Oct. 8, 1963 S. P. NEWBERRY 3,106,700

PHOTOGRAPHIC STORAGE SYSTEM

Filed June 27, 1957 5 Sheets-Sheet 1

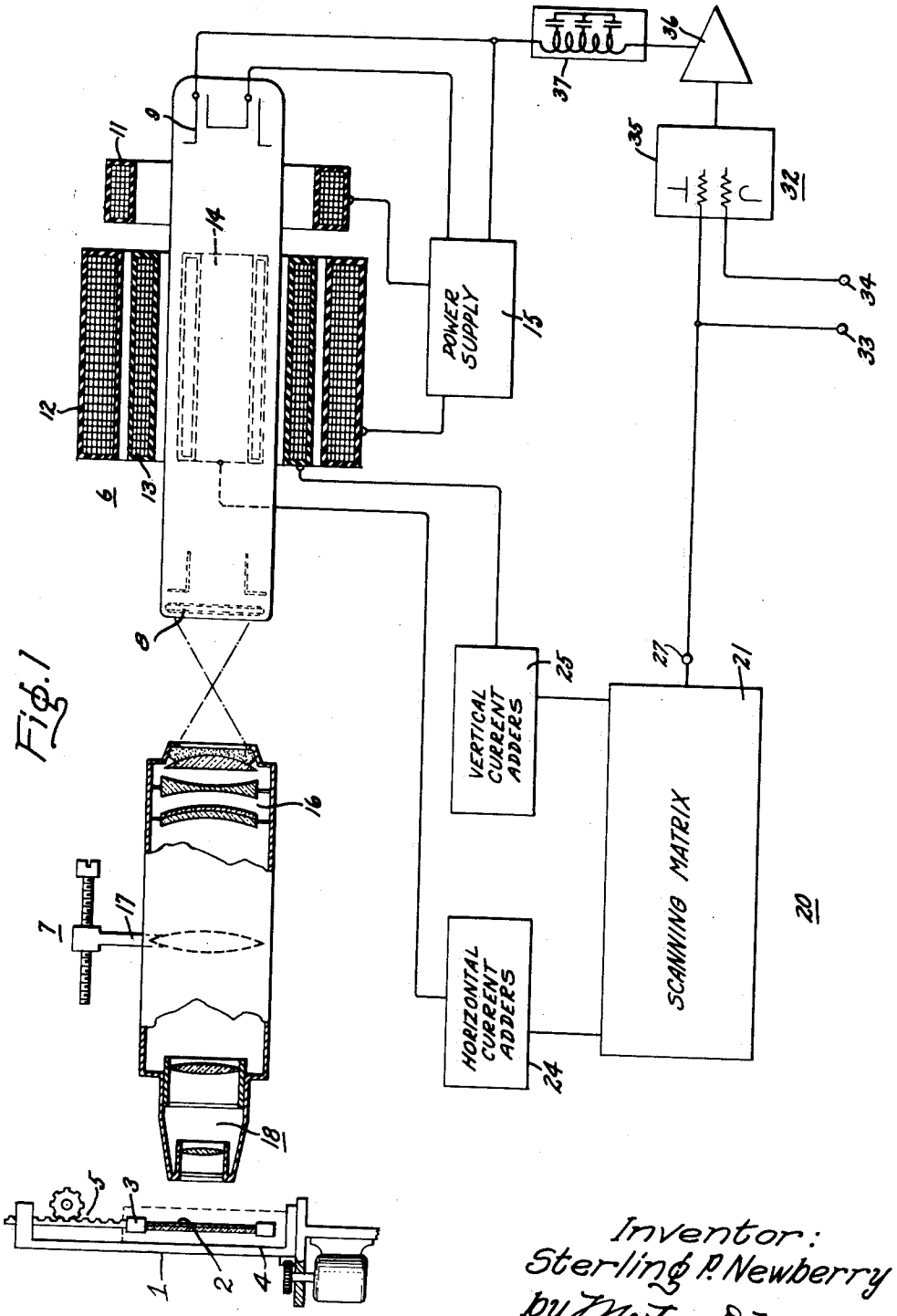


Fig. 1

Inventor:
Sterling P. Newberry
by Merton D Morse
His Attorney

Oct. 8, 1963 S. P. NEWBERRY 3,106,700

PHOTOGRAPHIC STORAGE SYSTEM

Filed June 27, 1957 5 Sheets-Sheet 2

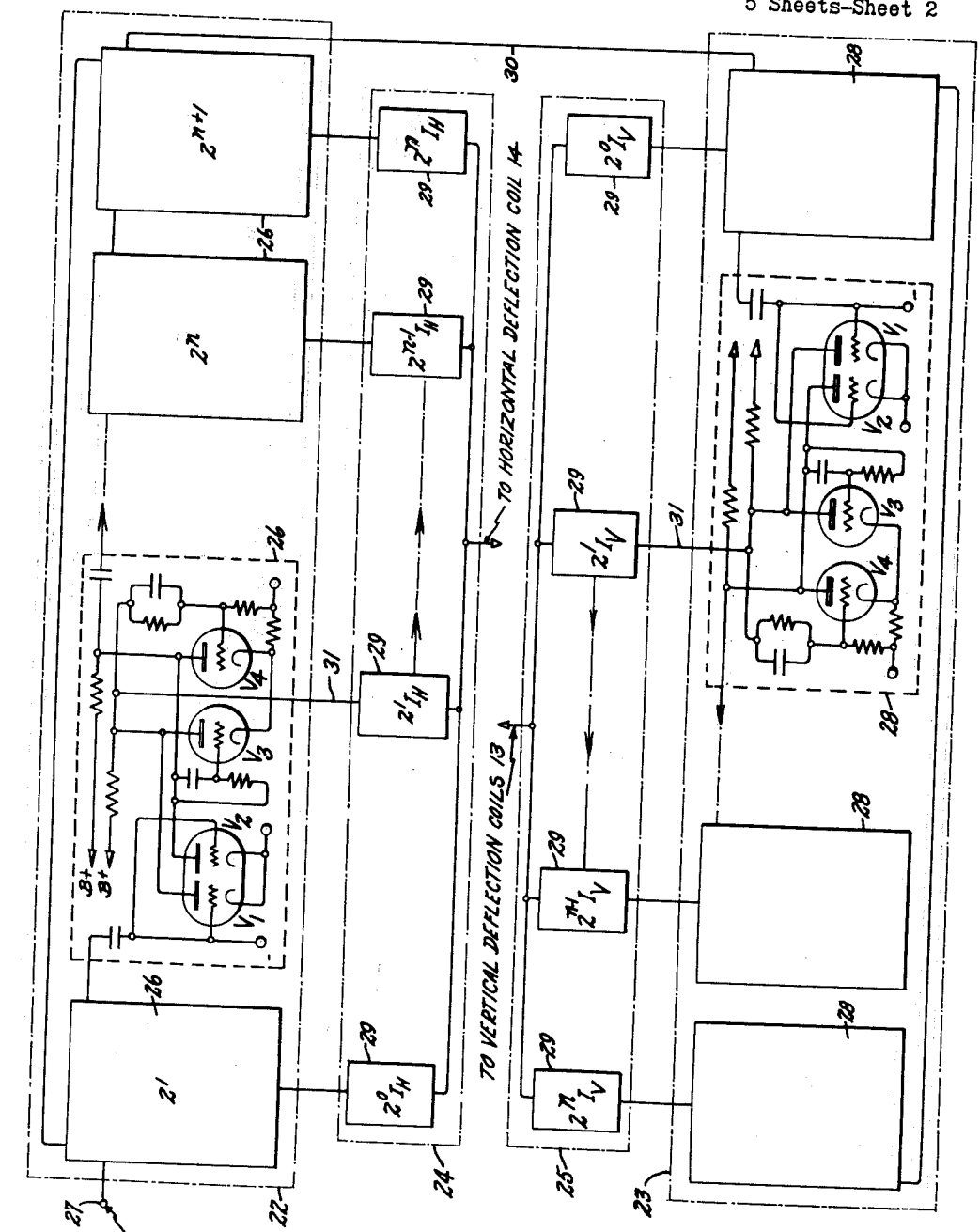


Fig. 2

Inventor:
Sterling P. Newberry
by Marston D Morse
His Attorney

Oct. 8, 1963 S. P. NEWBERRY 3,106,700

PHOTOGRAPHIC STORAGE SYSTEM

Filed June 27, 1957 5 Sheets-Sheet 3

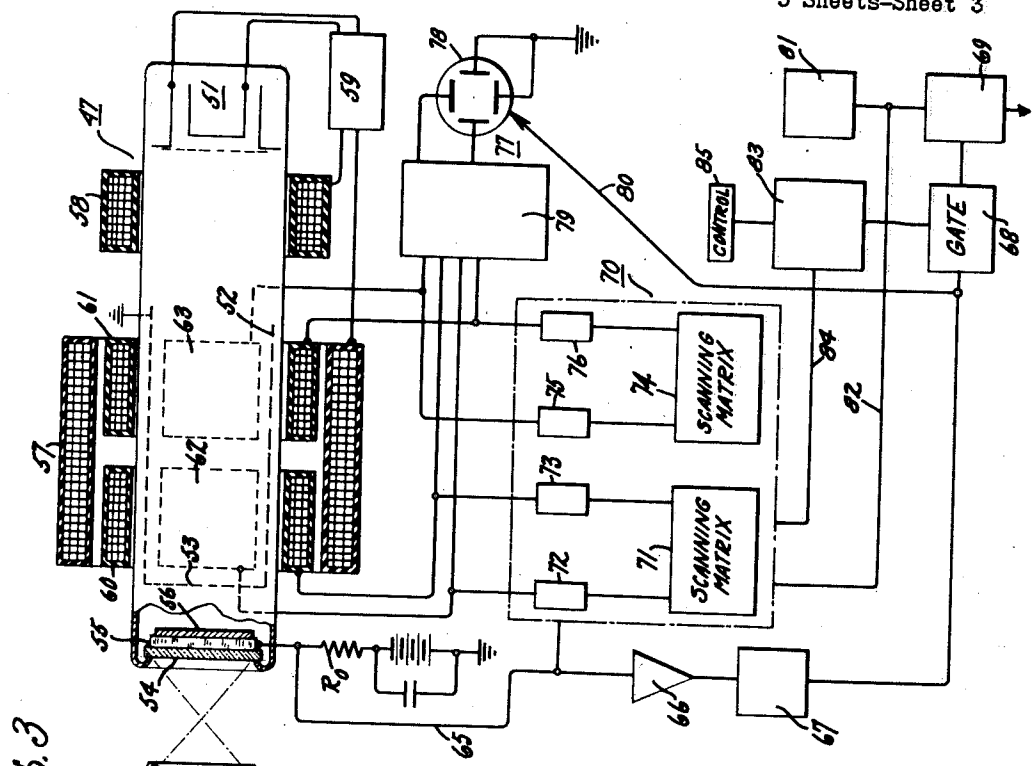


Fig. 3

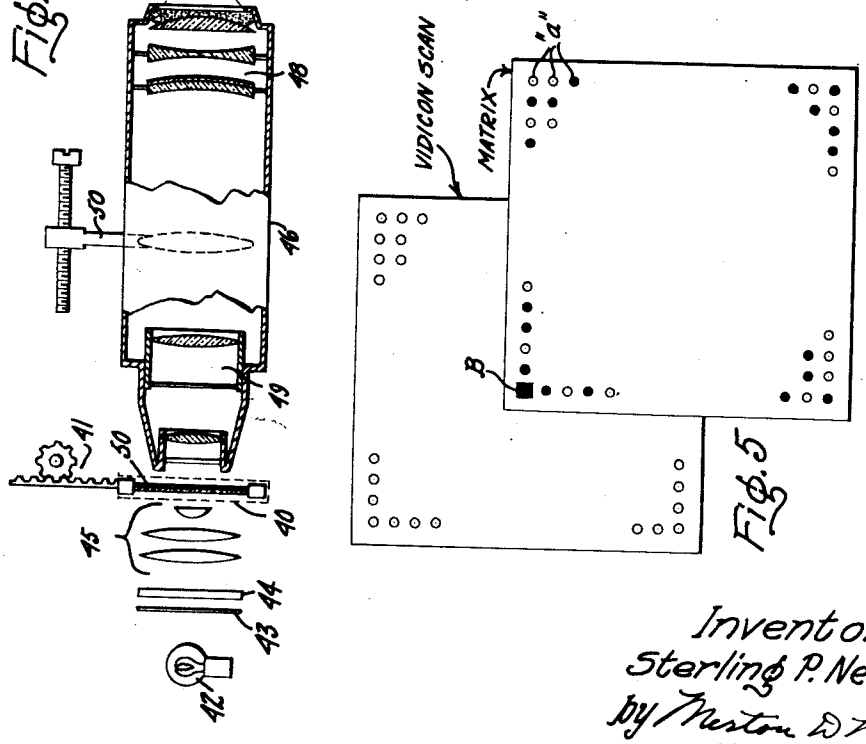


Fig. 5

Inventor:
Sterling P. Newberry
by Merton D. Morris
His Attorney

Oct. 8, 1963 S. P. NEWBERRY 3,106,700

PHOTOGRAPHIC STORAGE SYSTEM

Filed June 27, 1957 5 Sheets-Sheet 4

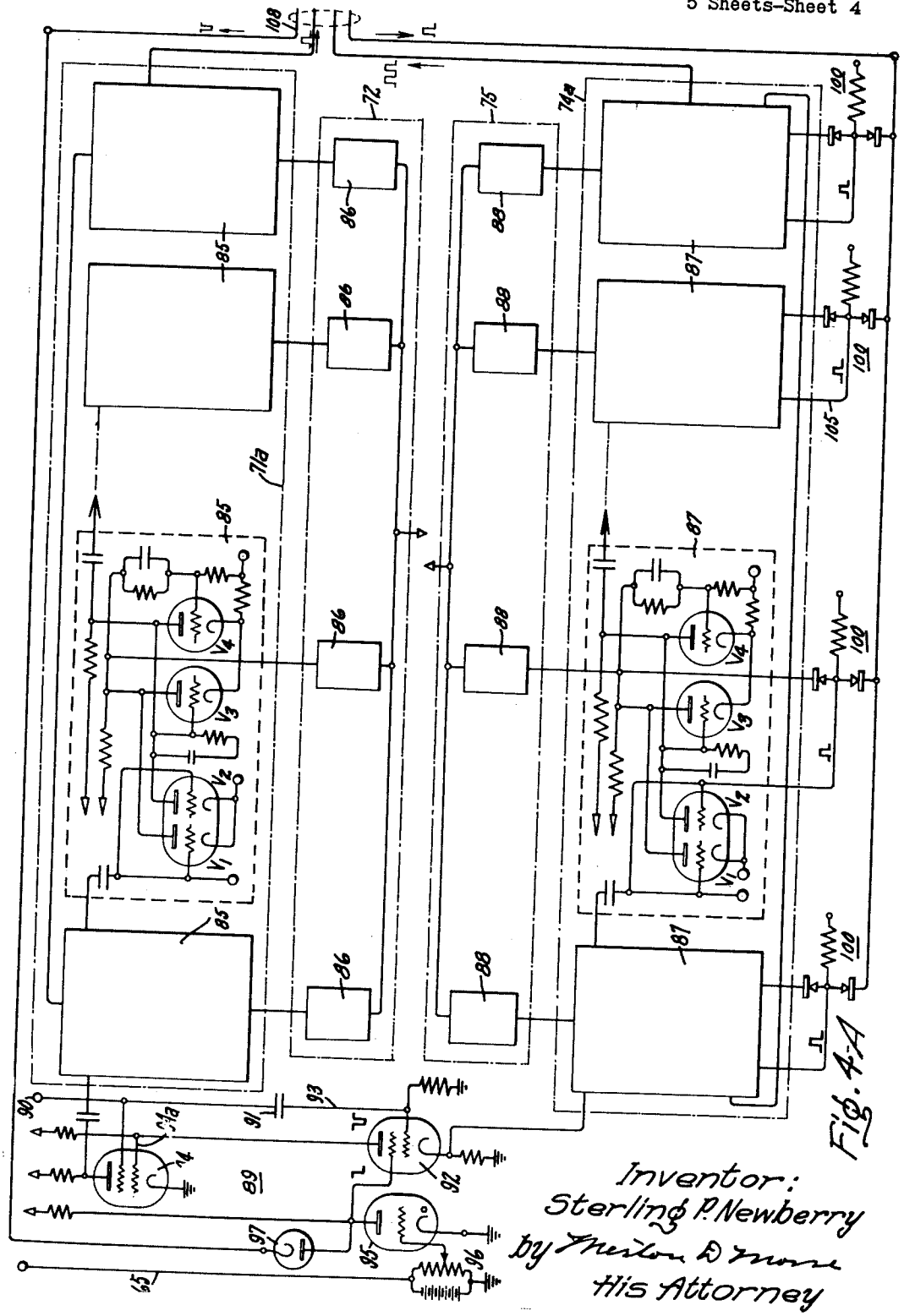


Fig. 4A

Inventor:
Sterling P. Newberry
by Preston D. Moore
His Attorney

Oct. 8, 1963 S. P. NEWBERRY 3,106,700

PHOTOGRAPHIC STORAGE SYSTEM

Filed June 27, 1957 5 Sheets-Sheet 5

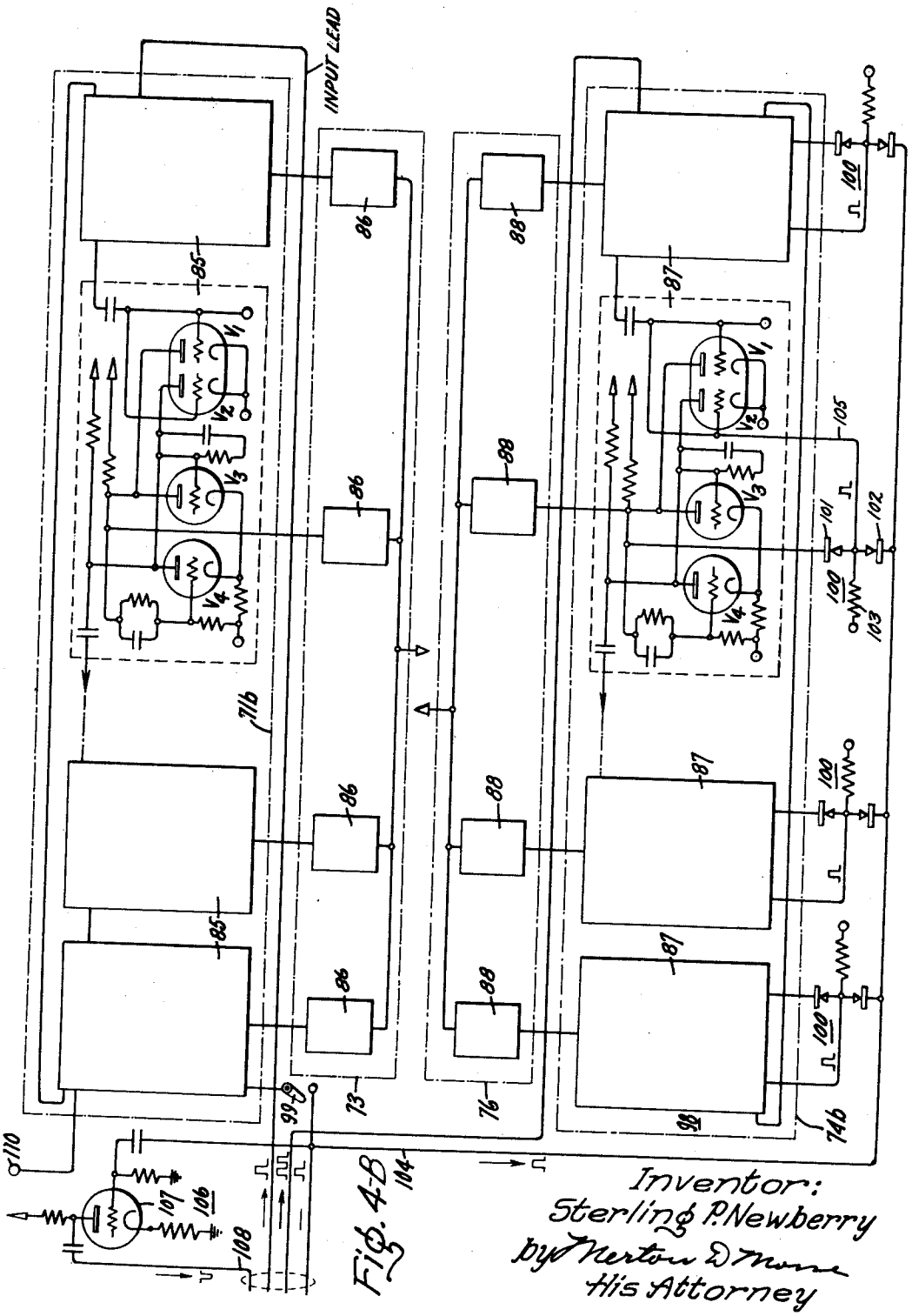


Fig. 4-B

Inventor:
Sterling P. Newberry
by Merton D. Morse
His Attorney

United States Patent Office 3,106,700 Patented Oct. 8, 1963

3,106,700

PHOTOGRAPHIC STORAGE SYSTEM

Sterling P. Newberry, Schenectady, N.Y., assignor to General Electric Company, a corporation of New York

Filed June 27, 1957, Ser. No. 668,490
7 Claims. (Cl. 340—173)

This invention relates to a method and apparatus for data storage and, more particularly, a photographic memory system of large capacity, high storage density, high reliability, and rapid access.

There is an urgent and growing need for a "memory" having very large capacity with rapid access to any part of the "memory' at high reliability of readout. This is especially important for maintaining necessary flexibility in automated production lines, industrial record files, computer applications, as well as the numerous other areas where data storage is desired. The use of a photographic emulsion as the recording medium presents an extremely promising approach since modern emulsions of very high quality and high resolving power are available. In the past, however, the storage densities in systems utilizing photographic emulsions were so low as to make them essentially useless for high capacity and fast access storage systems.

