present at various points on Figure 1, the frequency of the oscillations shown in Figure 2(d) to (f) being reduced below their usual value for clearness.

In order to understand the mechanism of the present invention, consider the operation of a known storage device of the type set forth in which there is an initial secondary emission ratio greater than 1. When a spot is bombarded, the potential of the screen under the spot will stabilise itself when the secondary emission ratio falls to unity at an equilibrium value E_0, which is slightly positive with respect to the nearest collector of secondary electrons, which is normally the final anode or an internal conducting coating of the tube. Consequently, if while a spot is being bombarded the potential of the final anode or wall coating is pulsed (momentarily changed in potential), the absolute value of the charge produced on the bombarded spot will reflect the magnitude and sign of the pulse. It would appear, therefore, that by suitable choice of pulsing signals binary information could be recorded in this way. Such a system is not workable, however, as the pulsing signals applied to the anode or wall coating, and which could very well be applied alternatively to the signal plate, completely mask any "read" or output signals developed in the signal plate. According to the invention of U. S. application Serial No. 205,459 filed January 1, 1951, this overloading or paralysing effect on the amplifier is effectively overcome by using radio frequency as the pulsing signal, the radio frequency being readily prevented from affecting the signal amplifier.

Consider a radio frequency oscillation of, say, 20 megacycles as shown in Figure 2(*d*) and peak to peak amplitude 50 volts applied to the signal plate of the storage tube, and assume that the grid has applied to it pulses A and B of the same radio frequency which are in opposite phase, pulse A being as shown in Figure 2(*e*) in anti-phase with the oscillation on the signal plate and pulse B being as shown in Figure 2(*f*) in phase with the oscillation on the signal plate. In a binary system the pulses A and B may represent 0 and 1 respectively. Assume also that the cut-off bias applied to the grid of the tube is such that beam current flows only in the neighbourhood of the positive peaks of the applied grid voltage wave form, that is only above the dotted lines C in Figure 2(*e*) and (*f*). During pulse A (Figure 2(*e*)) therefore the screen will be bombarded when the signal plate is driven to −25 volts from its means level and the screen surface potential is similarly shifted through the signal plate to screen capacity. So long as the duration of current flow during pulse A is adequate, the bombarded spot will assume the equilibrium potential E_0.

If following a pulse such as A, before the established charge has decayed appreciably, the same spot is again bombarded by applying a further pulse A to the control grid, no change of charge on the spot will occur and no signal will be derived from the signal plate (ignoring the pulses arising from the electron cloud produced by the switching on of the beam). Consider now the effect of following bombardment during pulse A with bombardment of the same spot produced by application of pulse B (Figure 2(*f*)) to the control grid. Beam current now flows when the signal plate potential is driven 25 volts positive with respect to its mean potential and the screen surface potential is as a result driven 50 volts positive with respect to the previously acquired equilibrium potential E_0, and so long as the duration of current flow is adequate, the spot potential will be again stabilised to E_0. If, now, however, the same spot is again bombarded by the application of a pulse A to the control grid, the spot will have to be stabilised to E_0 from a potential E_0 −50 volts, that is a positive charge equivalent to 50 volts will have to be produced on the spot and the production of this charge will give rise to a signal in the signal plate which may be fed through a filter to the amplifier and utilised in the normal way to indicate that the spot under examination had previously been subjected to bombardment under the control of both A and B pulses.

