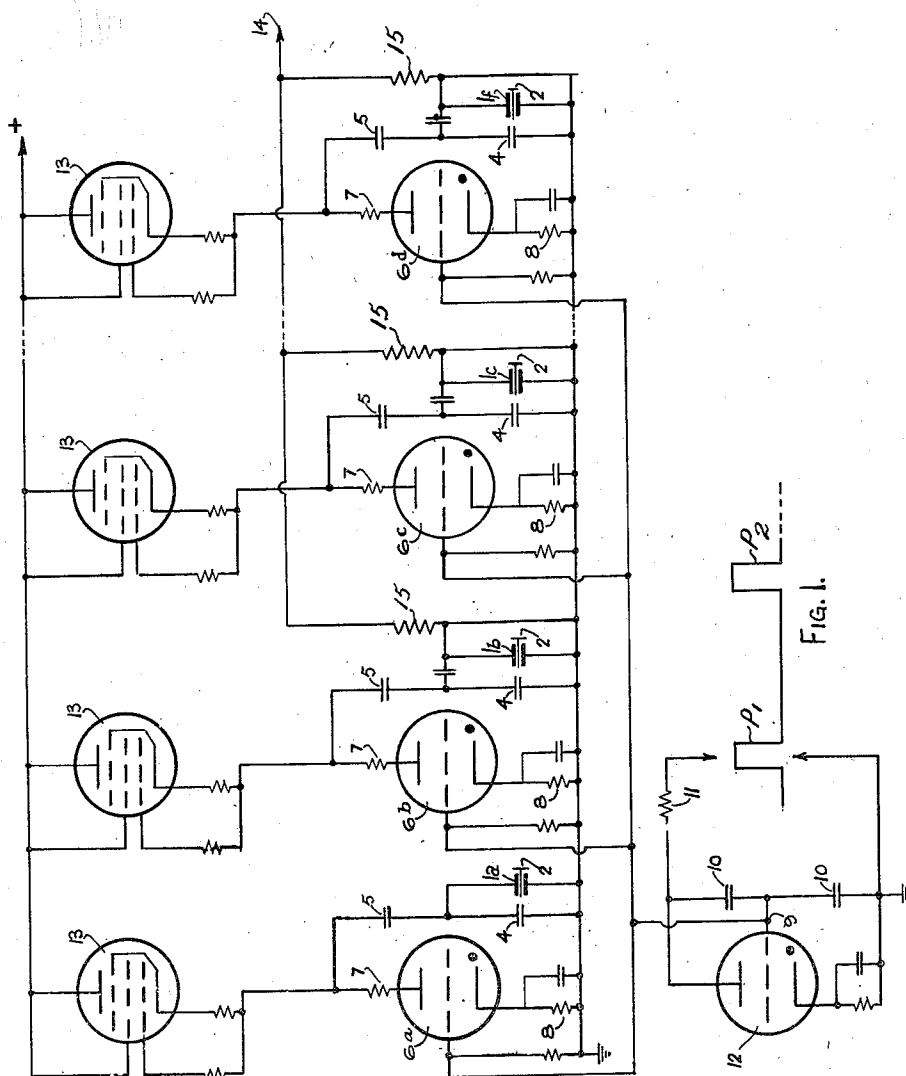


March 29, 1949. F. H. MARTIN 2,465,898
PLURALITY OF PIEZOELECTRIC CRYSTALS HAVING
MIRROR SURFACES FOR SCANNING
Filed April 1, 1947 4 Sheets-Sheet 1

F. H. MARTIN
PLURALITY OF PIEZOELECTRIC CRYSTALS HAVING
MIRROR SURFACES FOR SCANNING

2,465,898

4 Sheets-Sheet 1



INVENTOR

Fredrick Henry Martin

By

Pech & Pech
Attorneys

March 29, 1949.