The limits on storage density in the past have not been from the resolving power of the photographic emulsion but from artifacts caused by dust and scratches and from difficulties with tracking errors and data relocation. Because of the low storage density, storage elements of substantial size are necessary in order to store an adequate amount of data and, as a consequence, special handling to eliminate effects of dust particles, such as hermetic sealing or total oil immersion, is impractical. Furthermore, because of the size of the elements substantial relative movement between the storing and reading heads and the storage element are necessary to store and have access to all of the data. This results in scratches and other marring effects on the film surface further reducing the resolution. In addition, low storage density and large storage elements demand exact mechanical location of blocks of data during readout which requires a formidable level of mechanical precision and, consequently, complex and expensive equipment.

By utilizing an electro-optical system including a reduced and focussed beam of light generated by a stream of electrons striking the fluorescent surface of a cathode ray device, it is possible to produce a storage density of approximately 10^6 storage sites per square centimeter which is greater by a factor of 10^3 than the photographic storage systems hitherto known. With such high storage densities the problem of dust and scratches is eliminated by hermetically sealing the small area of photographic film required for large capacity storage. The problem of registering during readout also is immensely simplified by virtue of the fact that it becomes possible to utilize a rough mechanical register to bring the desired area of stored data into position and then electrically shifting the scanning center of an image tube which reads the data from the magnified image of the data until exact centering and registration of the desired block of data is achieved.

It is an object of this invention, therefore, to provide a photographic data storage system of extremely large capacity and high storage density.

A further object of this invention is to provide a photographic data storage system which is not limited in resolution by dust particles and scratches.

It is another object of this invention to provide a photographic data storage system having a storage element

of sufficiently small dimension to permit sealed handling thereof.

Yet another object of this invention is to provide a photographic data storage system which permits rapid access to any portion thereof by simple mechanical register and readout of information in the selected portion by an electro-optical system.

Yet another object of this invention is to provide a photographic data storage system wherein a simple mechanical movement provides a rough register and shifting of the scanning pattern of an image device provides the precise registration.

Other objects and purposes of the invention will become apparent as the description thereof proceeds.

