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ELECTRON STREAM TRANSMISSION DEVICE

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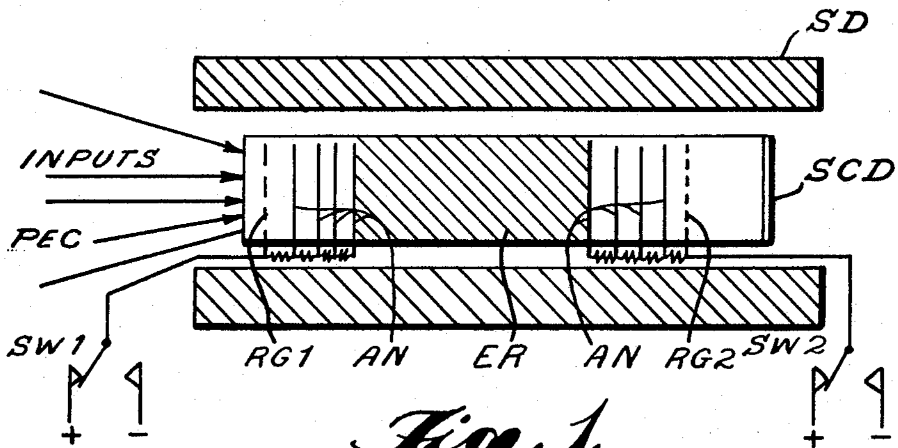


Fig. 1.

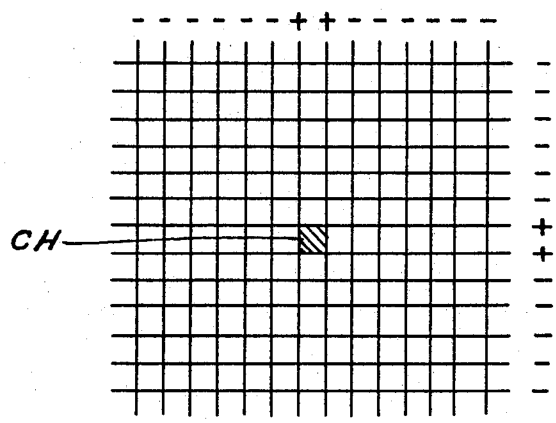
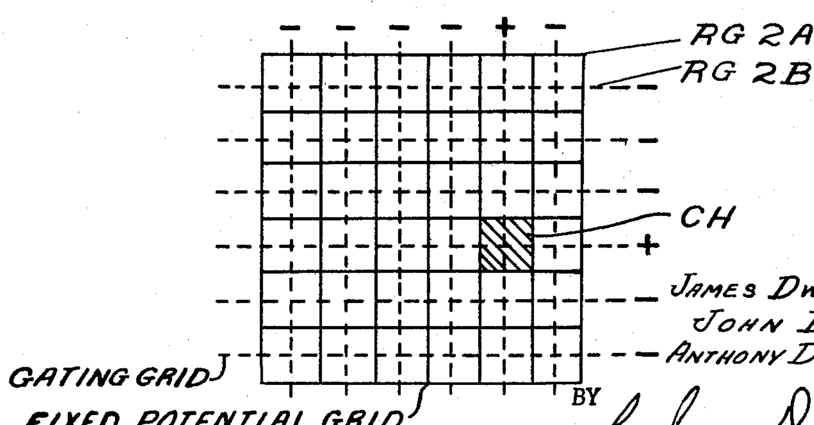


Fig. 2.

Fig. 3.



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ELECTRON STREAM TRANSMISSION DEVICE

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Int. Cl. H01j *39/12*
U.S. Cl. 250—213 9 Claims

ABSTRACT OF THE DISCLOSURE

A vacuum tube device suitable for timing, information-storage, information-translation and for detection and display of high-speed transients essentially comprising a vacuum envelope, an input electrode for responding to one or a multiplicity of signals and for transmitting one or a parallel multiplicity of electron streams in response thereto, a spaced pair of mesh screens spaced to provide an electron stream path of nano- or micro-second transmission length, a tubular electrode surrounding the electron stream path between the mesh screens, magnetic focussing means surrounding the vacuum space, and control circuits for controlling the mesh screens to act alternatively as electron gates and reflectors so that electron streams can be allowed to enter and leave the electron path between the screens at will and to reciprocate between the screens for up to millisecond periods for storage purposes, it being possible to selectively extract electron streams from a stored multiplicity.

