July 24, 1962 F. A. LITZ ET AL 3,046,540

ELECTRO-OPTICAL TRANSLATOR

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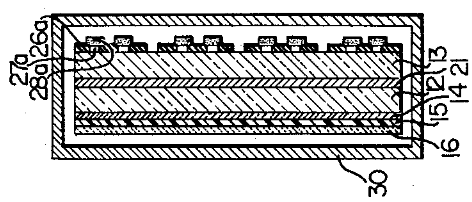

FIG. 2

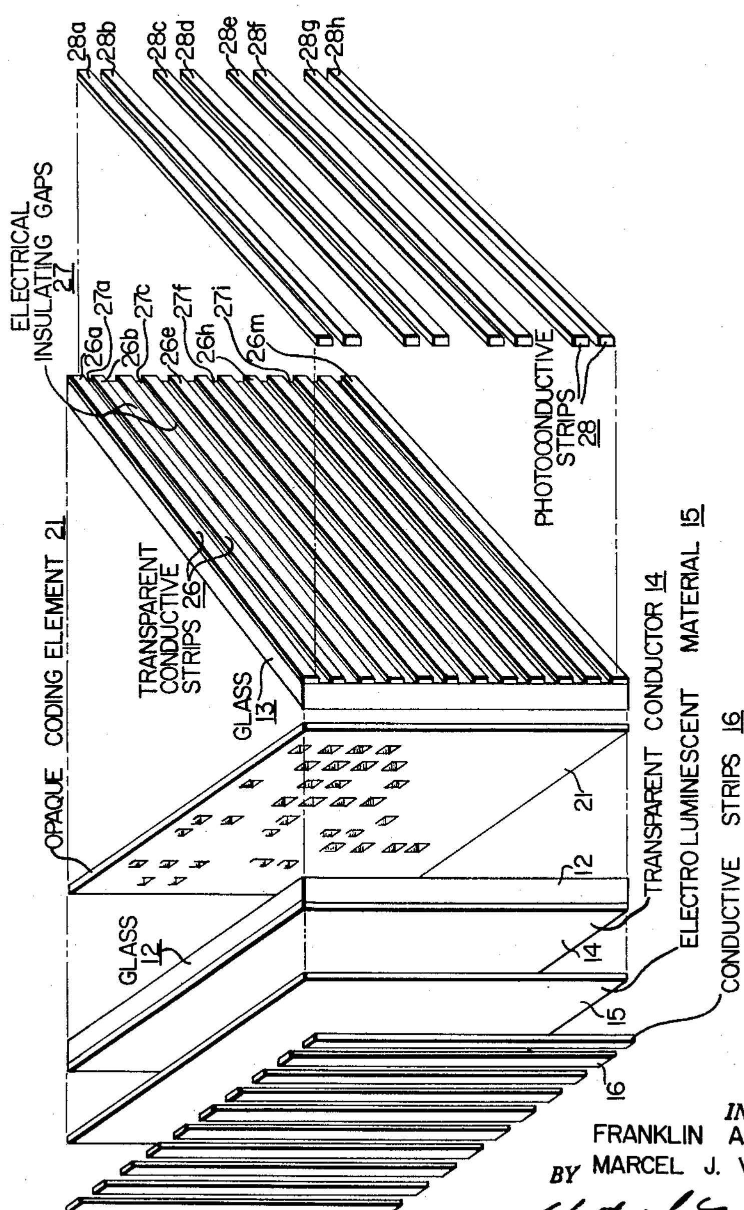

FIG. 1

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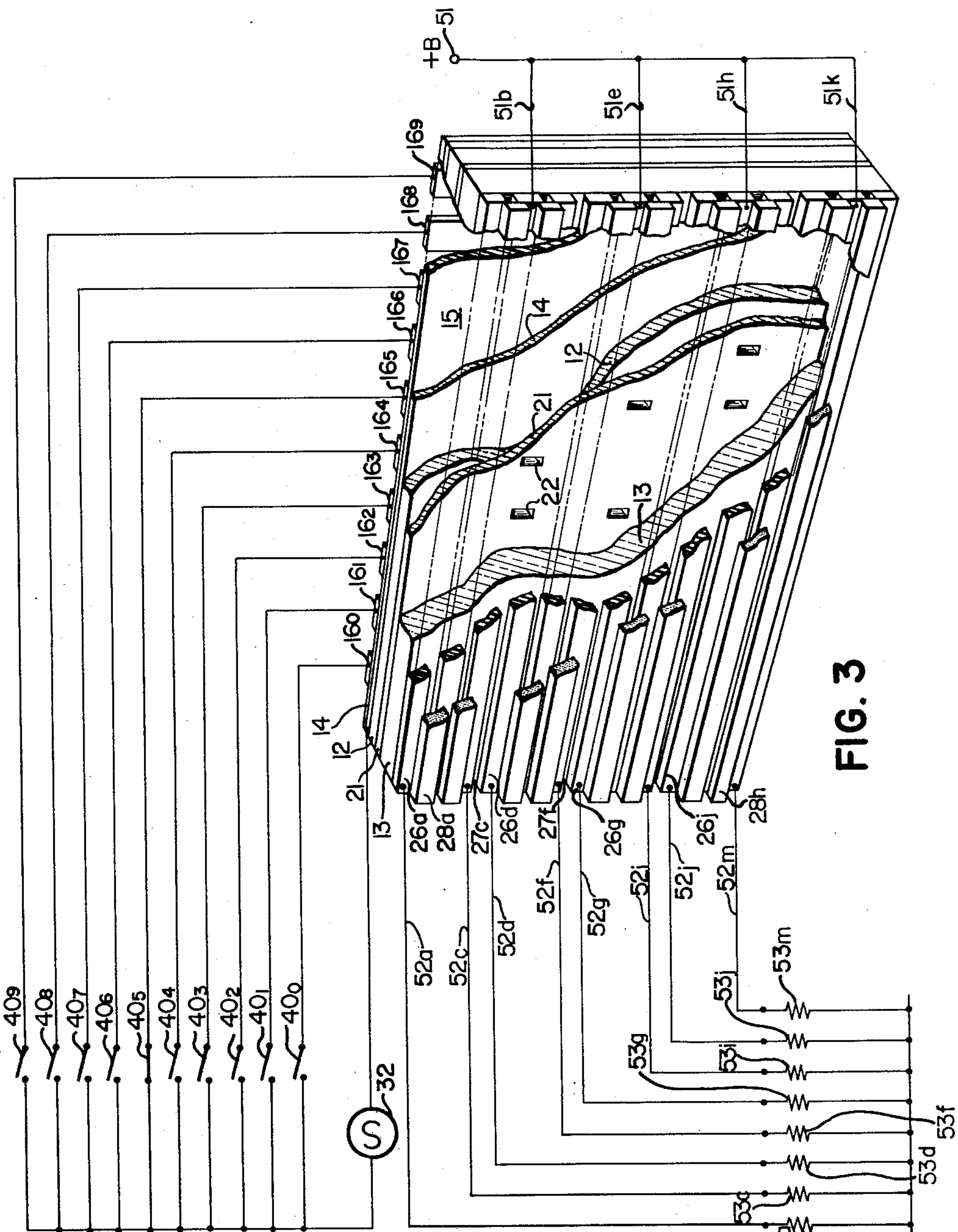