In accordance with the invention the foregoing objects are achieved by utilizing a spot of light from a kinescope flying spot device, reducing the size of the light spot by means of an optical device and focussing it on a photographic element in a predetermined sequence to produce data matrices in binary form as black and white dots. By virtue of this technique, storage density of the order of 10^6 storage sites per square centimeter are achieved.

During readout the high capacity and high storage density photographic data element is utilized under hermetically sealed conditions eliminating problems of dust and scratches and the data stored thereon is projected onto the face of the image tube device and readout thereby. The image tube scan is shifted electrically in response to data stored on the photographic element to relocate the information in the image plane so that only approximate mechanical registration is necessary.

The novel features which are believed to be characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which:

FIGURE 1 represents an embodiment of an apparatus for storing information on a photographic element;

FIGURE 2 represents a detailed showing of the scanning matrix and current adders of FIGURE 1;

FIGURE 3 represents an embodiment of a readout apparatus for the storage system;

FIGURE 4 is a detailed showing of the scanning matrix and the means for shifting the image tube can; and

FIGURE 5 is a diagrammatic illustration of the relative position of the stored information and the image tube scan before relocation.

In the embodiment of the invention, as illustrated in FIGURE 1, a photographic storage element **1** consisting of a high resolution emulsion **2** mounted on a transparent glass backing plate to provide dimensional stability is rigidly fixed to a metal frame element illustrated at **3** and is hermetically sealed in a casing **4** to eliminate dust particles and scratches on the photographic emulsion. A rack and pinion element **5**, shown diagrammatically, is provided for positioning the storage element **1** both in the horizontal and vertical directions, and may be manually operated or driven by a servo-mechanism device. A kinescope **6** on the fluorescent screen of which is produced a raster utilized as a spot light source is positioned at the conjugate focal position of a projection light microscope **7** which reduces and focuses the light spot from the kinescope onto the photographic emulsion to produce discrete 10 micron diameter light and dark spots, in the form of a matrix, which represent the data to be stored. The individual bits of data represented respectively by the light and dark spots are placed

on approximately 10 micron centers in the form of a 32 x 32 binary matrix, covering an area of approximately one-tenth of a square millimeter.