This invention relates to vacuum tubes and devices incorporating such tubes, and has for its object tubes and devices suitable for timing, information-storage, information-translation, and like purposes, and in connection with the detection and display of high-speed transients.

The main aspect of the invention comprises a vacuum tube within which are mounted axially in line in spaced relation, means for generating an electron stream of varying intensity, a first screen, a second screen spaced from the first screen by a distance requiring the use of electron-focussing means to ensure electron transmission between points having the same coordinates on the two screens, and electron-responsive means beyond the second screen, and which comprises electrode means encircling the space between the screens, first accelerator/retarder means immediately following said first screen, and second accelerator/retarder means immediately preceding said second screen, said screens, electrode means, and accelerator/retarder means being so mounted as to be individually controlled in potential.

Variation in the electrical condition of the screens will either allow free passage of electrons therethrough, or alternatively reflect electrons impinging thereon. The screens, acting as reflector gates, can wholly or partly span the tube, and a plurality of partial screens can be arranged to be complementary in that respect, to be at different locations in the tube, and to be separately controllable. Such tubes can form part of equipment by means of which the electron-stream generating means is activated by pulses: for example, light pulses; to set up pulse emission; and the screens potentials are varied to control the passage of pulse trains between and through the screens. Thus elemental areas or spots on a photo-electric cathode, for example, can be independently activated to set up electron emissions each of which can be magnetically controlled to follow a tight helical path parallel to the tube axis, so forming a number of transmission "channels" along the tube.

Electron pulse trains forming such channels can reciprocate to and fro, between the screens currently acting as reflectors, without losing their identity. By activating a cathode spot by a succcession of light pulses, a sequence of discrete bunches of electrons is emitted along the corresponding channel: for example, a sequence of light pulses corresponding to the "1's" of a binary information train will generate an information train of electron bunches along the channel. After passage through a first reflector-gate biassed to act as a gate, such an electron train can reciprocate or circulate along the channel between said first reflector gate and a second reflector-gate while both are biassed to the reflecting condition.

Reciprocating electron pulses can maintain direction and identity for a large number of passes along the tube, so that while the time taken for a single electron pulse to traverse along the tube is of the order of nanoseconds and a single reciprocation takes microseconds, electron pulse trains can reciprocate for periods of the order of milliseconds and still be recognisable.

The tube alone also has utility for nanosecond, microsecond and millisecond timing, time position transfers, and code translation purposes.

However, as in the case of solid-column and liquid-column pulse-circulation stores, it is possible to regenerate electron transmission by opening the outgoing reflector-gate at a suitable moment, detecting the electron bunches, amplifying and/or reshaping resulting electrical signal trains, and utilising them to generate a corresponding train of light pulses which are applied to the photocathode to start a regenerated electron train similar in content to the original train. This process can be continually repeated so that storage can be prolonged for an indefinite period.

It is apparent that information—a word, for example—can be introduced into the tube either in series in a single channel, or in parallel in a number of channels, and a number of channels can be used to reciprocate or store a sequence of parallel words, or any other arrangement of information, on a three-dimensional basis.

Further, since an electron stream in a channel can reciprocate without interference between oppositely moving electrons, a channel can store a stream or train of electrons longer than the distance between a pair of closed gates, so that any length of train up to two channel lengths can be reciprocated and extracted without confusion.

The maximum number of binary bits which can be stored in such a tube is equal to the number of bits which can be stored in a single channel with minimum spacing of the bits multiplied by the number of channels.

Several trains of pulses having pulse spacings which are multiples of the minimum bit-storage of which a channel is capable, can be stored in a single channel on an interpolation basis, so that each pulse position in a repetitive cycle of x pulse positions is allocated to a different one of x pulse trains.

While the invention has wide possibilities of use, it would appear capable of fulfilling an important need in very high speed computers: namely, the provision of a very high-speed store.

The invention will be described with reference to the accompanying drawings in which:

FIG. 1 illustrates schematically the basic construction of a storage device embodying the invention, while

FIGS. 2 and 3 illustrate exemplary forms of selectively-operable reflector-gates for use in the storage device of FIG. 1.