Referring to Figure 1, this shows a cathode ray tube **10** provided with a regenerative loop connecting hte signal or pick-up plate **11** and control grid **12**, the loop including an amplifier **13** and a reading and writing unit **14** which may have the form shown in Figure 3 of the specification of co-pending U. S. application Ser. No. 93,612 filed May 16, 1949, now Patent No. 2,777,971. A pulse generator **15**, serving to generate pulses for the control of the whole equipment, controls the generation of dot pulses by a generator **16**, strobe pulses by a generator **17** and dash pulses by a generator **18**. The dot, strobe and dash pulses are applied to the read and write unit **14** as described in the last-mentioned specification. The idealised wave form of the dot and dash pulses is shown in Figure 2 at (*a*) and (*b*) respectively, the former having a duration t_1 and the latter a duration t_2. The duration t_2 is what is previously referred to as the digit interval. Briefly, the action of the reading and writing unit **14** is as follows: The unit normally transmits to its output dot pulses from dot generater **16**. If a positive-going signal is generated on the pickup plate **11**, this signal is amplified at amplifier **13** and fed to the unit **14**, where a desired part is selected by a strobe pulse from strobe generator **17**, this desired part serving to pass to the output of the unit **14** a dash pulse from the generator **18**. In order to write a dash over a dot, a dash pulse is fed to the unit **14** through a "write" terminal **28**. The pick-up plate **11** has applied to it from an R. F. oscillator **19** a continuous 20-megacycle oscillation, filters **20** and **21** being provided to isolate the amplifier **13** from R. F. oscillations and to prevent read signals reaching the R. F. oscillator respectively. A modulator **22** is connected to the output of the unit **14** and is thus inserted between the unit **14** and the control grid **12**; a 20-megacycle signal from the oscillator **19** is fed to the modulator **22** by two paths one including a gate device **23** and the other a phase-reversing circuit **24** and another gate device **25**. In the example shown in Figure 1 the oscillator **19** together with the phase inverter **24** constitute oscillation generating means generating at two output terminals thereof respectively, namely at the outputs connected to the inputs of the gates **23** and **25**, two high-frequency oscillations having the same frequency and different phase. Dot pulses are fed to the gating device **25** to open this gate for the duration t_1 of each dot pulse and dash minus dot pulses, having the form shown in Figure 2(*c*), and derived in a generator **26** by the subtraction of dot pulses from dash pulses, are fed to the gating device **23** to open this gate for the duration $t_2 - t_1$ of the pulses **27**. The modulator **22** acts as a form of gate to pass R. F. oscillations from **23** or **25** only while positive pulses are applied thereto from the unit **14**.

The cathode ray beam is deflected to scan a raster on the screen of the tube **10** by saw-tooth oscillations generated by X-scan and Y-scan generators **29** and **30** respectively, controlled by the pulses from **15**, these oscillations being applied for example to coils **31** and **32** respectively. The X-scan generator is arranged to generate a stepped wave form so that the beam remains stationary at least throughout each digit interval (t_2).

In the example shown the collector of secondary electrons is a conducting wall coating **33** which is earthed, so that E_0 is approximately earth potential, and the cathode **34** is maintained at a suitable negative potential with respect to earth.

In operation, assuming that no information has been stored and no information is fed in at the write input terminal **28** the output applied by the unit **14** to the modulator **22** will consist only of dots which occur during the time that the gate **25** is open and the gate **23** is closed. Consequently the turning on of the cathode ray beam is effected by the peaks of R. F. oscillations of pulses A which are in anti-phase to the oscillations on the pick-up plate **11**. The result is to produce on the screen of the tube a charge which is characteristic of a dot and thus dots will be recorded over the whole screen. If now information is to be written in by converting certain of the dots to a second charge condition corresponding to dash, the appropriate dash signals are applied at terminal **28**. Whenever, as a result of this, a dash is applied from the output of the unit **14** to the modulator **22**, the modulator is rendered operative for the whole of a dash interval t_2 to pass oscillations from gates **23** or **25**. The gate **25** is open for the first part t_1 of this interval and passes A pulses to the grid **12**, and the gate **23** is open for the last part $t_2 - t_1$ of the period and passes B pulses to the grid **12**. Thus the first part of the bombardment is with anti-phase pulses at **11** and **12** and the last part is with in-phase pulses at **11** and **12**. The result, as already explained, is that the charge left on the bombarded spot is different from that when only the A pulses are used and when the beam next bombards the spot with an A pulse on grid **12**, the voltage developed in the pick-up plate **11** will correspond to a dash and will result in a dash being generated at the output of unit **14**. In this way a dash will continue to be regenerated at the spot in question until a change to a dot is indicated by a write signal applied at **28**.