FIG. 3

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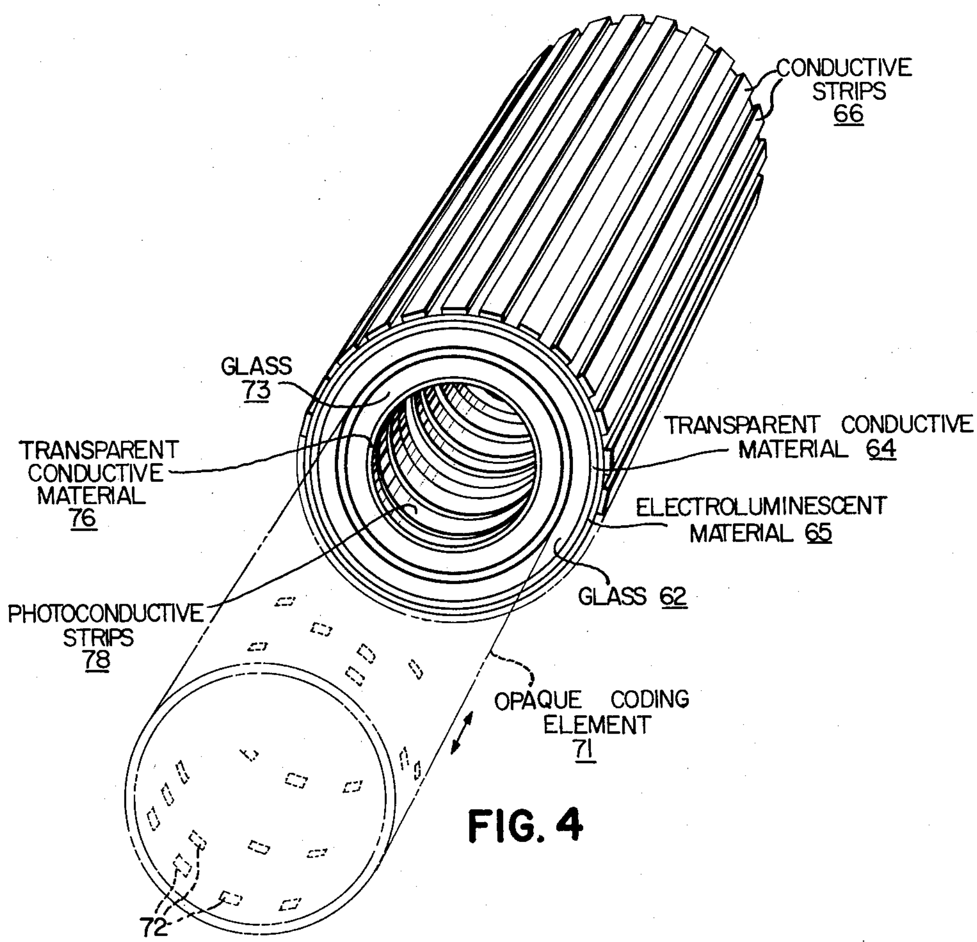

FIG. 4

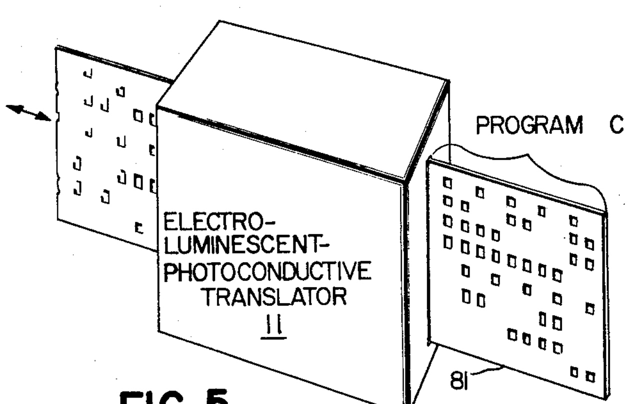

FIG. 5

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ELECTRO-OPTICAL TRANSLATOR

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10 Claims. (Cl. 340—347)

This invention relates in general to electro-optical translators and relates more particularly to such translators utilizing electroluminescent materials and photoconductive materials.

The present invention contemplates a translating device in which the information or data to be translated is converted to variations in the luminescence of discrete elements of an electroluminescent material, and these luminescent variations are sensed by photoconductive elements through coded openings in an opaque coding element which is disposed between the electroluminescent material and the photoconductive material. The elements of electroluminescent material are preferably in the form of generally parallel strips which are selectively excitable under the control of the information to be translated. Each of these strips is in registry with the corresponding series of coded openings in the coding element, so that the output from the coding element is a group of one or more light pulses from those openings which are in registry with the luminescing strip or strips. These light pulses are the code representation of the information being translated, and are projected onto the photoconductive material.