The kinescope **6** has a fluorescent viewing screen **8** and a source of electrons **9** consisting of an electron emitting cathode and an accelerating grid. A focusing coil **11** and an alignment coil **12** are positioned to control the trajectory of the electron beam in the kinescope tube in a well gnown manner to focus and align it with respect to the optical axis of the tube. Vertical and horizontal deflecting coils **13** and **14** constitute the means by which the electron beam is swept across the face of the fluorescent viewing screen **8** both in the horizontal and vertical directions to produce the flying spot source of light. A power supply, indicated generally at **15**, provides energization for the cathode of the kinescope element **6** as well as for the focussing and alignment coils **11** and **12**.

The horizontal and vertical deflection coils **13** and **14** are connected to a beam deflection coil supply circuit **20** which produces a staircase deflection current for deflecting the electron beam as a step scan to produce the flying spot of light. The precise construction and manner of operation of the beam deflection supply circuit will be explained in greater detail later with reference to FIGURE 2.

The projection light microscope **7** which reduces the flying light spot on the face of the kinescope **6** and focuses it onto the photographic storage element comprises a color-corrected achromatic amplifying lens system **16** positioned adjacent to the fluorescent screen **8** of the kinescope, which lens assembly comprises a projection lens element, field flattening lens element, and a field lens. Positioned at the opposite end of the microscope and adjacent to the field photographic element **1** is a color-corrected achromatic objective lens system **18** which, in conjunction with the amplifying lens **16**, reduces the light spot produced by the kinescope and focuses it onto a photographic element **1**. A focus control assembly **17** positioned intermediate the lenses **16** and **18** permits manual or, if desired, automatic adjustment of the focus of the microscope **7**.

In order to provide step scanning of the electron beam to produce the flying spot of light, it is necessary that the beam deflection coil currents for the kinescope **6** be in the form of a staircase. This is accomplished by means of the deflection circuit **20** comprising a scanning matrix **21** comprising horizontal and vertical scaling circuits **22** and **23**, as seen most clearly in FIGURE 2, and the horizontal and vertical current adder circuits **24** and **25**. FIGURE 2 illustrates partially in block diagram form both the horizontal and vertical scalers and current added circuits wherein the vertical scaling circuit **23** is fed from the output of the horizontal scaler **22**.

The horizontal scaling circuit **22** has a pulse input terminal **27** and comprises a number of bi-stable multivibrator circuits **26** arranged as a binary scaler circuit. Each of the bi-stable multivibrators, one of which is shown in detail, controls one stage of the current adder **24** consisting of a constant current generator circuit **29**, such as constant current pentode, for example.

Each of the bi-stable circuits **26** consists of multivibrator connected tube pairs V_3 and V_4 and a pair of trigger tubes V_1 and V_2 having a single common input and which are normally non-conducting by virtue of the negative biasing voltage applied to their grids. Whenever a positive pulse arrives on the input, V_1 and V_2 conduct transmitting a negative pulse to the tubes V_3 and V_4. Whichever of the tubes is non-conducting is, of course, not affected while the conducting tube is cut off by the negative pulse which, by virtue of the multivibratory connection, reverses the conducting states of the two tubes. The bi-stable circuit remains in this new state until the arrival of the next pulse which causes it to reverse its state. The output from each bi-stable circuitry **26** drives the next succeeding one by coupling the output pulse from tube V_4 to the input lead of the trigger tubes V_1 and V_2 of the succeeding bi-stable circuit **26**.

At the initiation of horizontal scaler operation each of the V_3 tubes are conducting and tubes V_4 are non-conducting and the application of pulses to the terminal **27** of the scaler starts operation thereof. It is clear that each time a tube V_4 in a bi-stable circuit changes from a *conducting* to a *non-conducting* condition, a positive pulse is introduced to the input of the next bi-stable circuit in the series causing it to change its state. As is well known, scalers of this sort are known as 2^n types and require "*n*" bi-stable circuits to scale 2^n pulses. For a more detailed description of such scaling circuits reference is made to High Speed Computing Devices, Engineering Research Associates, McGraw-Hill Book Company, Inc., New York (1950), and particularly chapter 3 which contains an excellent discussion of the principles and operation of such scaling circuits.

The output from the last horizontal bi-stable multivibrator is connected to the first vertical bi-stable multivibrator **28** through a lead **30** to shift the scan by one line at the end of each horizontal scan. That is, at the end of a horizontal line scan when all of the horizontal bi-stable multivibrators **26** are on, the next clock pulse resets the horizontal scaler to zero and the output pulse is fed to the first bi-stable multivibrator element **28** of the vertical scaler **23** and shifts the scan by one line.

Each of the bi-stable devices **26**, as has been stated previously, controls one of the constant current generators **29** of the respective current adders **24** and **25** by virtue of triggering pulses aplied thereto by a lead **31** from the anodes of the tubes V_3. Thus each time a tube V_3 in a bi-stable circuit changes from a *conducting* to a *non-conducting* state, a positive pulse is applied to the respective current generators **29** to initiate operation, while a change from *non-conduction* to *conduction* produces a negative pulse which terminates operation of the current generator.

The vertical scanning and current adder circuits **24** and **25** operate in the same manner as do the horizontal counterparts described above to produce a vertical step scan with the output from the last horizontal bi-stable multivibrator element, indicating the completion of one horizontal scan, triggering the first vertical bi-stable element **28** to shift the scan. Each of the binary scaler circuits **22** and **23** as is standard practice in such devices feed back from the last stage thereof to the first stage in order to reset the scaler at the end of the scan. Thus, the horizontal scaler **22** is reset at the end of every 32 pulses whereas the vertical scaler **23** is reset at the end of 1,024 pulses thus producing a scan over a 32×32 matrix.

The staircase deflection current may be produced not by adding successive equal increments of current, requiring a separate current generator for each increment, but generally by selectively adding current increments of the 2^n from (i.e., 2^0I, 2^1I, 2^2I, . . . $2^{n-1}I$, 2^nI) which makes it possible to produce a staircase of 2^n steps with $n+1$ current generators. Thus, to produce a 32 step staircase deflection current (2^5 steps) only 6 current generators and their associated bi-stable elements are necessary rather than 32. To illustrate the principle assume that, for simplicity of explanation, a 7 step staircase is desired; if equal increments are to be added then 7 current generators are necessary which are successively turned on to produce the 7 incremental current steps. On the other hand, if current generators producing output currents whose magnitudes are related by a 2^n, where

$$n=0, 1, 2, \ldots$$

factor then only 3 are necessary. That is, 3 current generators having currents of the following magnitudes,

2^0I, 2^1I, and 2^2I, may be selectively actuated to produce the staircase as shown in the following table:

Current step	Generator 2^0I	Generator 2^1I	Generator 2^2I	Output current
1	On	Off	Off	1
2	Off	On	Off	2
3	On	On	Off	3
4	Off	Off	On	4
5	On	Off	On	5
6	Off	On	On	6

As can be seen from the above table, the on-off sequences of the respective current generators follow the counting sequence of a binary scaler such as the horizontal scaler **24**.

The binary scaler illustrated in FIGURE 2 and the constant current generators associated with the individual elements thereof, are so arranged that "$n+1$" bi-stable multivibrator elements are utilized for a storage matrix of 2^n and the output currents from each of the constant current generators is adjusted to have a two-to-one ratio of current between any two successive stages so that the selective actuation of the bi-stable element and their associated constant current generators provide the desired staircase deflection coil current. However, it is obvious, as pointed out previously, that scaling circuits other than of the type illustrated and described may be utilized to produce the desired deflection coil current wave.

In order to store data on a photographic storage element, such as is illustrated in FIGURE 1, in binary form as black and white dots, it is necessary to blank the spot of light produced by the flying spot scanning kinescope element **6**, periodically so that discrete areas are selectively exposed to produce the black and white dots. To this end a blanking circuit **32** which provides voltage to blank the electron beam of the kinescope in synchronism with the data to be stored is connected to the accelerating and blanking grid **9** of the kinescope **6**. A pair of terminals **33** and **34** provide, respectively, a source of synchronizing clock pulses and the stored data in binary form (i.e., "pulse" or "no pulse") which are used to blank the electron beam of the kinescape **6**. The terminals **33** and **34** may be connected directly to the output terminals of a computer with the terminal **33** connected to the clock pulse generator of the computer and the terminal **34** being connected to the data output terminal of said computer.

