Aug. 2, 1960 G. R. HOFFMAN ET AL 2,947,912

ELECTRO-LUMINESCENT DISPLAY DEVICES

Filed April 7, 1958 2 Sheets-Sheet 1

Fig. 1.

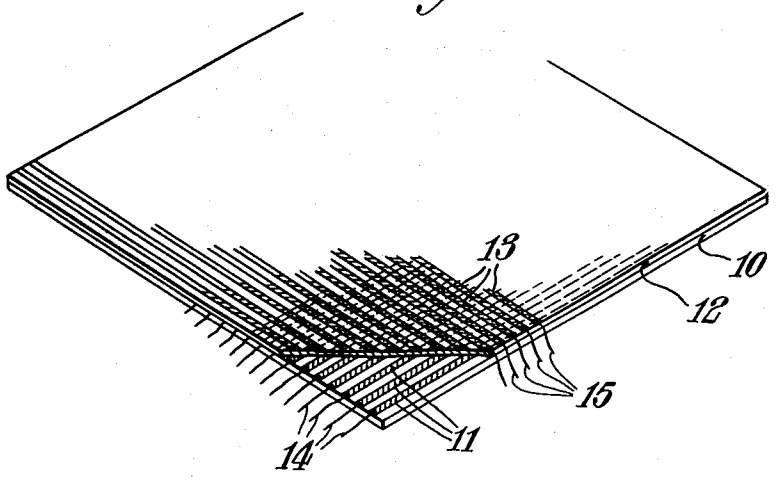


Fig. 2.

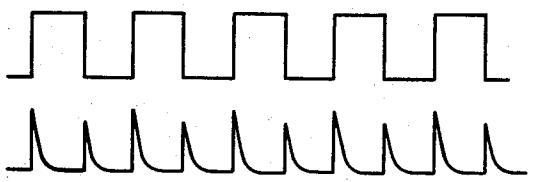


Fig. 3.

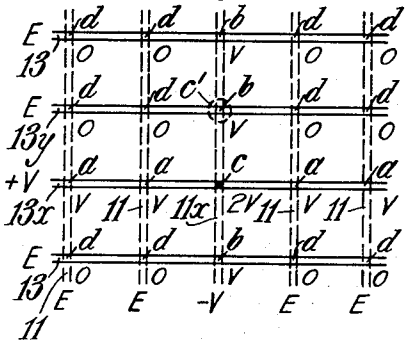
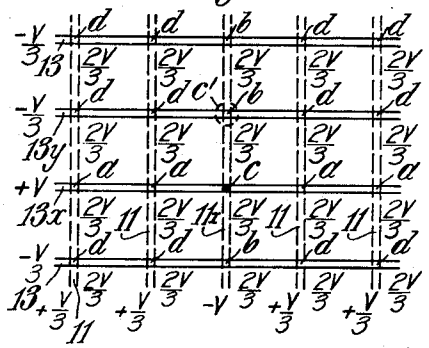


Fig. 4.



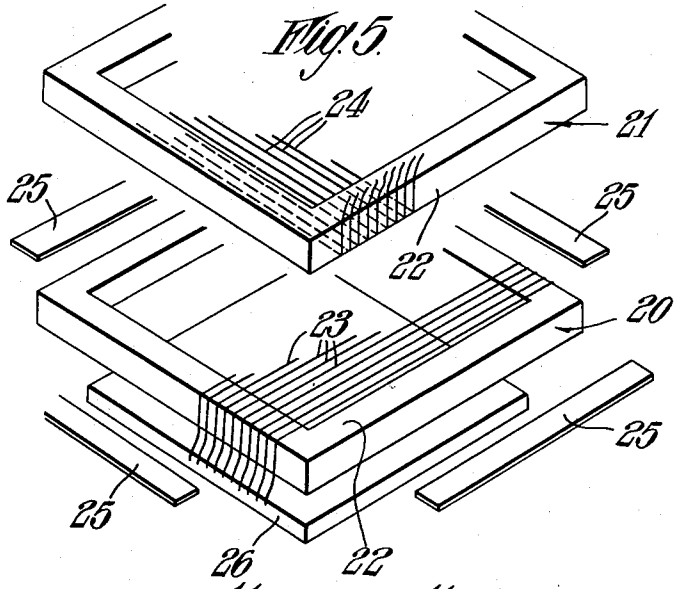
Inventors:
George Richard Hoffman
Roy Ernest Hayden
By: Stevens, Davis, Miller & Mosher
Attorneys

Aug. 2, 1960 G. R. HOFFMAN ET AL 2,947,912

ELECTRO-LUMINESCENT DISPLAY DEVICES

Filed April 7, 1958 2 Sheets-Sheet 2

Fig. 5.