F. H. MARTIN
PLURALITY OF PIEZOELECTRIC CRYSTALS HAVING
MIRROR SURFACES FOR SCANNING

2,465,898

Filed April 1, 1947

4 Sheets-Sheet 2

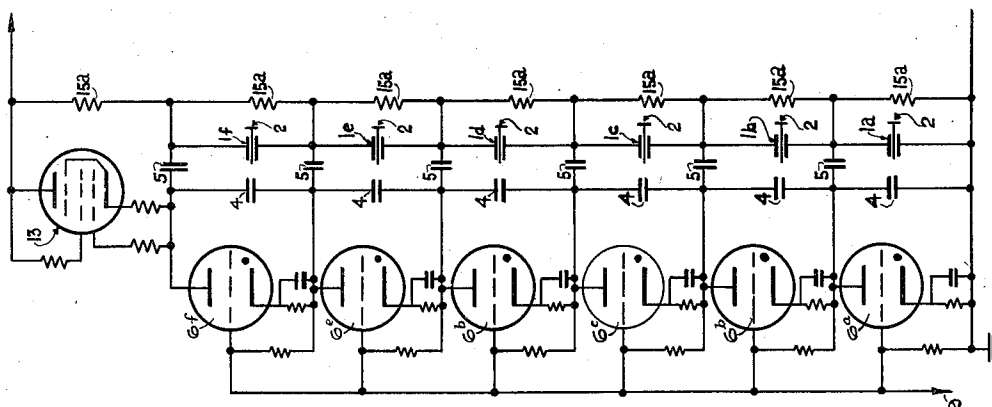


FIG. 2

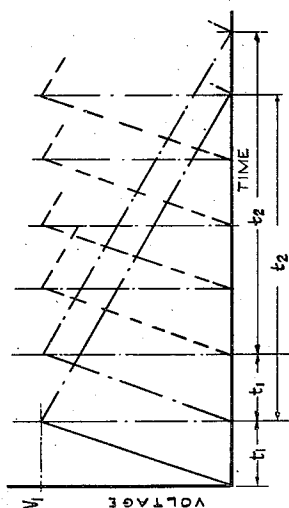


FIG. 3

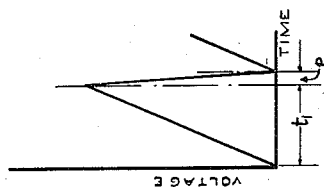


FIG. 4

INVENTOR
FREDRICK HENRY MARTIN
BY *Pech & Pech*
ATTORNEYS

March 29, 1949.

F. H. MARTIN
PLURALITY OF PIEZOELECTRIC CRYSTALS HAVING
MIRROR SURFACES FOR SCANNING

2,465,898

Filed April 1, 1947

4 Sheets-Sheet 3

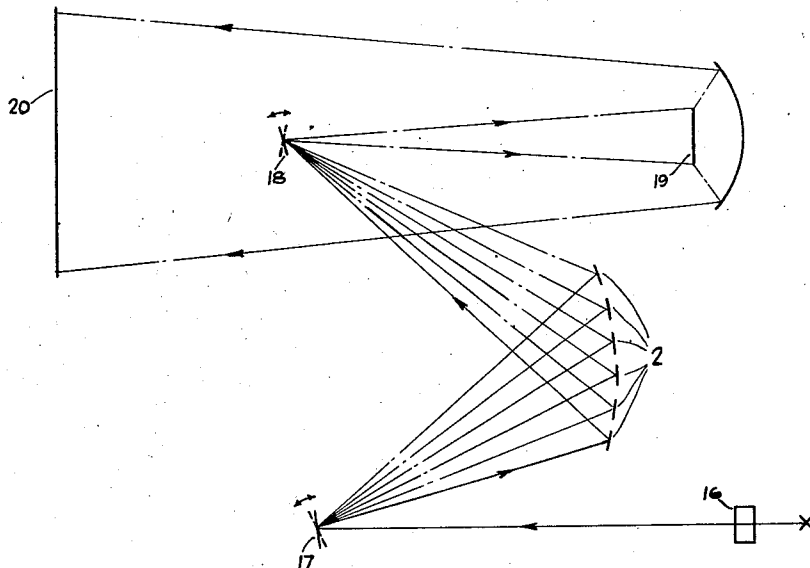


FIG. 6.