The photoconductive material is preferably in the form of generally parallel strips extending in a direction perpendicular to the direction of extension of the electroluminuescent strips and in registry with the coded openings. Those photoconductive strips which receive light pulses from the coded openings undergo a substantial resistance change by virtue of their photoconductive properties, and this resistance change is sensed to produce an output from the translator. The structure of the present invention is preferably of unitary form with the opaque coding element interposed between the electroluminescent material and the photoconductive material, and the entire structure may be disposed in an opaque enclosure. The translator of the present invention has a number of different applications, such as a decimal-to-binary or binary-to-decimal converter, a "read-only" memory or a programmer for programming some type of apparatus in response to a program represented by coded openings in the coding element.

It is therefore an object of this invention to provide an improved electro-optical translator.

It is a further object of the present invention to provide an improved electro-optical translator utilizing electroluminescent materials.

It is an additional object of the present invention to provide an electro-optical translator in which the input information is converted to variations in the luminescence of an electroluminescent material and these variations are sensed by photoconductive elements through coded openings in an opaque coding element.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings which disclose, by way of example, the principle of the invention and the best mode which has been contemplated of applying that principle.

In the drawings:

FIG. 1 is an exploded perspective view illustrating the structure of a translator in accordance with the present invention;

FIG. 2 is an elevational view in cross section illustrating the assembly of the device shown in FIG. 1;

FIG. 3 is a perspective view, partly in section, illustrating the device of FIGS. 1 and 2 with electrical connections thereto to function as a decimal to binary converter;

FIG. 4 is a perspective view of a translator in accordance with the present invention in cylindrical form; and

FIG. 5 is a perspective view of an alternative embodiment of the present invention for programming apparatus in response to a program represented by coded openings in a moving coding element.

Referring to FIG. 1 by character reference, there is shown in exploded form a translator 11 of generally rectangular form. The translator includes a pair of plate members 12 and 13 of glass or other transparent substrate material, such as mica, which form the body of the structure on which the electrominescent and photoconductive materials are supported. Member 12 is provided on one surface with a layer 14 of transparent, electrically conductive material such as stannic oxide. A layer 15 of electroluminescent material, such as ZnSCu, is disposed on transparent conductive material 14, and electroluminescent material 15 is overlaid with spaced strips 16 of electrically conductive material such as silver or aluminum. The elements 14, 15 and 16 form the means for converting information into variations in the luminescence of the electroluminescent material 15. Although the operation will be described in more detail below, it will be clear at this point that by supplying electrical currents to selected ones of the electrically conductive strips 16, the portions of the electroluminescent layer 15 underlying these strips will luminesce and this luminescence will be projected through the transparent conductive layer 14 and the transparent member 12.

An opaque coding element 21 is disposed between plates 12 and 13 and is provided with a plurality of coded openings 22 for selectively passing light produced by the luminescence of material 15 through plate 13 to the photoconductive elements. The locations of coded openings 22 in the opaque member 21 will depend upon the particular code being used in the conversion, and it will be understood that the positions of these openings may be varied in accordance with the particular code utilized. It is also understood that this code element may be fabricated in various forms, such as photographic film, punched cards, hard enameled transparent plastic forms and the like, and may be fixed, movable or replaceable. It is also understood that the code element may be a matrix of ferroelectric light gates such as barium titanate to permit electronic control of the code element configuration. Plate 13 is backed by a plurality of strips 26 of a suitable photoconductive material such as cadmium selenide or cadmium sulfide. Member 13 is provided on its surface opposite to coding element 21 with a plurality of conductive strip electrodes, *26a* through *26m*, which extend across member 13 in a direction perpendicular to the direction of the conductive strips 16. Conductive strips 26 may be formed on member 13 by any suitable method, such as by evaporation of platinum, zinc or silver, or preferably by forming separate transparent SnO_2 strips on the member 13 to provide the electrical insulating spaces *27a* through *27k* between these strips as shown. Transparent conductive strips 26 are best formed by first depositing a layer of transparent conductive material on the entire surface of member 13 and then sandblasting or acid etching the parallel grooves to form the insulating gaps 27.