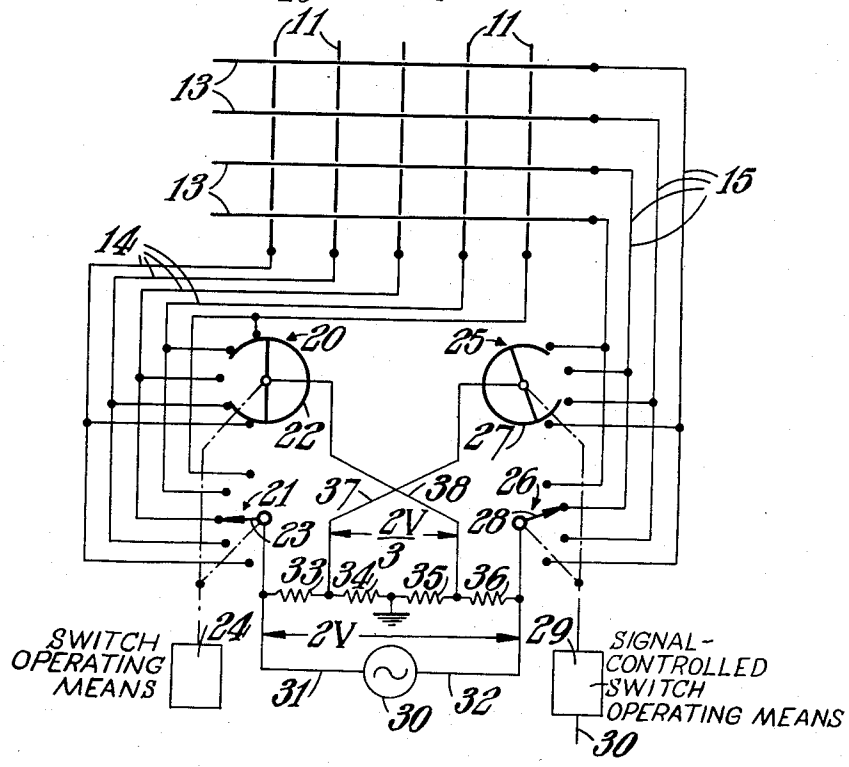


Fig. 6.

Inventors:
George Richard Hoffman
Ray Ernest Hayes
By: Stevens, Davis, Miller & Mosher
Attorneys

United States Patent Office 2,947,912 Patented Aug. 2, 1960

2,947,912

ELECTRO-LUMINESCENT DISPLAY DEVICES

George Richard Hoffman, Sale, and Roy Ernest Hayes, Cheltenham, England, assignors to National Research Development Corporation, London, England, a British corporation

Filed Apr. 7, 1958, Ser. No. 726,832

Claims priority, application Great Britain Apr. 9, 1957

11 Claims. (Cl. 315—169)

This invention relates to a display device usable instead of a cathode ray tube and employing the phenomena of electro-luminescence under the influence of a changing electric field.

Normal cathode ray tube devices have limited accuracy in the positioning of the focused light spot formed on the fluorescent screen of the tube by the impact therewith of the electron beam. Moreover, the deflection sensitivity of the produced light spot varies over the surface area of the screen with resultant barrel or pin-cushion distortion and precise repetition of any particular spot position is difficult unless expensive drift-free stabilisation techniques are employed in the associated apparatus.

The object of the present invention is to provide a display device capable of use as an alternative to a cathode ray tube and in which the above limitations of operation of cathode ray tube devices are avoided.

In the device according to the broadest aspect of the invention a layer of suitable phosphor is caused to fluoresce by the application thereto of a changing electric field produced between a selected one of a first set of electric conductors disposed on one side of the phosphor layer and a selected one of a second set of electric conductors which are disposed on the opposite side of such phosphor layer. Preferably the respective conductors of the two sets lie at right angles to each other to form a matrix.

In order that the nature of the invention may be more readily understood several embodiments thereof will now be described with reference to the accompanying drawings, in which:

Fig. 1 is a fragmentary perspective view of one form of electro-luminescent device according to the invention.