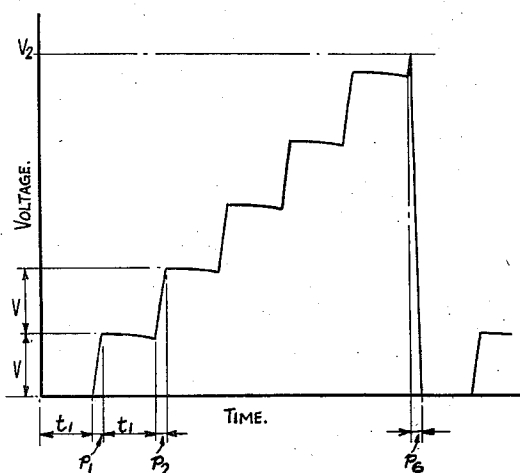


FIG. 5.

INVENTOR

Fredrick Henry Martin

by

Peck & Peck
Attorneys

March 29, 1949. F. H. MARTIN 2,465,898
PLURALITY OF PIEZOELECTRIC CRYSTALS HAVING
MIRROR SURFACES FOR SCANNING
Filed April 1, 1947 4 Sheets-Sheet 4

F. H. MARTIN
PLURALITY OF PIEZOELECTRIC CRYSTALS HAVING
MIRROR SURFACES FOR SCANNING

2,465,898

4 Sheets-Sheet 4



INVENTOR
FREDRICK HENRY MARTIN
BY Pech & Pech
ATTORNEYS

UNITED STATES PATENT OFFICE

2,465,898

PLURALITY OF PIEZOELECTRIC CRYSTALS
HAVING MIRROR SURFACES FOR SCANNINGFrederick Henry Martin, Lewisham, London,
EnglandApplication April 1, 1947, Serial No. 738,750
In Great Britain April 17, 1946

12 Claims. (Cl. 178—7.6)

1

This invention concerns scanning systems for electrical reproduction apparatus of the kind (hereinafter referred to as the kind described) in which a light beam is modulated by a receiver in accordance with signals received from a transmitter and caused to transverse or scan a screen in a series of parallel lines in rapid succession so as to produce a visible image of the object to which the transmitter signals correspond. The latter are usually generated or controlled by a similar scanning process at the transmitter, and the two scans are kept in step by means of synchronising pulses transmitted at regular intervals. Such apparatus is used, for example, in television broadcasting, photo-telegraphy and radar systems.

In reproduction apparatus of the kind described it is known to provide a single mirror which scans each line in turn, the mirror being rapidly returned to its zero position after each scan during the reception of the synchronising pulse. This return motion of the mirror is commonly referred to as the "flyback" and the period during which it takes place as the "flyback period." In the case of a television receiver operating on the standard 405-line public transmission of the B. B. C., however, the fundamental frequency of the line-scan time base is 10,125 cycles per second. The scanning apparatus must be capable of responding to the harmonics of this frequency in order to produce a distortionless scan, and harmonics of the order of the 11th to 15th are usually required for this purpose. The 11th harmonic is equal to 111.4 kc/s. and in an apparatus using one mirror, the mirror would have to be capable of responding to this frequency. The manufacture of such an apparatus presents almost insuperable difficulties, and it is an object of the present invention to overcome these difficulties in a simple and practical manner by using a series of independent mirrors for the line scanning in such a manner that each mirror, having scanned one complete line, is not made operative again until each successive mirror has also made one complete line scan. This arrangement has the advantage that the flyback period does not have to take place during the synchronising pulse, but can be slowed down so that the mirror returns to its original position whilst the other mirrors are effecting the scanning. In this way the operating frequency required to actuate the mirrors can be considerably reduced without losing the qualities of high definition required by modern television.

The invention accordingly provides, in or for

2

electrical reproduction apparatus of the kind described, a scanning system comprising two or more piezo-electric crystals each having a light-reflecting surface formed or secured on a free face thereof, means for applying across each crystal in turn a scanning potential to cause the reflecting surface to deflect the light beam along a scan line, means for removing the scanning potential progressively from each crystal after completion of its scanning operation whilst the other crystal or crystals are caused successively to perform their scanning operations, and means for directing the light beam on each reflecting surface in succession when the scanning potential is applied to the crystal.