Conductive strips 26 are overlaid by strips *28a* through *28h* of photoconductive material which extend in the same direction as the transparent conductive strips 26. As shown in FIG. 2 for this embodiment, each of photoconductive strips 28 is positioned so as to span one of the grooves 27 between adjacent transparent conductive strips 26. Thus, each of the photoconductive strips 28 is electrically connected to two adjacent transparent conductive strips 26, while each of the transparent conductive strips 26 is electrically isolated from the others by one of the grooves 27. In some embodiments it may be desirable to isolate both electrodes of each photoconductor strip.

All of the elements of the translator may be disposed closely adjacent each other as illustrated in FIG. 2, and the entire assembly may be enclosed in a suitable opaque enclosure 30. Enclosure 30 may be, for example, an opaque plastic material in which the translator assembly is encapsulated after assembly of the components.

The electrical connections to the different elements of the translator are best illustrated in FIG. 3, which is a perspective view, partly in section, of the device of FIGS. 1 and 2, utilized as a decimal to binary converter. In FIG. 3, opaque enclosure 30 has been removed for purposes of clarity, but it will be understood that in practice this enclosure would be provided to shield the device from ambient light. In the embodiment of FIG. 3 it is assumed that a decimal digit is to be converted to binary form utilizing a well known binary code employing the code elements 1, 2, 4, 8 and $\bar{1}$, $\bar{2}$, $\bar{4}$, $\bar{8}$. The decimal digit to be converted is entered into the system by means shown schematically as switches 40_0 through 40_9. Switches 40_0–40_9 may be mechanical switches which are selectively closed to represent the particular decimal digit associated therewith, or these switches may be photoconductors or any other type of switching elements capable of being selectively energized in response to the desired decimal digit.

One terminal of each of the switches is connected to an associated one of the conductive strips 16 which are numbered 16_0 through 16_9 to show their association with the different digits. The other terminals of the switches are connected in common to one terminal of a current source 32. The other terminal of source 32 is connected to the transparent conductive layer 14 which underlies electroluminescent layer 15 and the conductive strips 16. It will be seen that when one of switches 40_0–40_9 is closed, current will flow from source 32 through this closed switch to the associated one of the conductive strips 16, then through the portion of the electroluminescent material 15 which is directly under this conductive strip to the transparent conductive layer 14 and back to the other terminal of source 32. The electroluminescent material 15 thus has current flow therethrough in the portion thereof directly underlying the conductive strip 16 through which current is flowing. Material 15 will thus luminesce only in the area immediately underlying the energized one of conductive strips 16, to produce a strip of luminescence corresponding to the configuration of the energized conductive strip 16.

Assume that switch 40_5 has been closed, representing the decimal digit 5, thus producing current flow through the conductive strip 16_5 and producing a strip of electroluminescence in the portion of electroluminescent layer 15 immediately underlying conductive strip 16_5. This electroluminescence is projected through transparent conductive member 14 and member 12 to the column of coded openings 22 representing the digit 5 in the coding element 21.

The disposition of the openings 22 in the "5" column of coding element 21 will depend upon the particular code being utilized, but regardless of what code is employed, the light from the luminescing strip will be projected through these openings to produce one or more discrete light pulses representing the code for that particular digit. These coded light pulses pass through member 13 and transparent conductive material 26 to selectively fall upon the photoconductive strip or strips 28.

As shown in FIG. 3, the photoconductive strips 28 are connected to a source of electrical current represented by the B+ terminal 51. This may be an A.C. or D.C. source and has no electrical coupling to the electroluminescent power source. Current from terminal 51 is supplied through four parallel paths 51_b, 51_e, 51_h, 51_k to the ends of four common photoconductor electrode strips 26_b, 26_e, 26_h, 26_k. The other ends of the other eight conductive electrode strips 26_a, 26_c, 26_d, 26_f, 26_g, 26_i, 26_j, 26_m are connected to a series of external circuit conductors 52_a, 52_c, 52_d, 52_f, 52_g, 52_i, 52_j, 52_m. Each of conductors 52 is thus connected to a transparent conductive strip 26 at a point which is separated from any point of input connection 51 by one of the insulating gaps 27. Thus, current can flow between conductors 51 and conductors 52 only through one of the photoconductive strips 28. Current from each of conductors 52 goes through an associated load which is shown in this embodiment as resistors 53_a, 53_c, 53_d, 53_f, 53_g, 53_i, 53_j, 53_m. This load however could be an electroluminescent element, a transistor, a neon lamp or the grid of a vacuum tube. The other terminals of resistors 53 are connected in common to a return for the B+ source 51. Resistors 53 represent one form of output device across which the binary coded output signals appear for subsequent utilization.