Since their conception, digital calculators have been limited in their performance by the size and speed of their information storage facilities. A significant step forward in speed and capacity came with the introduction of the acoustic relay line. The electro-static storage system of F. C. Williams superseded this and finally the ferrite core store has become the basic component of all the fast computer stores.

For even faster machines the finite speed of propagation of electromagnetic signals becomes important and feeding of information into and out of circuit elements ("fan in" and "fan out") is a further problem because of reflection of step wavefronts-necessitating the use of matched lines.

An opto-electronic system (as proposed by Cooke-Yarborough: Proc I.E.E., vol. 111, No. 10, page 1641, 1964) has many advantages. Coupling between arithmetic units can be accomplished optically (e.g. using light fibre pipes), considerably reducing cross-talk and increasing the usuble fan-in and fan-out ratios.

Computer systems utilising piped light and photo-electronic high gain repeater tubes operating at electron speeds are capable of very fast computation speeds, and nano-second working can be achieved. To make use of such a system, it is necessary to have also a high-speed, high-capacity store and this is the object of the present invention.

FIG. 1 shows a photo-electronic vacuum tube device capable of acting as a computer store at nano-second and micro-second speeds. One end of the device is a photo-emissisive cathode PEC while the other end is a semi-conductor detector device SCD. The broken vertical lines RG **1**, **2** within the tube indicate mesh screens capable of acting as gates and as reflectors for electrons passing along the tube in response to differing electric potential conditions applied thereto via switches **SW1**, **SW2**. The group of full vertical lines at each end of the region between the screens **RG1**, **RG2** indicate groups of annuli AN which can act as electron accelerator/retarders (according to direction of electron travel) in response to progressively-varying potentials applied to the annuli of each group, preferably by a potentiometer control from the respective screen, as indicated in FIG. 1. Of course, there will be an electrode, for instance a cylindrical metal liner to the tube, in the region ER at a suitable positive potential.

A solenoid SD surrounds the tube and its magnetic field controls both the formation and the diameters of the helical paths followed by the electrons in each channel along the equipotential region ER in the tube.

The photo-emissive surface of the cathode PEC will emit electrons when illuminated with photons in 10^{-12} sec., and provides fast Read-in. Using light pipes to feed the information to elemental cathode areas, cross-talk is considerably reduced and the "fan in" ratio; that is, the number of discrete information-responsive areas; can be high.

The photo-electrons themselves are used to store the information.

The screen or mesh RG succeeding the photo-cathode controls the photo-electron stream. By biasing the mesh to a suitably negative potential the photo-electrons are all returned to the photocathode.

If now the mesh is turned positive, the electron stream passes through and, after acceleration by the left-hand annuli, enters the equipotential region, through which it drifts at a speed controlled by the voltage applied to the equipotential section of the tube. The path followed by the electrons is a very tight helix, the diameter of which is governed by the magnetic field produced by the solenoid SD, in which the whole tube is immersed. Electrons with 100 ev. energy travel at a speed of about 5.9 m./μsec. Thus if the equipotential region is about 60 cm. in length, the transit time of such electrons will be about 100 nanoseconds. The spatial resolution is maintained by the large magnetic field. Electron streams passing along the equipotential region are accelerated or are retarded as desired by the right hand annuli AN being encountering the second mesh **RG2** by which the electron flow can be controlled. If mesh **RG2** is positive the electrons can pass

through. If the mesh is negative they are reflected and return down the tube. Thus after a time equal to twice the one-way transit time an electron will again reach the first mesh **RG1**. If mesh **RG1** has been turned negative before the electrons reach it on their return journey, they will again be reflected. The electron information fed in over a period of 200 nsec. is trapped between the screens and forced to oscillate back and forth.

Each fully resolvable discrete area or picture point on the photocathode is the source of a stream of electrons which will be nearly 100% modulated by a random stream of photon pulses incident on the picture point. This modulation can be maintained through many traverses of the electron stream up and down the tube. If such an electron stream can be modulated at nanosecond rate and the spatial resolution of the image is 100 picture points in each direction (giving a coordinate array of 10,000 points), then the total number of bits of information trapped in the tube during 200 nsec. will be $200\ (100)^2=2.10^6$, comprising 200 bits in each of 10,000 storage channels.