Preferably, the means for applying a scanning potential across each crystal in turn comprises a condenser connected across each crystal, means for charging all the condensers simultaneously and means for applying to each crystal a characteristic bias potential to prevent the crystal from beginning its scanning operation until the potential across the associated condenser has reached the value of the said bias potential.

The condenser charging means may be arranged to charge all the condensers linearly with respect to time, the bias potentials increasing in value in the desired order of operation of the associated crystals.

The means for removing the scanning potential is conveniently rendered operative by a synchronising pulse received from the transmitter, and the said means advantageously comprises a grid-controlled gas-filled relay.

In order that the nature of the invention may be more clearly understood, preferred arrangements of a scanning system, suitable for use in a television receiver operating on the standard public 405-line transmission of the B. B. C., will now be described by way of example only with reference to the accompanying drawings in which—

Fig. 1 shows a first circuit arrangement of a six-crystal unit;

Fig. 2 shows a second circuit arrangement of a six-crystal unit;

Fig. 3 is a curve showing the wave form of the scanning voltage across each crystal of the arrangement shown in Fig. 1 or 2;

Fig. 4 is a curve showing a typical wave form of the scanning voltage in a known scanning system;

Fig. 5 is a curve showing the voltage across part of the circuit of Fig. 1 or 2;

Fig. 6 is a skeleton diagram of an optical ar-

range for a television receiver including a six-crystal unit, and

Fig. 7 is a diagrammatic representation of an optical arrangement of a known type of television receiver embodying the system according to the present invention.

The scanning system shown in Figs. 1 and 2 has six piezo-electric crystals *1a*, *1b*, . . . *1f* of the Rochelle salt type each having a small mirror 2 mounted on its free end. The crystals *1a* . . . *1f* are mounted on a single container 3 (Fig. 7) and are immersed in damping fluid, the electrical connections to the crystals being brought out to contacts on a standard radio valve base (not shown) whereby the unit can be plugged into a valve holder on the chassis of the receiver. The circuit of each crystal is basically the same, and consists of a scanning potential condenser 4 in parallel with the crystal *1*, and a series condenser 5.

Referring first to Fig. 1, the condensers 4, 5 form a capacity potential divider across a discharging circuit comprising a grid-controlled gas-filled relay 6*a* . . . 6*f* of the kind such as is sold under the Registered Trade Mark "Thyratron." The anode and cathode circuits of the gas-filled relay 6 each contains a resistance 7, 8, respectively, whilst the grid-circuits of all the discharging relays are connected to a common tapping point 9 on a capacity potential divider 10 across which is applied the synchronising pulse received from the transmitter through a resistance 11. Across this latter potential divider is connected another gas-filled relay 12 the grid of which is connected to the tapping point 9, this potential divider 10 and the relay 12 together forming what will, for convenience, be termed the "selective integrator circuit."

The scanning potential condensers 4 are each charged by means of a separate constant current pentode 13 connected between the H T supply and the anodes of the discharging relays 6*a* . . . 6*f*. Each of these condensers 4, except that associated with the first scanning crystal *1a*, has a bias potential applied to it through a tapping 14 from a source (not shown), the value of this bias potential increasing in the desired order of operation of the associated crystals *1b* . . . *1f*. Since the pentodes 13 charge all the condensers 4 at a constant rate, it will be seen that the bias potential for each crystal can be pre-selected by means of resistances 15 to ensure that a constant time interval *t*₁ (Fig. 3) will elapse between the instants of commencement of the scanning deflections of successive crystals, the voltage *V*₁ representing the potential developed across each crystal *1a* . . . *1f* at the instant of breakdown of its associated relay 6*a* . . . 6*f*.