The synchronizing clock pulses appearing at the terminal **33** are connected by means of a suitable conductor to the scanning matrix **21** of the sweep circuit **20** and to the input terminal **27** thereof to provide the triggering pulses for the scalers to produce the proper deflection of the electron beam. The clock pulses from the terminal **33** are also fed, over another conductor, to the input of a gate **35**, indicated in block diagram form but which may, for example, be a tetrode, which also has applied thereto the stored data blanking information from the terminal **34**. The data representing blanking pulses from the terminal **34** function as the gating signal for the gate **35** and permits passage of clock pulses therethrough only on the occurrence of a pulse from the terminal **34**. That is, as has been pointed out, the pulses from the terminal **34** are in binary form; i.e., "pulse" or "no pulse," and thus a clock pulse is permitted to pass through the gate **35** upon the occurrence of a "pulse" at terminal **34** and none is permitted to pass through during the "no pulse" condition at this terminal. Thus, clock pulses passing through the gate **35** may then be utilized as blanking pulses for the kinescope.

Connected to the output of the gate element **35** is an amplyfying and pulse shaping and clipping circuit, indicated generally in block diagram form at **36**, which functions to amplyfy the clock pulses passed through the gate and to reshape them into steep-fronted square wave pulses in the event the wave shape has degenerated during passage through the computer and the gate **35**. The reshaped and amplified clock pulses are then fed by means of a suitable conductor to a delay line **37** in order to delay their application to the accelerating and blanking grid **9** by a sufficient amount to insure that the electron beam has moved to its new scan position prior to the pplication of the blanking signal. There is, since the clock pulses from the terminal **33** are utilized both to trigger the scanning matrix of the kinescope sweep circuit **20** as well as providing the blanking voltage for said kinescope, it is necessary that the application of the blanking pulse to the grid **9** be delayed until the electron beam has been swept to its new position. Under certain circumstances it is possible that the delay inherent in the gate and the amplifying and clipping circuits may be sufficiently large to eliminate the need for a delay line; however, it should be kept in mind that the time delay in the scanning circuits **20** and the blanking circuits **32** must be equal in order to insure that the blanking of the beam takes place only after the beam has moved to its new scan position. Thus, it can be seen that the blanking circuit illustrated at **32** provides the means by which the light spot produced by the kinescope element **6** is controlled to produce discrete white and blank dots upon the photographic storage element **1** which dots represent the data to be stored in binary form.

In the data storage system illustrated in FIGURE 1, the pulsed fying spot light source is reduced and projected directly onto a high resolution photographic emulsion which constitutes the ultimate storage element. However, in some cases it may be desirable to utilize a two stage process wherein the data is first stored on an intermediate storage element of medium resolution by means of a pulsed fying light spot scanner and optical microscope combination and is then further reduced and stored on a high resolution photographic element which constitutes the ultimate storage element by means of a source of light and another optical microscope of the type illustrated and described with reference to FIGURE1.

The general system of the present invention which has been described with reference to FIGURES 1 and 2 for storing data on a photographic storage element by imaging a flying light spot on a photographic transparency constitutes a preferred embodiment of a system for storing such data on a photographic plate which information is to be read-out by means of an electro-optical readout system presently to be described and illustrated in FIGURE 3. However, it is possible to store data in binary form on a photographic storage element with the desired high storage density by means of a focussed, charged particle beam of the type produced by the electron-optics of an electron microscope or an X-ray microscope. Such an apparatus and method is described in the copending application of Sterling P. Newberry, Serial Number 668,489, filed June 27, 1957, now abandoned, and assigned to the General Electric Company.

Assuming that the data has been stored on a photographic storage element by an apparatus of the type described it, consequently becomes necessary to provide means by which such data may be read out. FIGURE 3 illustrates such a readout system which is characterized generally by the fact that an optical projection system enlarges and projects the stored data onto the surface of an image storage tube which translates it into a series of representative electrical pulses. The projected image of the information matrix and the scanning field of the storage tube are aligned by electronically shifting the field of scan of the storage tube until perfect alignment is achieved at which time the output and readout circuits of the apparatus are activated to produce output signals representative of the data.

Adverting now directly to FIGURE 3, there is illustrated a photographic storage element **40** of the type discussed with reference to FIGURE 1 consisting of a

hermetically sealed high resolution emulsion mounted on a transparent backing plate which contains stored data in the form of 32×32 matrices of discrete light and dark spots. A rack and pinion element, illustrated at **41**, is fastened to the storage element and provides a means for positioning the storage element to bring selected matrices into the field of view of a readout means presently to be described, which positioning means may be either manually operated or driven by a servo mechanism device. For the sake of simplicity only the rack and pinion for positioning the element in a single direction, the vertical, is shown; however, it is understood that a complementary horizontal positioning means is also utilized.

Positioned on one side of the photographic storage element **40** is a source of radiant energy such as an incandescent lamp **42** which, in conjunction with a heat absorbing means **43**, a filter **44** and a condenser lens assembly **45** projects a beam of light onto the photographic storage element in order to produce a light image of the matrices which, in turn, is amplified by means of a projection light microscope **46** positioned on the other side of the storage element.

The projection light microscope **46** projects the enlarged image onto the face of an image storage tube **47** which, in turn, translates the matrix into a series of electrical output pulses representative of the data. The projection light microscope is of the same type illustrated and discussed with reference to FIG. 1 and comprises a color-corrected achromatic objection lens system **49** positioned adjacent to the storage element **40** and a color-corrected achromatic amplyfying lens system **48** positioned adjacent to the face of the image storage tube **47**. A focus control assembly **50** is positioned intermediate the lenses **48** and **49** and permits manual or automatic adjustment of the focus of the microscope **46**.

The storage tube **47** which has the information matrix applied thereto as a light pattern is of photoconductive target type which has its photoconductivity varied to produce an output pulse train representative of the light pattern. Such a photoconductive image storage tube, commonly known in the art as a "vidicon," consists of an electron beam source **51** including an electron emitting filament, an accelerating anode **52**, a fine mesh screen **53**, positioned adjacent to a photoconductive target assembly. The photoconductive target assembly is positioned to intercept the electron beam and consists of a glass plate **54**, a transparent conducting back plate **55** and a photoconductive plate **56**. Focussing and alignment coils **57** and **58** are positioned to control the trajectory of the electron beam in a well known manner to focus and align it with respect to the optical axis. A power supply, indicated generally at **59**, provides energization for the electron source **51** as well as the coils **57** and **58**. First and second vertical deflecting coil pairs **60** and **61** and corresponding horizontal deflecting coil pairs **62** and **63** constitute the means by which the electron beam is swept across the face of the photoconductive target **56** in a desired sequence to produce the output pulse train representative of the binary information.

Photoconductive storage tubes such as the vidicon are based on the principle that the focussing of a pattern of light on the photoconductive target causes its conductivity to increase at the areas which are illuminated. Since the target conductivity varies with the intensity of the light, the discrete elements or areas shift their potential positive by varying amounts because of leakage currents to the transparent conducting plate **55** and in this manner a pattern of potential variation is established on the target surface **56** corresponding to the input light signal. The electron beam produced by the beam source **51** is scanned across the target and produces capacity current variations which flow to the conductive back plate **55** producing voltage variations corresponding to the input light signal across an output resistor R_o connected to the plate **55**. The output polarity of this device is negative in the sense that an increasing amount of incident light on a target element causes a greater negative variation in voltage across the output resistor R_o when the corresponding element is scanned by the beam. Thus, by projecting the image of a matrix constituted of discrete, exposed and unexposed spots onto the photoconductive target a series of output pulses in binary form (i.e., "pulse" or "no pulse") are produced with the "pulse" representing an exposed discrete area, and "no pulse" representing an unexposed area. In this fashion it is quite clear that the output pulse train faithfully represents the data stored on the photographic storage element **40**.

The respective vertical deflection coil pairs **60** and **61** as well as the horizontal pairs **62** and **63** are connected to a beam deflection coil current supply circuit, indicated generally at **70**, which produces a staircase shaped deflection current for scanning the electron beam of the vidicon **47** in a step-wise fashion across the photoconductive target **56**. The deflection circuit **70**, broadly speaking, includes a main deflection circuit channel having a first scanning matrix **71** controlling horizontal and vertical current adders **72** and **73** to produce a staircase shaped deflection coil current for scanning the 32×32 matrix projected onto the vidicon tube.

In addition, there is provided an auxiliary deflection circuit channel for electronically shifting the vidicon scan until there is alignment between the tube scan field and matrix projected thereon and which includes a second scanning matrix **74** controlling a second pair of horizontal and vertical current adder circuits **75** and **76**. The actual construction and manner of operation of the beam deflection supply circuit **70** will be explained in detail with reference to FIGURE 4, at this point, however, suffice it to say that the beam deflection circuit **70** operates in such as fashion that the auxiliary deflection circuit channel (**74**, **75** and **76**) function to shift the scan plane of the vidicon until a particular information bearing 32×32 matrix is coincident with the scan field of the vidicon, at which time it is inactivated and the main deflection channel is actuated to scan the matrix.