It is assumed that the effects of the pulses generated by the electron cloud produced on switching on the beam are eliminated by known means. The filter **20** may be found sufficient or the response of the amplifier **13** may be arranged to achieve the desired result.

It should be noted, however, that the effect of the electron cloud pulses can be made much smaller than in previous devices of the type referred to because of the greater magnitude which can be given to the signal representative of the dash condition. This can be explained as follows: In known devices of the type in question the positive signal derived on reading a dash is derived from the creation on a dot area of a positive charge of potential amounting to only a few volts. In the system of the present invention the potential which is produced when reading is determined primarily by the peak to peak amplitude of the R. F. voltage which is applied to the pick-up plate, and the read signal may, within reason, be made as large as is desired.

If desired the conventional dot and dash time intervals may be replaced by two dot intervals, information of one sort being written by the illumination only during the first dot interval which corresponds also to the reading interval, information of the second sort being recorded by illumination during the first (reading) dot interval followed by illumination during the following (modifying) dot interval. By reversal of the relative phase of the radio frequency on the signal plate and that applied to switch on the beam, that is to say by using in-phase oscillations during the first interval and anti-phase oscillations during the second interval, the polarity of the read signal developed may be arranged to be negative. If a negative read signal is employed, the effect of negative cloud pulses may be eliminated by integration as described in U. S. application Serial No. 193,772 filed November 3, 1950, now patent 2,749,439.

Although this invention has been described with the R. F. oscillations applied to the pick-up plate **11**, it will be apparent that a corresponding result can be obtained by applying the R. F. oscillations instead to the collector electrode which may then with advantage take the form of a mesh interposed between the electron gun and the screen and located fairly close to the latter. This follows because what is relevant is the potential difference between the collector electrode and the screen surface. Of course the R. F. oscillations may be applied to the cathode **34** instead of to the grid **12** and for a given effect are then applied in opposite phase.

If desired, the phase of the R. F. oscillations applied to switch the beam may be maintained constant and the phase of the R. F. oscillations applied to the pick-up plate or collector electrode may be varied between the in-phase and anti-phase condition. Gate circuits such as **23** and **25** may be provided for this purpose.

In a modification of the invention the R. F. oscillations applied to the pick-up plate and control grid (or cathode) differ in frequency by an amount equal to the digit repetition rate. In this arrangement the "beat" effect between the two frequencies can be caused to give approximately in-phase bombardment for illumination during the periods t_1 and approximately anti-phase bombardment during the periods t_2—t_1.

Although this invention has been described in terms of two states of charge only, it will be realised that additional states are possible, for example either by variation of the relative phasing between the extremes of in-phase and anti-phase referred to or by amplitude modulation of the R. F. oscillation applied to the signal plate. Thus the state of charge developed depends upon the value of the signal plate potential at the times during which the beam is switched on and this potential can clearly be given more than two different values by the use of more than one phase difference or by amplitude modulation. A third state of charge may, for example, be obtained by providing a circuit for generating an oscillation in phase quadrature and employing with this circuit a further gate circuit such as **23** and **25**. Alternatively, using amplitude modulation, means may be provided for applying to the pick-up plate oscillations from the oscillator **19** modulated to any desired number of fixed amplitudes, the desired one of these fixed amplitudes being selected according to the nature of the information to be stored.

A number of different conditions greater than two may of course be obtained by providing means for varying the phase of the oscillations applied to the pick-up plate and the grid or cathode of the tube or for modulating the amplitude of the oscillations applied to the pick-up plate and also providing means to vary the phase of the oscillations applied to the grid or cathode of the tube.