Fig. 2 consists of diagrams (*a*) and (*b*) illustrating respectively a suitable energising waveform and the resultant light output produced thereby.

Figs. 3 and 4 are diagrams of small parts of the conductor matrix shown to a much enlarged scale.

Fig. 5 is an exploded perspective view illustrating the manner of manufacture of an alternative embodiment of the invention.

Fig. 6 is a schematic diagram showing one display device arrangement according to the invention.

In the constructional form of display device for use in the invention illustrated in Fig. 1, a glass plate **10** first has deposited thereon a suitable number, for instance 1,000, of parallel and, preferably, transparent first electric conductors **11**. These conductors are conveniently in the form of very thin gold film bars 0.001 inch wide and are equally spaced 50 to the inch. The deposition of these gold film conductors can be by any already well known deposition technique. Upon this surface of the plate and on top of the conductors **11** is then deposited a thin uniform layer **12** of electro-luminescent phosphor. The phosphor material employed may be any of those already well known in connection wtih electro-fluorescence phenomena. Thereafter, a number of further or second conductors **13**, for instance 1,000 are then deposited on the surface of the phosphor layer with a disposition at right angles to those of the transparent conductors **11** on the underside of the phosphor. These second conductors **13** may be opaque and are conveniently of similar width and spacing to those of the underside or first conductors.

An individual connecting lead **14** is provided for each of the first conductors **11** and a similar individual connecting lead **15** is provided for each of the second conductors **13**. These leads may be joined to the conductors themselves by use of any suitable one of the already well known methods.

If any selected conductor of the first set **11** is now energised with a voltage V of one polarity and any selected conductor of the second set **13** is similarly energised with a voltage V of opposite polarity, then at the intersection point of the selected conductors electro-luminescence of the phosphor layer **12** is produced. This can be viewed through the glass plate **10**. By arranging for the sequential selective energisation of the different conductors of the two sets so a graphical or other figure can be displayed.

As electro-luminescence is a function of a changing electric field it is normally necessary to employ a fluctuating energising potential on each conductor and this is conveniently in the form of a voltage square wave. The resultant light output for a square wave energising input as shown in Fig. 2(*a*) is indicated approximately in Fig. 2(*b*) and with many useful phosphors the "time constant" of the light output decay is of the order of 10 microseconds. In consequence of this, the integrated light output increases substantially linearly with increase of frequency of the applied voltage square wave until the period time of such wave is of the same order as the decay time. A 50 kc./s. square wave has been found to be a reasonable frequency for the applied energising square wave voltage.

The integrated light output from such a device varies with the voltage applied and over a limited range can be expressed by the simple law $L=aV^n$ where

L is the integrated light output
a is a constant,
V is the voltage applied and
n is a factor of the order of 8.

In practice, with an example constructed as described above, a change of applied voltage between intersecting first and second conductors **11** and **13** from a first value of 150 v. to a second value of 300 v. caused an integrated light output change of the ratio of 1:300.

A device of the character described may readily be adapted to provide a graphical display, such as that of a curve or complex line figure, by suitably energising each of one set of conductors, for instance, the set of conductors **11** in a regular cyclic manner whilst controlling the selective connection of the conductors of the other set **13** to the energising voltage source by means responsive to the variable factor which is to be displayed. Thus, one set of conductors such as those which are disposed to lie vertically on a display panel may be energised in turn through a suitable time-controlled selector switch while the opposite set of horizontal conductors may be connected to their energising source by way of a relay tree, the form of operation of which is continuously controlled by binary input signals representing the variable value which is to be displayed to the time scale set by the aforesaid selector switch.

Such an arrangement is particularly suitable for obtaining photographic records by means of a suitable light sensitive plate disposed adjacent the display element or subjected to the light therefrom through a suitable lens system.

One difficulty which arises, however, with any arrangement, such as photographic recording, where integration of the total light output from any one electro-luminescent point is effected, is demonstrated as follows. If, as would usually be the case, all of the conductors which are unused at any given instant are earthed, then along each of the selected conductors there is a voltage difference V at each of the intersections of that conductor with the unused and earthed opposing conductors as well as the desired voltage difference 2V at the intersection of the two selected conductors where electro-luminescence is desired. This is illustrated in Fig. 3 where the various intersection points *a* between the selected conductor 13^x of the set of conductors **13** and the unused and earthed conductors of the set of conductors **11** provide a voltage difference V and the similar intersection points *b* between the selected conductor 11^x and the unused and earthed conductors **13** also provide a voltage difference V. Point *c* at the intersection of conductors 11^x and 13^x provides the required operative voltage difference 2V while at the remaining intersection points *d* of the earthed conductors of each set there is, of course, zero voltage difference.