It can be shown that, by suitably choosing the length of the equipotential drift and the speed-control region at each end, any difference in initial axial energies will introduce only small dispersion in their time of arrival. This can be seen qualitatively by considering first the equipotential region. An electron with large emission energy will travel faster and thus take less time to complete its journey than an electron leaving the photocathode with low energy. When the decelerating region is reached, however, the extra energy now has the opposite effect. The more energetic electron penetrates further into the retarding field and thus spends longer in this region. Electron kinetic considerations lead to a very simple relation which balances these two effects and yields zero time dispersion for any value of electron emission energy, $>>V$, where V is the voltage on the equipotential region. This information fed into the tube can be stored over many transits with virtually no loss of time resolution.

Two main features govern the maximum storage time possible.

(1) residual gas pressure,

(2) non-linear regions in the electric and magnetic fields.

Due to the direct relation between the storage time and electron path length (for any particular voltage on the equipotential region) the mean free path and hence the residual gas pressure in the device control the maximum storage time. With reasonably good vacuum techniques, electrons are not likely to make a gas collision more than once in ten thousand double transits, or an electron pulse (information bit) could make a thousand double transits before it would have lost 10% of its electrons, which is about the attenuation allowable before the pulse becomes unrealiable. Any non-linearity in the electric and magnetic fields add geometrical distortions and loss of axial energy on each transit and hence limit the maximum number of transits possible before the loss of image resolution becomes intolerable. These fields can be made almost as uniform as desired and hence it becomes feasible to make this electron image information store such that there is no serious loss of information in, say, 10 microseconds.

The second mesh can be switched on and off in 1 or 2 nseconds and this will let through that portion of the electron streams arriving at the mesh during that period. Detection and amplification for the electron output of each channel may be provided by the semi-conductor termination SCD comprising, for example, suitably-biassed semiconductor p-n junctions which will produce an electron hole pair for each 3 ev. incident energy when struck by an energetic electron; or an electron multiplier array. In this way, the electron pulses are accelerated up to, say, 20 kv., so that a gain of about 6,700 is achieved.

Because of the accelerating fields, the transit time of the electron and hence the delay involved in the amplification is short (1 nsec.) In this way an output current is generated if an electron passes through mesh RG2 when it is acting as a gate. Output current from a channel is applied to a corresponding light diode (not shown) and the system is complete.

Computer techniques involve the use of serial or parallel machines. In a serial machine the bits which go to make up a word are handled in sequence. In a parallel machine all bits of one word are processed at the same time. If a 50 bits/word system is under consideration, clearly a speed gain of 50 is potentially available by operating in the parallel mode.

The store described is adaptable for use in either mode; the various problems associated with each will be considered individually.

Serial operation

A serial binary 50-bit word can be read into the store by applying a corresponding pulse series to a light diode which is coupled to a resolution element of the input photocathode. The word is thus stored in the channel associated with the resolution element as a series of electron bunches corresponding to the 0's and 1's of the binary system. If the fundamental time element is 1 nsec., the 50 bit word will occupy 50 nsecs. The individual wires of mesh RG2 are now electrically insulated as indicated in FIG. 2. For example, the horizontal and vertical sets of wires of mesh RG2 can be slightly spaced axially. If all the wires are biased negative, FIG. 2, the storage or reflector state is defined, and the electron information will oscillate back and forth. If, however, adjacent pairs of horizontal and vertical wires are pulsed positive, as shown, one region of the "mesh" bounded by the four wires and constituting an electron channel will let a stream of information through. Thus a word can be removed from the store.

FIG. 3 shows an alternative arrangement of mesh comprising two axially-spaced coordinate wire grids RG2A, RG2B staggered in both directions in relation to one another.

Grid RG2A has a fixed potential while the gating grid RG2B is formed like the mesh of FIG. 2. In this case however a single wire in each direction is given positive potential in order to open the fixed grid channel CH which contains the cross-point of the two positive wires.

Parallel operation

For operation in the parallel mode all 50 bits are fed in at the same time on to the front photocathode and enter the 50 channels in the store simultaneously. Thus a particular word now occupies a slice of the equipotential region normal to the axis and can be removed by pulsing on the second mesh RG2 to allow all the bits of the word to pass through simultaneously. By arranging a suitable number of output channels the whole word can be processed at once.