In the absence of light pulses on the photoconductive strips, the full supply voltage appears across each of the photoconductor strips owing to their extremely high, dark impedance. When a photoconductor strip is illuminated, its impedance decreases and a voltage V_L appears across the load according to the formula

$$V_L=\frac{Z_{pc}.E}{Z_{pc}+Z_L}$$

where: V_L=voltage across the load; Z_{pc}=the photoconductor impedance; Z_L=the load impedance; and E=the supply voltage.

From the above description, again assuming that the decimal digit 5 is to be converted to binary form in accordance with the particular code shown, it will be seen that the discrete light pulses projected through the coded openings 22 in response to luminescence of the strip of luminescent material 15 underlying conductive strip 16_5 will fall on those photoconductive strips 28 which are in registry with the coded openings. The receipt of these light pulses by the photoconductive strips produces a significant change in the resistance of the photoconductive strip to produce a large voltage swing across the associated load resistor 53. These voltage swings are sensed by the utilization apparatus such as neon indicator lamps or electroluminescent elements (not shown), to provide an indication of the binary representation of the particular decimal digit being converted. It is understood that the load may be the input to other optoelectronic devices.

FIG. 4 illustrates an alternative embodiment of the present invention in which the translator has a cylindrical shape. The device of FIG. 4 contains the same elements shown in the embodiment of FIGS. 1, 2 and 3, and these elements function in the same manner described in connection with the above embodiment. The device of FIG. 4 includes a plurality of strips 66 of a conductive material which are similar in function to the strips 16 in the above embodiment. The strips 66 are spaced apart from each other around the periphery of a cylinder and each of the strips extends longitudinally of the axis of the cylinder. A layer of electroluminescent material 65 is disposed under the conductive strips 66 and corresponds to the electroluminescent layer 15. Electroluminescent layer 65 is underlaid by a transparent conductive layer 64 which rests on a transparent glass or mica base 62.

The photoconductive portion of the apparatus of FIG. 4 includes a plurality of strips of photoconductive material 78 disposed around the inner surface of the cylinder and extending in a direction perpendicular to the direction of extension of the conductive strips **66**. Photoconductive strips **78** span insulating gaps between adjacent strips of a transparent conductive material **76** which in turn rests on a transparent glass or mica member **73**. The insulating gaps are similar to gaps **27** of FIGS. 1, 2 and 3 and serve to provide electrical insulation between adjacent strips of material **76**.

The space between cylindrical members **62** and **73** is occupied by a cylindrical opaque coding element **71** which is similar in function to the coding element **21** of the above described embodiment. Coding element **71** is preferably freely insertable in and removable from the space between members **62** and **73** so as to facilitate the use of different coding elements **71** in the programmer. Coding element **71** is provided with a plurality of coded openings **72** which serve to encode the light produced by luminescent material **65** into light pulses for transmission to the photoconductive strips **78**. It will be understood that in practice the device will be enclosed in an opaque enclosure to provide shielding from ambient light.

When suitable electrical connections (not shown) are made to the device of FIG. 4 in a manner similar to that shown in FIG. 3, the device may be utilized as a decimal-to-binary or binary-to-decimal converter as in the embodiment of FIGS. 1, 2 and 3. Alternately, the device may serve as a "read only" memory with the memory stored in the openings **72** in coding element **71** and read out therefrom when the associated electrical circuits are energized or addressed. It will be understood that different coding elements **71** may be utilized to vary the "memory" stored in the device.