Consider now an extreme case where each of 1,000 conductors **11** are energised in turn to provide, for example, a horizontal time scale, and where the variable quantity to be displayed is constant at the level of one conductor 13^x for the whole time period of the horizontal scale except for one instant when, say, at the time instant corresponding to energisation of conductor 11^x, the quantity value alters to require energisation of conductor 13^y. This should produce a record having no luminescent image at point *c* and an image at point c^1.

Owing, however, to the otherwise continuous energisation of conductor 13^x the phosphor at intersection point *c* will have been subjected to the voltage difference V (i.e. that with an earthed unused conductor) 999 times whereas the wanted display point c^1 will have been subjected to the voltage difference 2V only once. Under the above noted law governing integrated light output, the integrated light output from point c^1 will be 300 units whereas that from point *c* will be 999 units. In consequence the required display point c^1 will be obscured by the unwanted display point *c*.

In order to overcome this difficulty and in accordance with another feature of the invention, arrangements are provided for supplying to each of the conductors of each set which are unused at any time a "bias" voltage

$$\frac{V}{3}$$

and having a polarity opposite to that with which the same set of conductors is energised to produce display. Thus, and as shown in Fig. 4, taking the same conditions as already described with relation to Fig. 3, the intersection point such as *c* of two energised conductors **11** and **13** still produces an energising voltage difference 2V whereas the phosphor is subjected to all of the other unselected intersection points *a*, *b* and *d* to a voltage difference

$$\frac{2V}{3}$$

Applying the above quoted law, the difference in integrated light output between a point such as *c* and points such as *a*, *b* or *d* now becomes proportional to

$$\frac{2V^8}{\left(\frac{2V}{3}\right)^8}=6{,}500$$

In consequence, in the extreme case previously discussed the ratio of the respective integrated light outputs of points c^1 and *c* is of the order of 6,500 to 999 or greater than 6:1. This is amply sufficient to provide adequate discrimination.

It will be understood that the aforesaid

$$+\frac{V}{3} \text{ or } -\frac{V}{3}$$

bias voltages are each one-third amplitude versions of the fluctuating, e.g. square wave, voltages used on the selected conductors. Although a square wave voltage is preferable, a sine waveform may be used and is more conveniently obtainable.

By suitable selection of exposure and development techniques in photographic recording, it is possible to increase the contrast of the wanted to unwanted spot positions and the exposure threshold of the photographic material employed may readily be exploited.

Fig. 6 illustrates, in schematic diagram form, one arrangement for operating with the above described "biased" system of the unused conductors. For simplicity the matrix is shown with only five first conductors **11** and four second conductors **13** but it will be understood that many more conductors may be used in each set with appropriate modification of the associated switching means.

Each of the first conductors **11** is connected by way of leads **14** to individual contacts of two multi-point selector switches **20, 21**. The rotors **22, 23** of these switches are ganged together for operation in unison by means **24** which may be a time-controlled or synchronous motor. The rotor **23** of switch **21** is arranged to make connection with only one of the switch contacts at any one time whereas the rotor **22** of switch **20** is arranged to bridge all of the switch contacts except that which is joined in parallel with the particular contact of switch **21** engaged by rotor **23** at the particular switch position in use.

Each of the second conductors **13** is likewise connected by way of leads **15** to individual contacts of two further multi-point switches **25, 26**. The rotors **27, 28** of these switches are also ganged for operation in unison by signal-controlled means **29** whereby the switches **25, 26** may be set in any one of the various alternative positions under the control of an input signal on lead **30**. The rotor **28** of switch **26** is arranged to make connection with only one of the switch contacts at any one time whereas the rotor **27** of switch **26** is arranged to bridge all of the switch contacts except that which is joined in parallel with the particular contact of switch **26** engaged by rotor **27** at the particular switch position in use.