As soon as the first crystal *1a* has reached the limit of its scanning deflection, a first synchronising pulse *p*₁ charges the condensers 10 of the selective integrating circuit to a value such that the bias of the first discharging relay 6*a* is overcome, the relay strikes, and the first scan condenser 4 begins to discharge through the relay 6*a* at a rate determined by the combined values of the anode and cathode loads 7, 8. The time *t*₂ of this discharge (Fig. 3) is arranged to be not greater than the time of five line scans, so that the scanning potential is removed from the crystal *1a* progressively whilst the succeeding crystals *1b* . . . *1f* perform their scanning operations.

One advantage of an arrangement such as that described above in which the fly-back period is

extended over a relatively long period of time, is that successive scans can be made to follow without any delay between them, whilst another advantage is that simplification of manufacture of the crystals is possible owing to their lower frequency of operation. These advantages become more clear when the curves of Figure 3 are compared with the curve shown in Fig. 4 which represents the operation of a single scanning mirror. In this latter arrangement, the fly-back period is extremely short, corresponding to the period *p* of the synchronising pulse. This makes high demands on the accuracy of manufacture of the crystal and on its durability in use.

Meanwhile, the scan condenser 4 of the second crystal *1b* has been charged until its potential approaches the value of the bias potential applied to this crystal, and at or shortly after the instant of breakdown of the first discharging relay 6*a*, this potential is reached and the crystal *1b* begins its scanning deflection. This continues for the second period *t*₁ until the second synchronising pulse *p*₂ is received to overcome the bias of the second relay 6*b* and cause it to fire, discharging the second condenser 4 over a second period *t*₂. This sequence is repeated for each crystal *1c* . . . *1f* in turn, the charge on the condensers 10 of the selective integrator circuit remaining substantially constant during each scan period *t*₁ and being increased in equal steps *V* (Fig. 5) by each synchronising pulse *p*. The latter occupies the brief period of time *p* at the conclusion of each scanning period *t*₁, and the resulting wave form at the tapping point 9 is as shown in Fig. 5. The potential across the integrator relay 12 thus builds up until, when the sixth pulse *p*₆ is received and fires the sixth discharging relay 6*f*, it also raises both the anode and grid potentials of the integrator relay 12 to values (represented by *V*₂ in Fig. 5) such as to cause it to fire and reset the whole circuit to its initial state, whereupon the sequential operation of the crystals *1a* . . . *1f* is repeated.

In the alternative arrangement shown in Fig. 2 the six crystal units, each comprising a crystal *1* . . . , condensers 4, 5, and gas-filled relay 6 are connected in cascade between the cathode of the pentode 13 and earth, the bias potential being obtained from a resistance potential divider 15*a* which is connected between H T positive and earth. The control grids of the relays 6 are all connected to the tapping point 9 on the selective integrator circuit 10, 12 of Fig. 1. The operation of this circuit is as follows:

A charging current which is linear with respect to time flows through the constant current pentode 13, and the condensers 4 are charged at a constant rate, the voltage across each condenser rising from zero and increasing until the associated relay 6*a* . . . 6*f* is caused to strike by the synchronising pulse *p*₁ . . . *p*₆ respectively (Fig. 5) applied through the tapping point 9 on the selective integrator circuit 10, 12 (Fig. 1). Thus the first relay 6*a* is arranged to be triggered by the potential developed at the point 9 when the first pulse *p*₁ is received, this pulse occurring at the end of the first period *t*₁ (Figs. 3 and 5) during which the first crystal *1a* performs its scanning deflection under the action of the rising potential of the associated condenser 4.

The resistances 15*a* serve to apply across each crystal a biasing potential such that while a crystal (for example the crystal *1a*) is performing its scanning deflection, the potentials de-

5

veloped across the condensers 4 associated with all the subsequent crystals (in the example chosen, the crystals 1b . . . 1f) are insufficient to overcome the bias potentials applied across these crystals and so cause them to perform their scanning deflections. Thus, only the crystal 1a is deflected during the first period t_1 . In similar manner, when the crystal 1b is performing its scanning deflection, the bias potentials on the crystals 1c . . . 1f are greater than the potentials across their respective condensers 4, so that only the crystal 1b is deflected during the second period t_1 . The condensers 5 serve to isolate the tapping points between the resistances 15a from the condensers 4 so that the voltage/time characteristic of the latter is not affected by the bias potentials of the crystals.