The pulse train output from the vidicon **47** appearing across the resistor R_o is fed by means of any convenient lead **65** to the input of an amplifying means **66** and in turn to a pulse shaping circuit **67** which sharpens the wave shapes of the amplified vidicon output pulses. The "vidicon" output pulses appearing on the lead **65** are also applied to the coil deflection circuit **70** in order to disable the auxiliary scan shifting circuit and actuate the main deflection circuit when the scan field is aligned with the 32×32 matrix in a manner which will be explained in detail with reference to FIGURE 4.

In order to provide an additional check on the alignment and focus the data matrix and in order to provide a read command signal to the readout circuitry to be described presently, there is provided a monitor circuit **77** comprising an electrostatic deflection cathode ray tube **78**, the deflection voltage of which is obtained from the beam deflection circuit **70** through a monitor sweep amplifier **79**. The "vidicon" pulse output is applied to the CRT by means of a lead **80** coupled to the control grid of the CRT (not illustrated) from the output of pulse shaper **67**. Since a series of pulses corresponding to the black and white dot pattern comprising the stored information are generated as the electron beam scans the "vidicon" target, the application of this pulse train to the CRT **78** whose deflection voltage is in synchronism with the vidicon coil deflection voltage makes it possible to observe visually when the vidicon scan field is coincident with the information bearing 32×32 matrix at which time the readout circuitry may be actuated in order to produce output pulses representative of the stored data. In this fashion an additional safeguard is provided to insure that the output of the system contains no ambiguities due to a misalignment of the data matrix and the vidicon scanning system.

In order to insure that the output pulses from the data

storage system are uniform in shape and as precisely timed as possible, the output signal is composed, not of the amplified and shaped vidicon output pulses themselves, but of clock pulses gated by the vidicon output pulse train. This is accomplished by applying the vidicon output pulses from the pulse shaping circuit **67** to a readout gate means wherein the gating of a source of clock pulses by the vidicon output signal takes place. To this end a clock pulse generator means **81**, illustrated in block diagram form, which may be either a blocking oscillator, free-running multivibrator or the like, produces output pulses having some constant predetermined repetition rate. The clock pulses from the generator **81**, in addition to being utilized as the output pulses from the data storage system, provide the triggering pulses for operating the scanning matrices **71** and **74** of the main deflection circuit **70** being applied thereto by means of any convenient lead **82**.

The gating of the clock pulses from the generator **81** to produce the output pulses is achieved by a pair of gates **68** and **69** denominated as readout synchronizing gate, and a readout gate respectively. The readout synchronizing gate **68**, which may be a pentode or any other similar well known gating arrangement, makes certain that readout is initiated only at the beginning of the "vidicon" scan. Accordingly, the readout synchronizing gate **68** is opened and closed by means of a readout synchronizing signal generated by a readout control circuit **83** which is actuated by output pulses from the scanning matrix produced at the end of the previous scan and prior to the beginning of each vidicon scan. The readout control circuit **83**, indicated in block diagram form for the sake of simplicity, may be a bi-stable multivibrator, for example, which produces a synchronizing gate signal in response to a triggering pulse from the deflection circuit **70** applied by means of any convenient lead **84**. As will be explained in detail later, with reference to FIGURE 4, the reset pulse from the vertical scaling circuit of the deflection circuit **70** produced at the end of each 32×32 scan is applied to the control circuit **83** to produce the synchronizing signal for the gate **68**.

In addition, a readout command circuit **85** is connected to the circuit **83** to insure that a readout synchronizing signal is produced only when readout is actually desired. The circuit **85** may be a manually operated switch which enables the control circuit **83** and makes it responsive to the appearance of the trigger pulse on the lead **84**.

In operation the control circuit **85** is manually operated after the alignment and focus of the data matrix on the "vidicon" target has been checked by means of the monitor CRT **78**. At this time a read command signal from the control circuit **85** actuates the readout control circuit **83** permitting a pulse from the scanning matrix to open the readout synchronizing gate at the completion of the next scan. The synchronizing signal from the readout control circuit **83** is applied to the gate **68** opening it. The gate **68** stays open during the remainder of the scan allowing the shaped vidicon output signals from the pulse shaping circuit **67** to pass to the readout gate **69**. At the termination of the scan another pulse from the deflection circuti **70** is transmitted by the lead **84** to the readout control circuit **83** terminating the synchronizing gate pulse and closing the readout synchronizing gate **68** until the initiation of another scan. The vidicon output pulses which have been passed through the gate **68** are applied to the readout of gate **69** and act as gating signals to permit the passage of clock pulses from the clock pulse generator **81**, which clock pulses are applied to any desirable utilization circuit and represent the data stored on the photographic data storage element **40**.

Before proceeding with the description of the beam deflection coil supply circuit **70**, which is shown in detail in FIGURE 4, it will be useful to discuss briefly the underlying reasons and objectives which constitute the basis for the particular approach chosen. As has been pointed out previously in the introductory remarks, one of the objects of the instant invention is to produce a data storage system utilizing a photographic storage element of high storage density in which selected blocks of data in 32×32 matrix form are located by means of a rough mechanical registering means and then producing exact centering and registration of the desired block of data by electricaly shifting the scanning center of the image tube. Hence, it is no longer necessary to provide high precision mechanical registering means in order to locate the blocks of data.

FIGURE 5 illustrates, schematically, the relative position of the 32×32 matrix and the vidicon scan field immediately after this block of data has been roughly registered by means of the rack and pinion. The projected image consists of a 32×32 matrix of discrete light and dark spots *"a"* representing the data and denominated by the legend "matrix." Offset and partially over-lapping the matrix is the vidicon scan field, identified by the legend "vidicon scan," which is initially located to the left and slightly above the matrix. Located at the upper left hand corner of the matrix is a relatively large indexing mark B which, as will be pointed out in detail later, provides a registering pulse indicating that exact centering and registration of the desired block of data has been achieved and which inactivates the auxiliary deflection channel and actuates the main deflection channel in order to provide scan of the photoconductive target.

Exact centering of the vidicon scan may be achieved, generally speaking, by initiating the vidicon scan in the offset position illustrated in FIGURE 5 until the indexing mark B is reached, at which time a registering pulse is produced which disables the auxiliary deflection channel. The auxiliary channel thus produces a biasing deflection current the magnitude of which is related to the deflection necessary to locate the matrix precisely at which time the main deflection circuit takes over and produces the main deflection current which is superimposed on the biasing deflection current and which causes the actual readout scanning of the information bearing matrix.

In order to provide the above described action there is provided electronic circuitry, illustrated in detail in FIGURES 4*a* and 4*b*, which can be broken down broadly into four major components: (1) Main Deflection Coil Current Channel, (2) Auxiliary Deflection Coil Current Channel for electronically shifting the vidicon scanning until the matrix is located, (3) Switching Means to apply the clock pulses selectively to the main and auxiliary channels, and (4) Resetting Means for the Switching Means.

Main Deflection Coil Current Channel

Referring now to FIGURES 4*a* and 4*b*, the main deflection channel comprises, broadly speaking, a scanning matrix **71** consisting of horizontal and vertical scaling circuits **71***a* (FIGURE 4*a*) and **71***b* (FIGURE 4*b*) with the vertical circuit driven from the output of the horizontal scaler. Horizontal and vertical adder circuits **72** (FIGURE 4*a*) and **73** (FIGURE 4*b*) are connected respectively to the horizontal and vertical scaling circuits.

The horizontal scaling circuit **71***a* and the vertical scaling circuit **71***b*, in a manner similar to that described with reference to FIGURE 2, comprise a number of bi-stable multivibrator circuits **85** arranged as binary scaler circuits. Each of the bi-stable multivibrators, one of which is shown in detail in each scaler, controls one stage of their respective current adders consisting of a constant current generator **86** which may, for example, consist of a constant current pentode.

Each of the bi-stable circuits **85** consist of a pair of multivibrator connected tubes V_3 and V_4 and a pair of normally non-conducting trigger tubes V_1 and V_2 having a single common input. The arrival of a positive pulse on the common input lead of the trigger tubes V_1 and V_2

causes them to conduct and pass a negative pulse to the multivibrator connected tubes V_3 and V_4 thus causing them to reverse their state and remain thus until the appearance of the next input pulse. The output from each of the bi-stable circuits drives the next succeeding one by coupling the output pulse from the tube V_4 to the input lead of the trigger tubes V_1 and V_2 of the succeeding bi-stable circuit **85**. In this fashion a positive pulse is introduced into the input of the next bi-stable circuit in the series each time the tube V_4 from a *conducting* to a *non-conducting* condition, thus producing a scaler of the sort known as the 2^n type.