When information is read out of this store, the stored information is eliminated. However, the information, besides going to the other sections of the computer can also be fed back into the store by applying corresponding signals to the input; if necessary after a suitable predetermined time delay. All stored information can be extracted periodically, reshaped, amplified, and reinjected into the cathode end of the tube. One or more channels may be fed with a series of coded signals to act as identifying or indexing signals for the stored information.

In FIG. 2, by applying positive potential to all the vertical wires, for example, and also to two adjacent horizontal wires only, negative potential being applied to the remaining horizontal wires, a line of transmission apertures can be opened to pass a line of bits constituting, for example, a complete word.

When it is desired to store on a line basis only, the outgoing screen can be a set of parallel horizontal, or vertical, wires only, and a line of bits will be read by applying positive potential to one wire only, while the other wires are biased negative. In all the above cases, the incoming screen can be of the same construction as the outgoing screen, or can be of a different construction: for example, a wholly ON-OFF incoming screen can be associated with an outgoing screen of one of the more sophisticated constructions discussed above.

What we claim is:

1. An electron stream transmission device comprising in a vacuum:

means for generating an electron stream of variable intensity,

an output device directly responsive to electrons from the stream and separated from the generating means by a straight electron transmission path having a length such that for a direct transit of the stream along said path there is negligible transmission loss due to electrons striking gas molecules,

a tubular electrode disposed between the generating means and the output device so as to be coaxial with said transmission path,

a first mesh screen which is disposed across said path adjacent said generating means,

a second mesh screen which is disposed across said path between the tubular electrode and the output device, and comprising

means for providing a focussing magnetic field extending along said transmission path.

2. An electron stream transmission device as in claim **1** wherein said electron-stream generating means is capable of generating simultaneously a number of discrete parallel electron streams and said screens are capable of passing and reflecting such discrete parallel electron streams, and wherein said device comprises a like number of individual pulse inputs to said generating means, and a like number of individual pulse outputs from said electron-responsive means.

3. An electron stream transmission device as in claim **1** wherein said electron stream generating means is a photo-electric cathode.

4. Apparatus comprising an electron stream transmission device as in claim **1**, and comprising:

means for applying a pulse train to said generating means while the first screen is controlled to function as a gate allowing passage of an electron stream from said generating means and said second screen is controlled to function as a reflector;

means for changing the cotnrol on the first screen after a time interval from the commencement of said pulse train no longer than the time required for an electron to travel from the first screen to the second screen and back, so that the first screen now acts as a reflector so that the electron stream shuttles back and forth between the screens; and

means for changing the control on the second screen after an arbitrary interval so that the second screen now acts as a gate to allow transmission of the electron stream which has been dynamically stored between the screens, to the electron-responsive means.

5. An electron stream transmission device as in claim **1** wherein at least the outgoing screen is comprised solely of a set of parallel wires mounted so that individual electrical conditions can be applied to each individual wire.

6. An electron stream transmission device as in claim **1** wherein at least the outgoing screen is a coordinate wire mesh mounted so that individual electrical conditions can be applied to each wire of the mesh.

7. Apparatus comprising an electron stream transmission device as in claim **6**, comprising:

means for biassing all the wires of a screen positive so that the whole area of the screen will transmit electron streams;

means for biassing all the wires of a screen negative so that the whole area of the screen will reflect electron streams; and

means for biassing adjacent pairs of vertical and horizontal wires of a screen positive while all the other wires are biassed negative so that one region of the mesh bounded by the four wires biassed positive will constitute an electron stream transmission path while the remainder of the screen acts as an electron-stream reflector.

8. An electron stream transmission device as in claim 1 wherein at least the outgoing screen comprises two axially-spaced coordinate wire grids staggered in both directions in relation to one another, one of said grids being mounted so that a common electrical condition can be applied to all the wires, and the other grid being mounted so that individual electrical conditions can be applied to the individual wires of the grid.

9. Apparatus comprising an electron stream transmission device as in claim 8, comprising:

means for biassing said one grid positive so that the whole screen will transmit electron streams;

means for biassing said one grid negative so that the whole screen will reflect electron streams; and

means for biassing said one grid negative and of biassing one vertical wire and one horizontal wire of said other grid positive, so that four-sided mesh of the one grid which contains the cross-point of the positively-biassed wires of the other grid constitutes an electron-stream transmission channel while the remainder of the area of the screen acts as an electron-stream reflector.

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