In both forms of the apparatus shown in Figs. 1 and 2, it will be seen that each crystal has a bias potential applied thereto which is characteristic of its position in the scanning sequence, and that this potential is adjusted to ensure that the crystals perform their scanning deflections in the correct sequence, only one crystal being operative at any one instant. The sequence is kept in step by means of the synchronising pulses.

With the above-described sequential mirror scanning system, the operating frequency of each crystal 1a . . . 1f is reduced in direct proportion to the number of mirrors 2 being used; i. e. the fundamental frequency for the six-crystal unit described, and operating on the standard 405-line transmission, becomes one-sixth of 10,125 cycles per sec., or 1,680 cycles per sec. The 11th harmonic is then 18.5 kc./s., which is a more practical operating figure for crystal scanning units.

As shown in Fig. 6, the mirror 2 on each crystal is illuminated in turn by a single light beam which is modulated by, say, any known type of supersonic wave cell 16, this beam being directed on to each scanning mirror 2 in turn by means of a beam shift mirror 17 also preferably formed or mounted on a crystal which is energised directly from the integrator circuit 10, 12. The line scan mirrors 2 reflect the beam on to a frame scan mirror 18 operated by a known form of frame scanning circuit and thence to an intermediate screen 19 the image on which is projected by a suitable optical system on to a viewing screen 20. By the use of the beam shift mirror 17, a single modulated light beam only can be used, thus enabling a relatively simple optical circuit to be adopted and ensuring a relatively high light intensity in the final image.

It can be shown that even after the line operating frequency has been reduced by using several mirrors scanning in sequence, the crystals 1a . . . 1f will have a relatively small angle of deflection and the picture obtained directly from the mirrors 2 will be small in consequence. In order to overcome this and to provide a picture of satisfactory dimensions it will be necessary to project the image on to a final screen by means of suitable optical arrangements. This is an advantage because the size of the final picture is then virtually independent of the scanning apparatus itself. The picture size becomes mainly dependent on the intensity of the light source, the efficiency of the light modulator and the nature of the projection lens system.

The frame scanning unit can be fairly simple as the frequency of operation is very low and no special methods are called for. The unit may be of the mirror drum variety or a single mirror crystal unit. This latter method is preferable

6

from the point of view of light efficiency and ease of synchronising, but may suffer from a disadvantage unless the mirrored surface can be made long enough to accommodate the complete line scan. If the size of mirror is found in practice to be strictly limited, it may be necessary to adopt a split-focus lens system in order to reduce the line scan down to the limit acceptable to the frame scanning mirror, and to enlarge the line after it has left the frame scanning unit.

An advantageous application of the invention is to a television receiver circuit such as is illustrated in Fig. 7. This circuit depends upon the Debye Sears effect, whereby a light beam is diffracted by the supersonic waves which are set up in a translucent liquid in which a quartz crystal is immersed when the crystal has an oscillatory H. F. potential applied across it. Cells containing liquid in which quartz crystals are immersed are already known as light modulators for use in television receivers. In hitherto known arrangements, a light beam, which is modulated in accordance with incoming signals applied to the crystal in a cell, is focused on to a rotating polygonal scanning mirror which is rotated at high speed. The light is reflected from the scanning mirror through a suitable optical system on to a screen on which the picture is built up.

It has hitherto, however, been a drawback of such known systems that the rotating scanning mirror has been required to rotate at high speed whilst, at the same time, no play or vibration in the bearings is permissible if a steady picture is to be obtained. This mechanical requirement has proved difficult of attainment. It is an advantage of the present invention that apparatus in accordance therewith can replace the rotating mirror and thereby avoid the difficulties hitherto experienced in satisfactory mechanical design of the scanning mirror mountings.