FIG. 5 illustrates an additional embodiment of the present invention utilized as a programming device. The translating device **11** of FIG. 5 is similar to that shown in FIGS. 1, 2 and 3, except that the coding element in the embodiment of FIG. 5 is in the form of a movable member **81** which is movable through the space between members **12** and **13**. Coding element **81** contains a plurality of separate programs, such as program C shown, each program comprising a plurality of coded openings which are in registry with the electroluminescent and photoconductive members when the program is positioned in device **11**. Coding element **81** may be advanced in steps by suitable means (not shown), with each separate step presenting a different program to the translator. With the appropriate electrical connections to the translator input electroluminescent strips, the output from the photoconductive strips may be utilized to control or program some equipment as a function of the different programs represented by the different openings in element **81**.

As an example, format control of a printer coupled to an accounting machine may be effected by commutating through the electroluminescent strips which in this case would correspond to different specific line positions on a given form. The coded mask would contain the information corresponding to the addresses of data stored in the accounting machine registers to be printed in specific fields or columns on the form. Accordingly, the translator photoconductor outputs would gate specific data registers and also operate on the printer horizontal and vertical tab controls to effect the printing of specific data, such as quantity or unit price, in appropriate fields or columns on the form. Changing forms would require a change in code mask. This is analogous to changing plug boards or plug board wiring on some typical present accounting machines, and represent a major improvement over this technique.

From this it becomes apparent that other plug board functions may be performed using this typical solid state translator technique. Other examples are computer subroutine programming or stored program computer plug board functions.

Computer subroutine programming may be illustrated by the following example: Let each electroluminescent strip correspond to a program step and the photoconductor strips correspond to specific register and control gates. To add "A" and "B" and store the results in "C," the code mask in step 1 would contain a code instruction to reset the accumulator "C" through a translator output photoconductor control gate; next, commutating to EL strip 2 would scan the data stored in the code mask which would transfer the contents of "A" register to "C" register; stepping to EL strip 3 would result in the transfer of the contents of register "B" to register "C," thus giving the results "A" and "B" in "C" as required. Step 4 might contain control instructions to transfer the contents of register "C" to an output printer, etc.

While there have been shown and described and pointed out the fundamental novel features of the invention as applied to the preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the device illustrated and in its operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. An electro-optical translator for converting a first signal to another signal in accordance with a given conversion code comprising an electroluminescent member, a plurality of strip members overlying said member for producing electroluminescence of selected strips of said electroluminescent member as a function of said first signal, an opaque coding element having openings therein corresponding to said conversion code disposed adjacent said electroluminescent member for modulating said selected electroluminescence in accordance with said conversion code between said first signal and said second signal, and a photoconductive material having different areas thereof responsive to said modulated electroluminescence for producing an output signal representing said second signal.

2. An electro-optical translator for converting a first signal to another signal in accordance with a given conversion code comprising an electroluminescent member, a plurality of electrically conductive strip members overlying said member, means for selectively energizing said strips as a function of said first signal to produce electroluminescence of selected strips of said electroluminescent member, an opaque coding element having openings therein corresponding to said conversion code disposed adjacent said electroluminescent member for modulating said selected electroluminescence in accordance with said conversion code between said first signal and said second signal, and a photoconductive material having different areas thereof responsive to said modulated electroluminescence for producing an output signal representing said second signal.

3. An electro-optical translator for converting a first signal to another signal in accordance with a given conversion code comprising an electroluminescent member, a plurality of generally parallel electrically conductive strips overlying said member, means for selectively energizing said strips as a function of said first signal to produce electroluminescence of selected portions of said electroluminescent member, an opaque coding element having openings therein corresponding to said conversion code disposed adjacent said electroluminescent member for modulating said selected electroluminescence in accordance with said conversion code between said first signal and said second signal, and a plurality of parallel strips of photoconductive material extending normal to said conductive strips and responsive to said modulated electroluminescence for producing an output signal representing said second signal.

4. An electro-optical translator for converting a first signal to another signal in accordance with a given conversion code comprising a cylindrical electroluminescent member, a plurality of electrically conductive members overlying said member, means for selectively energizing said strips as a function of said first signal to produce

electroluminescence of selected strips of said electroluminescent member, an opaque coding element disposed adjacent said member and having openings for modulating said selected electroluminescence in accordance with said conversion code between said first signal and said second signal, and a plurality of strips of photoconductive material disposed adjacent said openings and responsive to said modulated electroluminescence for producing an output signal representing said second signal.