The constant current generator **86** of the current adder circuit are each connected to the tubes V_3 of each of the multivibrator connected circuits. Thus, each time a tube V_3 in the circuit changes from a *conducting* to a *non-conducting* state, a positive pulse is applied to its particular constant current generator **86** to initiate operation while a change from *non-conduction* to *conduction* produces a negative pulse which terminates operation of the current generator. As described with reference to FIGURE 2, there will be produced at the output lead of the current adders a deflection coil current in the form of a staircase which causes the electron beam of the vidicon tube to scan the photoconductive target in a stepwise fashion.

Each of the binary scaler circuits **71***a* and **71***b*, as is standard practice in such devices, feed back from the last stage thereof to the first stage in order to reset the scaler at the end of the scan.

Auxiliary Deflection Coil Current Channel

The auxiliary deflection channel **74** in a similar fashion comprises a horizontal scaling circuit **74***a* (FIGURE 4*a*) and a vertical scaling circuit **74***b* (FIGURE 4*b*) actuated from the output from the horizontal scaling circuit. A horizontal current adder **75** and a vertical current adder **76** are connected to the respective horizontal and vertical scaling systems in the manner described above to produce the respective deflection coil currents in a staircase form. The horizontal scaler **74***a* and the vertical scaler **74***b* consist of a number of bi-stable multivibrator circuits **87** arranged as a binary scaler circuit with each of the bi-stable elements controlling one stage of its respective current adder, each consisting of a constant current generator **88**. Since the auxiliary deflection circuit and the components constituting it operate in precisely the same manner as the main deflection channel described above, the operational description need not be repeated here. Each of the horizontal and vertical current adders and both of the main and auxiliary deflection channels are connected to their respective vertical and horizontal deflecting coils shown and described with reference to the "vidicon" of FIGURE 3.

Selective Switching Means

In order to apply the clock pulses from the clock pulse generator **81** of FIGURE 3 selectively to the auxiliary and main deflection channels, a switching means **89** shown in FIGURE 4*a* at the upper left-hand corner is provided which applies the clock pulses selectively to the auxiliary channel **74** for electronically shifting the vidicon scan until exact registration of the matrix is achieved and then to the main deflection channel to initiate the step-scan of the matrix. To this end an input terminal **90** connected to the clock pulse generator **81** has the clock pulses which actuate the scaling circuits applied thereto. The clock pulses appearing at the terminal **90** are applied through a coupling capacitor **91** and a lead **93** to a *normally open* gate **92** and a *normally closed* gate **94** which control the application of the clock pulses to the auxiliary and main channels respectively.

The normally open gate means **92** comprises a tetrode vacuum tube, the anode of which is connected to a source of operating potential through a suitable anode resistor and the cathode to a source of reference potential, such as ground, through a cathode resistor. The lead **93** from the input terminal **90** is connected to the control electrode of the tetrode **92** while the cathode is connected by means of a suitable lead to the input of the horizontal scaling circuit **74***a*.

The normally closed gate means **94** similarly comprises a tetrode vacuum tube, the anode of which is connected to a source of operating potential by means of an anode resistor and the cathode directly to a source of reference potential, such as ground. The control electrode **94***a* of the normally closed gate means **94** is connected directly to the anode of the normally open gate **92**. Thus, while the normally open gate **92** is in its conducting condition and passing clock pulses to the auxiliary channel, the normally closed gate **94** is maintained non-conducting by virtue of the anode drop of the tube **92** and does not permit the application of clock pulses therethough, thus maintaining its associated deflection channel **71** in a quiescent state. As soon as the normally open gate **92** is made non-conducting its anode potential rises, and unblocks the normally blocked gate **94** thus applying clock pulses to the main deflection channel, the input terminal of which is connected to the anode of the gate **94**. In this fashion the clock pulses which actuate the respective deflection channels are selectively applied either to the auxiliary or main channels.

There is provided, in addition, a triggering means, actuated in response to a positive pulse produced whenever the electron beam of the vidicon scan strikes the registering mark B on the 32×32 matrix, to close the gate **92** and open the normally closed gate **94** to initiate scanning of the now exactly registered matrix. There is provided a gaseous trigger tube **95**, which may be a thyratron or the like, having a cathode, control electrode, and an anode. The anode of the gaseous tube is connected to a source of operating voltage by means of a suitable anode resistor whereas the cathode is connected to a source of reference potential such as ground while the control electrode is connected to a movable tap on a potentiometer connected in shunt with a source of negative biasing voltage **96** such as a battery. As is well known to those skilled in the art, such gas tubes may be maintained in a non-conducting condition by means of such a critical negative bias until the bias is overcome at which time the tube conducts and remains in a conducting condition until the anode potential is reduced sufficiently to extinguish conduction.

The anode of the gaseous trigger tube **95** is directly coupled to the screen grid of the normally open gate means **92** and in this fashion provides gating voltage therefor. Also connected to the control electrode of the gaseous tube **95** is the lead **65** from the photoconductive target element of the vidicon **47** illustrated in FIGURE 3. Initially, the gaseous triggering tube **95** is non-conducting and its anode potential is highly positive maintaining the gate **92** in a conducting condition to permit passage of the clock pulses. Whenever the electron beam of the vidicon tube is deflected sufficiently, by virtue of the deflection current produced by the auxiliary deflection channel, to strike the registering mark B at the upper left hand corner of each matrix, a positive pulse appears on the lead **65** connnected to the photoconductive target. This positive pulse is of sufficient magnitude to overcome the negative biasing on the control electrode provided by the biasing means **96** causing the tube to conduct heavily. The conduction of the gaseous trigger tube **95** causes a rapid drop of anode potential which is transmitted directly to the screen electrode of the normally open gate **92** causing that gate to close and preventing further clock pulses from being applied to the auxiliary channel. The anode potential of the tetrode **92** rises removing the biasing on the control electrode of the normally closed gate tube **94** permitting the clock pulses to pass to the main deflection channel to initiate the scan of the now registered and aligned 32×32 matrix.

Connected to the anode of the gaseous trigger tube **95** is a diode **97** which is so poled as to pass only the negative pulses which, as will be explained in detail later, resets the gaseous trigger tube to its non-conducting condition prior to initiation of subsequent readouts.

Resetting Circuit

In order to reset both the switching means **89**, as well as the individual bi-stable units of the auxiliary channel **74**, there is provided a manually actuated circuit operated from the output of the last bi-stable unit of the main vertical scaler **71***b* to place the entire circuit in condition to repeat the operation for a new matrix. A reset circuit, indicated at **98**, for the auxiliary deflection channel is connected through a manually operated switch **99** and a lead **104** to the last bi-stable element **85** of the vertical scale **71***b*. The reset circuit **98** consists of a multiplicity of "and" gates **100**, each coupled to individual ones of the bi-stable elements **87**. Each of the "and" gates **100** consist of a pair of crystal diodes **101** and **102** having their respective anodes connected to a common terminal point. A resistor **103** connected between the common terminal point and a source of positive voltage provides biasing for the gate, while a lead **105** carrying a positive reset pulse is connected between the terminal point and the common input lead of the trigger tubes V_1 and V_2. The cathode of the diode **101** is connected to the anode of the current generator controlling tube V_3 of each bi-stable multivibrator while the cathode of the diode **102**, on the other hand, is connected to the lead **104** carrying the positive pulse from the vertical scaler **71***b*.

"And" gates of the type illustrated at **100** are characterized by the fact that if both crystal diodes are simultaneously driven positive the potential at their common junction, to which the lead **105** is connected, is caused to rise thus applying a positive pulse to the trigger tubes V_2 and V_1. Thus, if in any given bi-stable element the tube V_3 is in a non-conducting condition; that is, its anode potential is high and consequently its respective constant current generator is conducting, both of the diodes **101** and **102** will be simultaneously positive thus producing a positive pulse at the output lead **105** which, through the action of the trigger tubes V_1 and V_2, reverses the states of the tubes V_3 and V_4 thus terminating the operation of the current generator. If, on the other hand, the tube V_3 is in a conducting condition, its anode potential is low and consequently no positive pulse appears on the lead **105** and the bi-stable element remains in the same condition. Thus, by means of the "and" gates **100** those bi-stable elements **87** which are in the state that their associated current generators **88** are conducting are reversed resetting the auxiliary deflection channel and reducing the deflection coil current produced thereby to zero.