A source of alternating potential **30**, e.g. a square or sine wave generator operating at a frequency of the order of 50 kc./s. and providing an alternating potential output which is balanced with respect to earth, has its respective output leads **31, 32** connected to opposite ends of a potentiometer network of resistors **33, 34, 35** and **36**. Lead **31** is also connected to the rotor **23** of switch **21** while lead **32** is also connected to the rotor **28** of switch **26**. Resistors **33** and **36** are of twice the ohmic value of resistors **34** and **35** while the junction point of such resistors **34, 35** is connected to earth. Leads **37, 38** connected respectively to the junction points between resistors **33** and **34** and between resistors **35** and **36** carry a potential 2V/3 which is one third that of 2V carried on leads **31** and **32**. Lead **37** is connected to rotor **27** of switch **25** whereas lead **38** is connected to rotor **22** of switch **20**.

By appropriate operation of the selector switch means constituted by the switch pairs **20, 21** and **25, 26** any desired one of the first conductors **11** and of the second conductors **13** may be connected respectively across the full potential 2V of the source **30** while each of the remaining and unselected conductors **11** and **13** are connected respectively to the one-third value potential point of polarity opposite that with which the related selected conductor **11** or **13** is supplied.

While the selector switch means have been shown as of simple mechanical switch form, it will be understood that any suitable electronic or other high-speed switching means may be employed in lieu.

In the construction of devices as described above certain problems arise and the first of these is the making of the individual connections **14** and **15** to each of the energising conductors **11** and **13**. This may be effected by use of combination of printed circuit methods with evaporation techniques. A second problem is the obtaining of a uniform phosphor thickness since variations of such thickness introduce major differences in the applied electric field. Methods such as spraying, spinning or dragging a casting knife across the surface have so far been found to provide the best solution.

In an alternative construction of display device according to the invention each of the two sets of conductors are opaque and only the light available around the edges of one of the sets of conductors is available for display purposes. In spite of this disadvantage, the increased facility for construction is in many circumstances more advantageous. One construction of this nature is illustrated in Fig. 5 and comprises a pair of rectangular frames **20, 21**, e.g. of metal. One surface **22** of each frame is ground flat. Each frame is then provided with a series of accurately spaced wires **23, 24** conveniently located and held in a series of notches along edges of the frames. The two frames with their attached wires are then brought together with their ground surfaces **22** facing each other and spaced apart at an accurately determined distance by means of inserted metal shim plates **25**. A glass plate **26** to support the finished structure is then placed adjacent to the underside of the bottom set of wires **23** and phosphor material (not shown) is persuaded to encompass the matrix of parallel wires by spraying, dipping or the like. With this method the conductors are accurately spaced and the difficulty of providing connecting wires to the various conductors of the matrix is avoided. At least the upper or outer set of wires are preferably very thin, conveniently of the order of 0.003 inch diameter which has been found sufficient to produce reasonable fluorescence at the wire edges and still allow visibility of the electro-luminescence produced. With such a device the photographic recording material may be laid directly adjacent the surface of the phosphor with consequent decrease of the exposure time necessary.

We claim:

1. An electro-luminescent display device comprising a phosphor layer, a first set of electric conductors disposed on one side of said layer, a second set of electric conductors disposed on the opposite side of said layer in non-parallel relationship to said first set conductors whereby each second set conductor crosses a plurality of said first set conductors, a source of varying electric operating potential, a source of varying electric biasing potential having at all times a predetermined and constant fractional value which is between one half and one quarter of that of said source of operating potential, said sources of potential each having first and second terminals, said first terminals being of like polarity at any instant and said second terminals being also of like polarity at any instant but of opposite polarity to said first terminals and selector switching means including equally conductive bi-directional connections for connecting the first terminal of said operating potential source to one of said first set conductors and the second terminal of said operating potential source to one of said second set conductors and simultaneously connecting the second terminal of said biasing potential source to each of said first set conductors which is not connected to said operating potential source and for connecting said first terminal of said biasing potential source to each of said second set conductors which is not connected to said operating potential source.

2. An electro-luminescent display device comprising a phosphor layer, a first set of parallel linear electric conductors disposed on one side of said layer, a second set of parallel linear electric conductors disposed on the opposite side of said layer at right angles to said first set conductors whereby each second set conductor crosses each of said first set conductors, a source of alternating electric operating potential, a source of alternating electric biasing potential having at all times a value which is one third that of said source of operating potential, said sources of potential each having first terminals which are of like polarity at any instant and second terminals which are of like polarity at any instant and selector switching means including equally conductive bi-directional connections for connecting the first terminal of said operating potential source to any chosen one of said first set conductors and the second terminal of said operating potential source to any chosen one of said second set conductors and simultaneously connecting the second terminal of said biasing potential source to each of said first set conductors which is not connected to said operating potential source and for connecting said first terminal of said biasing potential source to each of said second set conductors which is not connected to said operating potential source.