I claim:

1. A method of storing digital information employing a cathode ray tube having an electric charge-retaining recording surface positioned to be explored by the cathode ray beam and a collecting electrode positioned to collect secondary electrons from said surface, the method comprising directing the beam successively towards spaced areas of said surface and maintaining the beam substantially stationary in such directions, recording one digit by applying a first burst of high frequency oscillation to switch said beam on and off upon one of said areas and at the same time applying a burst of high frequency oscillation to vary the potential difference between said collecting electrode and said surface, the said potential difference having at least one value within a first range of values during the times when the beam is switched on, and recording another digit by applying a burst of high frequency oscillation to switch said beam on and off upon another of said areas and at the same time applying a burst of high frequency oscillation first to vary the said potential difference to cause such potential difference to assume at least one value within the said first range of values during the times when the beam is switched on, and subsequently applying a burst of high frequency oscillation to vary the said potential difference to cause such potential difference to assume at least one value within a second range of values, different from said first range, during the times when the beam is switched on.

2. A method according to claim 1, wherein all said high frequency oscillations have the same frequency.

3. A method according to claim 2, wherein one of said ranges of values of potential difference is obtained by applying to vary the potential difference and to switch said beam on and off, high frequency oscillations approximately in phase with one another and the other of said ranges of values is obtained by applying to vary the potential difference and to switch said beam on and off, high frequency oscillations approximately in anti-phase with one another.

4. Apparatus for storing digital information comprising a cathode ray tube, an electric charge-retaining recording surface in said tube, beam-intensity control means for said tube, beam deflecting means to direct the cathode ray beam successively on spaced areas of said surface, a signal pick-up electrode capacitively coupled to said surface, a collecting electrode positioned to collect secondary electrons from said surface, oscillation generating means generating a first and a second high frequency oscillation, said first and second oscillations having the same frequency and different phase, coupling means between said oscillation generating means and one of said electrodes applying said first oscillation to vary the potential difference between said electrodes, and coupling means between said oscillation generating means and said beam-intensity control means applying said second oscillation to vary the intensity of said beam.

5. Apparatus according to claim 4, wherein said first and second high frequency oscillations are substantially in anti-phase with one another.

6. Apparatus according to claim 4 comprising a pulse generator generating beam intensity controlling pulses to vary a bias upon said beam-intensity control electrode between conditions in which said high frequency oscilla-

tions applied to said control electrode do and do not switch said beam on and off, a selective control device to permit and prevent application of pulses from said pulse generator to said beam-intensity control electrode and means rendering said selective control device operative and inoperative in response to information to be stored.

7. Apparatus according to claim 6, comprising coupling means between said signal pick-up electrode and said selective control device to apply voltage from said pick-up electrode to control the application of pulses from said pulse generator to said beam intensity control electrode and thereby to regenerate electrostatic charges on said surface.

8. Apparatus for storing digital information comprising a cathode ray tube, an electric charge-retaining recording surface in said tube, a beam-intensity control electrode for said tube forming part of a first control system, beam deflecting means to direct the cathode ray beam successively on spaced areas of said surface, a second control system comprising a signal pick-up electrode capacitively coupled to said surface and a collecting electrode positioned to collect secondary electrons from said surface, oscillation generating means having two output terminals and generating at said terminals respectively two high frequency oscillations of a predetermined frequency and of different phases, switching means connecting two input terminals in succession to an output terminal thereof, couplings between the two outputs of said generating means and said two input terminals respectively, a coupling between said output terminal of said switching means and an electrode of one of said control systems, and a coupling between one of the terminals of said generating means and an electrode of the other of said control systems.

9. Apparatus according to claim 8, wherein said switching means comprise gating means and pulse-generating means applying pulses to actuate said gating means.

10. Apparatus according to claim 8 in which said switching means connect a first of said input terminals to the output terminal of said switching means during a first recurrent time interval and connect the second of said input terminals to the output terminal of said switching means during a second recurrent time interval following said first time interval, said apparatus comprising a pulse generator generating pulses extending over at least part of said second time interval, and means coupling said pulse generator to said beam-intensity control electrode, said coupling means including selective switch means responsive to signals to be stored to control the application of said pulses to said beam-intensity control electrode and thereby to render said beam operative on peaks of said high frequency oscillations during at least part of said second time interval only in response to a signal of a predetermined character.

11. Apparatus according to claim 10 comprising coupling means between said signal pick-up electrode and said selective switch means to apply voltages from said pick-up electrode to said selective switch means, whereby electrostatic charges on said surface are regenerated.

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