5. An electro-optical translator for converting a first signal to a second signal in accordance with a given code comprising an electroluminescent member, means for producing electroluminescence of selected areas of said electroluminescent member in response to said first signal, an opaque coding element disposed adjacent said electroluminescent member and having coded openings therein in registry with different areas of said electroluminescent material for transmitting light from said electroluminescent material in accordance with said code, a photoconductive material disposed on the opposite side of said coding element from said electroluminescent material and having a plurality of separate photoconductive elements in registry with said openings for receiving said transmitted light, and means responsive to changes in the electrical characteristics of said photoconductive elements as a result of receipt of said transmitted light for producing an indication of said second signal.

6. An electro-optical translator for converting a first signal to another signal in accordance with a given code comprising a cylindrical electroluminescent member, means for producing electroluminescence of selected areas of said electroluminescent member in response to said first signal, a cylindrical opaque coding element disposed adjacent said electroluminescent member and having coded openings therein in registry with different areas of said electroluminescent member for transmitting light from said electroluminescent member in accordance with said code, a cylindrical photoconductive member disposed on the opposite side of said coding element from said electroluminescent member and having a plurality of separate photoconductive elements in registry with said openings for receiving said transmitted light, and means responsive to changes in the electrical characteristics of said photoconductive elements as a result of receipt of said transmitted light for producing an indication of said second signal.

7. An electro-optical translator for converting a first signal to another signal in accordance wtih a given code program for programming an output device comprising an electroluminescent member, means for producing electroluminescence of selected areas to said electroluminescent member in response to said first signal, a movable coding element having a plurality of different programs thereon which are separately disposable adjacent said electroluminescent member, each of said programs comprising a plurality of coded openings which are in registry with different areas of said electroluminescent member for transmitting light from said electroluminescent member in accordance with said program, a photoconductive material disposed on the opposite side of said coding element from said electroluminescent member and having a plurality of separate photoconductive elements in registry with said openings for receiving said transmitted light, and means responsive to changes in the electrical characteristics of said photoconductive elements as a result of receipt of said transmitted light for producing an output signal.

8. An electro-optical translator for converting a first signal to another signal in accordance with a given code comprising an electroluminescent member, a plurality of parallel electrically conductive strips overlying said member, means for selectively energizing said strips as a function of said first signal to produce electroluminescence of selected areas of said electroluminescent member underlying said strips, a coding element disposed adjacent said electroluminescent member and having coded openings therein in registry with different areas of said electroluminescent member for transmitting light from said electroluminescent member in accordance with said code, a plurality of strips of photoconductive material disposed on the opposite side of said coding element from said electroluminescent material and extending in a direction normal to said conductive strips, each of said photoconductive strips being in registry with some of said openings for receiving said transmitted light, and means responsive to changes in the electrical characteristics of said photoconductive elements as a result of receipt of said transmitted light for producing an indication of said second signal.

9. An electro-optical translator for sequentially carrying out the instructions of a program comprising an electroluminescent member, a plurality of generally parallel electrically conductive strips overlying said member and corresponding to the steps of said program, means for selectively energizing said strips as a function of said program to produce electroluminescence of selected portions of said electroluminescent member, an opaque coding element having openings therein corresponding to said program disposed adjacent said electroluminescent member for modulating said selected electroluminescence in accordance with said program instructions, and a plurality of parallel strips of photoconductive material extending normal to said conductive strips and responsive to said modulated electroluminescence for producing an output signal in accordance with said program.

10. An electro-optical translator for converting a first signal to another signal in accordance with a given conversion code comprising an electroluminescent member, a plurality of strip members overlying said member for producing electroluminescence of selected strips of said electroluminescent member as a function of said first signal, a plurality of ferroelectric light gates for controllably modulating said selected electroluminescence in accordance with said conversion code between said first signal and said second signal, and a photoconductive material having different areas thereof responsive to said modulated electroluminescence for producing an output signal representing said second signal.

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