Fig. 7 illustrates diagrammatically an optical arrangement for a television receiver working on the Debye Sears principle. In this figure a beam of light from a light source 21 is passed through a slit 22 and modulated by a supersonic wave cell 23 in which a quartz crystal is embedded at one end 24. The direction of the wave train set up in the liquid in the cell 23 is indicated by the arrow 25. The modulated beam is reflected from a beam shift mirror 26 on to successive mirrors 2 of a six-crystal line scan unit 3 constructed in accordance with the invention and is reflected by these mirrors on to a frame scan mirror 27 and focused on a screen 28. Each mirror 2 is deflected at such a speed and in such a direction that a stationary image 29 of the wave train in the cell 23 is produced on the screen 28. This image 29 constitutes a complete line scan occupying, say, 50 microseconds of received signals of a picture to be built up on the screen 28, the arrow 30 indicating the direction of travel of the wave train in the image 29 whilst the arrow 31 indicates the direction of scanning of the line.

As already indicated, the velocity of the wave train in the direction of the arrow 30 must be equal to the velocity of scan in the direction of the arrow 31 in order to produce a stationary image 29. As will be understood, this can readily be achieved by suitable selection of the rate of charge of the condensers 4 which are connected to the crystal units 1a . . . 1f in the crystal scanning unit 3. The arrangement has the advantage that there are no rotating mechanical parts requiring a high degree of accuracy of manufacture

of bearings, whilst a high degree of constancy in speed of line scan is readily achieved. The optical circuit illustrated in Figure 7 constitutes a known arrangement, and it is not therefore proposed to describe it in fuller detail.

Instead of gas-filled relays in the discharging circuits, "hard" valves may be used, these being normally biased well back, preferably beyond the cut-off point, to ensure that no current flows through them during the period of line scanning of their respective crystals. The application of the synchronising pulse is then arranged to overcome this bias and allow a relatively large current to flow. With such an arrangement, however, it is preferred to retain a grid-controlled gas-filled relay in the selective integrator circuit, since the discharge time is short and a correspondingly heavy current must flow.

It should be understood, however, that if preferred a "hard" valve, suitably biased, may be employed in place of a gas-filled relay in this part of the circuit.

The crystals may be made by any of the known methods. For example, each crystal may consist of a pair of thin rectangular plates cut from a "mother" crystal of Rochelle salt with their edges parallel to the main axes of the crystal the plates being cemented together and clamped at one end. Such a unit will then twist on the application to the electrodes of the deflecting potential, and is sometimes known in the art as a "twister."

What I claim is:

1. In electrical reproduction apparatus of the kind described a scanning system comprising a plurality of piezo-electric crystals each having a light-reflecting surface on a free face thereof and adapted to deflect the light reflecting surface through a predetermined scanning angle as a potential applied across the respective crystal progressively varies through a predetermined range of values, means for directing a modulated light beam on to the reflecting surfaces of the crystals in succession and in a predetermined sequence, means for applying across the crystals a potential varying progressively from an initial value through a range including the said predetermined range, means for causing the said potential to pass through the predetermined range for each crystal in turn as the reflecting surface thereon is illuminated by the light beam, and means for progressively restoring to its initial value, in a period of time during which at least one other crystal is being illuminated, the potential across each crystal after the said crystal has completed its scanning deflection.

2. A scanning system as claimed in claim 1 having means for applying across a crystal a bias potential which is characteristic of the position of the said crystal in the scanning sequence to ensure that the crystals perform their scanning deflections in turn and in the predetermined sequence.

3. A scanning system as claimed in claim 1 having means for rendering the succession of scanning deflections of the crystals repetitive.

4. A scanning system as claimed in claim 1 having means for applying across a crystal a bias potential which is characteristic of the position of the said crystal in the scanning sequence to ensure that the crystals perform their scanning deflections in turn and in the predetermined sequence, and means for rendering the said sequence repetitive.

5. A scanning system for electrical reproduc-

tion apparatus of the kind described comprising a plurality of piezo-electric crystals each having a light-reflecting surface on a free face thereof, means for directing a modulated light beam on to the light reflecting surfaces of the crystals one at a time as the respective crystal commences its scanning deflection, a condenser connected across each crystal, a supply of current to charge each condenser to a potential sufficient to deflect the crystal through a scanning angle, a discharging relay connected across each condenser, and a control circuit for rendering each discharging relay operative in turn in the same sequence as that in which the crystals perform their successive scanning deflections.