3. An electro-luminescent display device comprising a planar layer of electro-luminescent phosphor material, a plurality of parallel first electric conductors disposed on and in contact with one side of said phosphor layer, a plurality of parallel second electric conductors disposed on the opposite side of and in contact with said phosphor layer, said second conductors being disposed at right angles to said first conductors, a source of varying electric operating potential having first and second terminals of respective polarities which are opposite to each other at any given instant, a source of varying electric biasing potential having first and second terminals which are respectively of opposite polarity to each other at any instant and of the same polarity as said first and second terminals of said operating potential source at any instant, said source of biasing potential being at all times one third the value of said operating potential and selector switch means including equally conductive bi-directional connections for connecting said first and second terminals respectively of said operating potential source to a selected one of said first conductors and to a selected one of said second conductors and for simultaneously connecting all of the remaining first conductors to said second terminal of said biasing potential source and for connecting all of the remaining second conductors to said first terminal of said biasing potential source.

4. An electro-luminescent display device according to claim 3 in which the varying potential applied between said first and second conductors is of alternating character with an alternation frequency of the order of 50 kc./s.

5. An electro-luminescent display device according to claim 4 in which the varying potential applied between said first and second conductors has a square waveform.

6. An electro-luminescent display device comprising a planar layer of electro-luminescent phosphor material, a plurality of linear and parallel first electric conductors disposed on and in contact with one side of said phosphor layer, a plurality of linear and parallel second electric conductors disposed on the opposite side of and in contact with said phosphor layer, said second conductors being disposed at right angles to said first conductors, a source of alternating electric operating potential having first and second terminals of respective polarities which are opposite to each other at any given instant, a source of alternating electric biasing potential having first and second terminals which are respectively of opposite polarity to each other at any instant and of the same polarity as said first and second terminals of said operating potential source at any instant, the voltage of said biasing potential being at all times one third the voltage of said operating potential and selector switch means including equally conductive bi-directional connections for connecting said first and second terminals respectively of said operating potential source to a selected one of

said first conductors and to a selected one of said second conductors and for simultaneously connecting all of the remaining first conductors to said second terminal of said biasing potential source and for connecting all of the remaining second conductors to said first terminal of said biasing potential source.

7. An electro-luminescent display device according to claim 6 in which said first and second conductors are each in the form of thin metal wires embedded within a body of phosphor material forming said phosphor layer.

8. An electro-luminescent display device according to claim 6 in which said selector switch means include a first cyclically operable switch for connecting each of said first conductors in turn to said operating potential source and a second signal-controlled switch for connecting any chosen one of said second conductors to said operating potential source in dependence upon the nature of a control signal applied to said second switch.

9. An electro-luminescent display device according to claim 8 in which said first cyclically operable switch comprises time-controlled switch operating means.

10. An electro-luminescent display device according to claim 8 in which said second signal-controlled switch comprises a relay tree.

11. An electro-luminescent display device comprising a planar layer of electro-luminescent phosphor material, a plurality of linear and parallel first electric conductors disposed on and in contact with one side of said phosphor layer, a plurality of parallel second electric conductors disposed on the opposite side of and in contact with said phosphor layer, said second conductors being

transparent and disposed at right angles to said first conductors, a source of alternating electric operating potential having first and second terminals of respective polarities which are opposite to each other at any given instant, a source of alternating electric biasing potential having first and second terminals which are respectively of opposite polarity to each other at any instant and of the same polarity as said first and second terminals of said operating potential source at any instant, the voltage of said biasing potential being at all times one third the voltage of said operating potential and selector switch means including equally conductive bi-directional connections for connecting said first and second terminals respectively of said operating potential source to a selected one of said first conductors and a selected one of said second conductors and for simultaneously connecting all of the remaining first conductors to said second terminal of said biasing potential source and for connecting all of the remaining second conductors to said first terminal of said biasing potential source.

References Cited in the file of this patent

UNITED STATES PATENTS

2,774,813	Livingston	Dec. 18, 1956
2,796,584	Hurvitz	June 18, 1957
2,818,531	Peek	Dec. 31, 1957
2,877,371	Orthuber et al.	Mar. 10, 1959
2,881,360	Livingston	Apr. 7, 1959
2,883,582	Hanlet	Apr. 21, 1959
2,892,968	Kallman et al.	June 30, 1959