In addition, a reset circuit **106** returns the gaseous trigger means **95** to a non-conducting condition returning the *normally open* and *normally closed* gates to their initial operating conditions. There is provided a triode amplifying element **107** connected to the output of the vertical scaler **71***b* through the manually operated switch **99**. The amplifier **107** consists of a cathode, control electrode, and an anode, the latter of which is connected to a source of voltage through a suitable anode resistor and the cathode of which is connected to a source of reference potential such as ground through a suitable cathode resistor. With the switch **99** in the closed position, the positive pulse produced by the last bi-stable element **85** at the end of the scan is applied to the amplifier **107** which reverses its polarity. The now negative pulse is coupled by a lead **108** to the diode **97** connected to the anode of the gaseous trigger tube **95**. As is well known, gaseous tubes of the type illustrated at **95** once fired are independent of grid voltage and can only be reset by reducing their anode potential below the critical extinction voltage. Thus, the negative pulse appearing on the lead **108** passes through the diode **97** reducing the anode voltage of the tube **95** below the extinction voltage causing conduction to terminate. The cessation of conduction by the tube **95** raises its anode voltage re-opening normally open gate **92** to pass clock pulses once more to the auxiliary channel from the terminal **90**. The conduction of the normally open gate **92**, of course, reduces its anode voltage which, being connected to control the electrode of the normally closed gate **94**, applies a negative bias thereto causing that gate to cease conducting and preventing any further clock pulses from being applied to the main deflection channel **71**. Thus, it can be seen that both the auxiliary and main deflection channels **71** and **74** are now in condition to repeat the operation. Clock pulses are again fed to the auxiliary channel until the indexing mark B of the matrix is reached at which time another positive pulse appears on the lead **65** of the control electrode of the gaseous trigger **95** at which time the gate **92** is once more closed, opening gate **94** and permitting the main deflection channel to scan the new block of data projected onto the face of the vidicon tube.

A terminal **110** connected to the last bi-stable element **85** of the vertical scaler **71***b* of the main deflection channel **71** is connected to the readout control circuit **83**, shown and discussed with reference to FIGURE 3, and provides the trigger pulse for that control circuit to produce the synchronizing pulse for operating synchronizing readout gate **68**. It is obvious that only at the end of a vertical scan will a positive pulse appear at the terminal **110** in order to trigger the readout control circuit **83**. It can be seen that the readout synchronizing pulse thus produced enables the readout synchronizing gate **68** only at the beginning of a vidicon scan.

In discussing the data storage circuit of FIGURES 3 and 4, the storage tube which translates the information matrix on the photographic data storage element has, for illustrative purposes, been shown and described as a "vidicon" which is of the type having a photoconductive target structure. It is obvious to those skilled in the art that many variations and changes may be made in the type of storage tube utilized without going outside the spirit and scope of this invention.

It is clear from the previous discussion that there has been provided a data storage system utilizing a photographic storage element which is capable of large capacity, high storage density, high reliability, and rapid access. Furthermore, a readout system has been disclosed in which the readout and translation of the stored data is achieved by means of a rough mechanical register of the desired block of data and exact centering and registration thereof by means of an electronic shifting of the scanning center of an image tube.

While a particular embodiment of this invention has been shown it will, of course, be understood that it is not limited thereto since many modifications both in the circuit arrangement and in the instrumentalities employed may be made. It is contemplated by the appended claims to cover any such modifications as fall within the true spirit and scope of this invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a data storage apparatus the combination comprising a photographic storage element having data stored thereon in the form of individual exposure pattern matrices, means to translate said matrices into electrical output pulses including a photoconductive storage tube having a scanning electron beam, optical light microscope projection means including an achromatic lens system having a field flattening lens to project an enlarged image of entire individual matrices onto said storage tube, said tube operating to produce electrical pulses representative of the stored data as said electron beam scans the image on said tube, means to control the scan field of said beam to align it with said image including a main beam deflection

supply circuit and an auxiliary beam deflection supply circuit, said auxiliary circuit being actuated to shift the beam scan until a data indexing mark on said matrix image is located and an output pulse is produced from said storage tube to disable said auxiliary circuit and energize said main circuit in response to said pulse to control the further scanning of said image.

2. In a data storage system the combination comprising a photographic storage element having data stored thereon in the form of individual matrices, means to translate the individual data matrices into electrical output pulse trains representative of said data, said translating means including a storage tube means, optical light microscope projection means including an achromatic lens system having a field flattening lens for projecting an enlarged image of an entire matrix onto said storage tube means, scan control means associated with said storage tube means operative in response to an indexing mark on said matrix to align the tube scan field with the projected image of one such matrix, pulse generating means connected to said scan control means to initiate and synchronize operation thereof, and means actuated in response to output pulses from said storage tube means to apply pulses from said pulse generating means selectively to a utilization circuit.

3. In a data storage system the combination comprising a photographic storage element having data stored thereon in the form of individual matrices, means to translate said data matrices into output pulse trains representative of said data, said translating means including a storage tube readout device having a readout electron beam, beam scan control means for said readout beam, a light microscope optical projection element including an achromatic lens system having a field flattening lens positioned between said storage element and said storage tube readout device to project an enlarged image of an entire data matrix onto said storage tube device, pulse generating means connected to said beam scan control means to initiate and synchronize said scan, means to apply pulses from said pulse generating means selectively to an output circuit in response to output pulses from said translating means including gating means coupled to said pulse generating and said storage means, said gating means transmitting pulses from said generating means in response to the output pulses from said storage tube readout device.

4. In a data storage system the combination comprising a photographic storage element having data stored thereon in the form of data matrices, each of said matrices comprising an exposure pattern of discrete dots, projection light microscope optical means including an achromatic lens system having a field flattening lens to produce an enlarged spatial image of said data matrices, electro-optical means having a predetermined field of view to translate the stored data in the matrices from the enlarged spatial image into electrical output pulses, mechanical positioning means for adjusting the position of said storage element in two coordinates relative to said means for producing a spatial image so that selected matrices are brought into substantial alignment with the readout field of view of said electro-optical means, and means to shift the entire scan field of said electro-optical means electronically to further align it with said enlarged spatial image prior to reading out said data.

5. In a data storage apparatus the combination comprising a photographic storage element having data matrices stored thereon in the form of an exposure pattern of discrete dots, projection light microscope optical means including an achromatic lens system having a field flattening lens to produce an enlarged image of said pattern, cathode ray beam readout means having a predetermined field of scan, said readout means being so positioned that the entire data matrices in the form of said enlarged pattern are projected thereon to be scanned by the cathode ray beam to produce electrical output pulses representative of said data, and means to shift the entire scan field of said cathode ray means electronically to align it with said enlarged pattern prior to reading out said data.

6. In a data storage system the combination comprising a photographic storage element having data stored thereon in the form of individual matrices, means to translate said data into output pulses including a photoconductive storage tube having a scanning electron beam, projection light microscope optical means including an achromatic lens system having a field flattening lens to form and project enlarged images of entire individual matrices onto the viewing face of said photoconductive storage tube, step scan beam deflection means for said photoconductive storage tube to scan said projected images and produce said output pulse trains representative of said data, pulse generating means connected to said scan means to initiate and synchronize said step scan, means to gate the output from said pulse generating means in synchronism with the output pulses from said photoconductive storage tube including a first gate means for passing the photoconductive storage tube output pulses actuated in response to the initiation of said scan, a second gate means for passing pulses from said pulse generating means to a utilization circuit, said second gate being coupled to said first gate means and gated by photoconductive storage tube output pulses passed by said first gate means to pass pulses from said generating means.

7. In a data storage apparatus the combination comprising a storage element having a pattern of discrete transparent and opaque areas representing stored data, means to project a beam of light through said storage element to produce an image of said pattern in space, projection light microscope optical means including an achromatic lens system having a field flattening lens for viewing said image and producing an enlarged spatial image of said entire pattern, electro-optical means having a predetermined field of view of said enlarged image for converting the stored data on said storage element into electrical output pulses representative of said data, and means to align said image and the field of view of said electro-optical means in response to an indexing mark on said pattern.

References Cited in the file of this patent

UNITED STATES PATENTS

2,295,000	Morse	Sept. 8, 1942
2,659,072	Coales	Nov. 10, 1953
2,712,898	Knutsen	July 12, 1955
2,714,841	Demer	Aug. 9, 1955
2,714,843	Hoover	Aug. 9, 1955
2,731,200	Koelsch	Jan. 17, 1956
2,738,499	Sprick	Mar. 13, 1956
2,795,705	Rabinow	June 11, 1957
2,807,728	Kilburn	Sept. 24, 1957
2,816,246	Bliss	Dec. 10, 1957
2,817,041	Urry	Dec. 17, 1957
2,830,285	Davis	Apr. 8, 1958
2,843,841	King	July 15, 1958
2,859,427	McNaney	Nov. 4, 1958
2,939,632	Demer	June 7, 1960
2,950,465	Fox	Aug. 23, 1960