6. A scanning system according to claim 1 having a condenser connected across each crystal, a supply of current to charge each condenser to a potential sufficient to deflect the crystal through a scanning angle, and a source of characteristic bias potential connected to a crystal to prevent that crystal from beginning its scanning operation until the potential across the associated condenser has exceeded the value of the said bias potential.

7. A scanning system for electrical reproduction apparatus of the kind described comprising a plurality of piezo-electric crystals each having a light-reflecting surface on a free face thereof, means for directing a modulated light beam on to the light reflecting surface on each crystal as it commences its scanning deflection, a condenser connected across each crystal, a supply of current to charge each condenser to a potential sufficient to deflect the crystal through a scanning angle, a source of characteristic bias potential connected to a crystal to prevent that crystal from beginning its scanning deflection until the potential across the associated condenser has exceeded the value of the said bias potential, a grid-controlled gas-filled relay connected across each condenser, a capacity potential divider connected to a source of synchronising pulses, and a connection from a tapping point on the potential divider to the grid of each gas-filled relay.

8. A scanning system as claimed in claim 7 including means for discharging the capacity potential divider at the end of each sequence of scanning operations.

9. A scanning system for electrical reproduction apparatus of the kind described comprising a plurality of piezo-electric crystals each having a light-reflecting surface on a free face thereof, means for directing a modulated light beam on to the light reflecting surface on each crystal as it commences its scanning deflection, a condenser connected across each crystal, a supply of current to charge each condenser to a potential sufficient to deflect the crystal through a scanning angle, a source of characteristic bias potential connected to a crystal to prevent that crystal from beginning its scanning deflection until the potential across the associated condenser has exceeded the value of the said bias potential, a grid-controlled gas-filled relay connected across each condenser, a capacity potential divider connected to a source of synchronising pulses, a connection from a tapping point on the potential divider to the grid of each gas-filled relay, a grid-controlled electron discharge device connected across the ends of the potential divider and biased back to the non-conducting state, and a connection from the control grid thereof to a point on the potential divider such that the discharge device is rendered conducting

when the synchronizing pulse which triggers the relay associated with the last crystal in the sequence of scanning operations is applied to the potential divider.

10. A scanning system as claimed in claim 1 wherein the means for directing the modulated light beam on to the reflecting surfaces of the crystals comprises a light reflecting element to illuminate the reflecting surface of each crystal singly and means to deflect the said light reflecting element in steps on the reception of each successive synchronising pulse to illuminate each crystal in turn while it deflects through the scanning angle.

11. A scanning system as claimed in claim 7 including a further crystal having a reflecting surface on a free face thereof and arranged to illuminate the reflecting surface of a line scanning crystal during its scanning deflection, said further crystal being connected across the capacity potential divider so as to be deflected in steps at the reception of each synchronising pulse through an angle sufficient to deflect the modulated light beam from the reflecting surface of one line scanning crystal to the corresponding surface of the next crystal in the predetermined scanning succession.

12. In a scanning system as claimed in claim 1, a light modulating device operating on the Debye

Sears principle in combination with a source of scanning potential applied to each crystal such that the crystal deflects the light beam in such a direction and at such a speed that the image of the wave train set up in the light modulating device appears stationary.

FREDERICK HENRY MARTIN.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,423,737	Sandell	July 25, 1922
1,760,198	Hough	May 27, 1930
1,789,521	Feingold	Jan. 20, 1931
2,320,380	Okolicsanyi et al.	June 1, 1943

FOREIGN PATENTS

Number	Country	Date
536,803	Great Britain	May 28, 1941

OTHER REFERENCES

- Television, Zworykin and Morton, John Wiley and Sons, Inc., 1940, pages 455 and 456.
Radio Engineers' Handbook, Terman, McGraw-Hill Book Co., 1943, pages 512, 513.