ABSTRACT
The present invention is directed to a printer and display system wherein the images from an optical character generator are directed along two separate optical paths. A planar light-to-heat transducer element is positioned in one of the optical paths to intercept the generated character images for thermal printing a permanent reproduction of the intercepted characters. A visual display is positioned in the other optical path to intercept the generated character images for forming viewable images of the generated character images.

15 Claims, 12 Drawing Figures
PRINTER AND DISPLAY SYSTEM

BACKGROUND OF THE INVENTION

In business machines, such as cash registers, there exists a need for providing a visual display of the price of each item and of the totals along with a sales slip for use by the vendor and the customer. In the past the printing mechanisms which prints the sales slips has been electromechanical in nature and has required relatively large amounts of power to operate. Due to recent advances in the electronic arts, there has been a trend by business machine manufacturers towards substituting electronic circuits for mechanical parts whenever practical. The printer section of the business machine has been one of the mechanical units which has been found to be difficult to replace. Although a variety of electro-optic devices, such as gaseous discharge display panels, have been used for the visual display, hammer type printers are still commonly utilized for making the permanent copies. In certain select applications thermal printers have been used to eliminate the mechanical hammers. Because the driving requirements of electro-optic display devices differ greatly from those of either the mechanical hammer printer or the thermal printer, separate driving systems have been required for each of these units. A system which could merge the driving requirements of the printer and visual display while still providing a display similar to the gas discharge or other electro-optic type displays would be highly desirable in that such a merging would provide not only a cost reduction but a reduction in weight and the total number of components used per system. Additional and significant improvement is realized if the power requirements of the logic and control circuitry is compatible with state of the art integrated circuits.

Examples of prior art visual display devices can be found in U.S. Pat. No. 3,690,745 by D. Jones, entitled "Electro-Optical Devices Using Lyotrophic Nematic Liquid Crystals," and in U.S. Pat. No. 3,703,331 by J. E. Goldmacher, entitled "Liquid Crystal Display Element Having Storage." The devices of these prior art patents utilize a thin cell containing a liquid crystal. The Jones patent additionally utilizes a standard seven bar electrode arrangement for generating numeric images. The Goldmacher device utilizes a matrix of elements, which matrix would theoretically be capable of generating both numeric and character images.

A prior art field effect liquid crystal shutter device is described in U.S. Pat. No. 3,700,306 by Cartmell, et al., entitled "Electro-Optic Shutter Having A Thin Glass Or Silicon Oxide Layer Between The Electrodes And The Liquid Crystal," which patent is assigned to The National Cash Register Company, the assignee of the present application.

The present state of the art in electronic displays has been summarized in an article entitled "Electronic Numbers" authored by Alan Sobel, which appeared in Scientific American, June 1973, Volume 228, Number 6, Pgs. 64–73.

A thermal type printer particularly adaptable to business machines is disclosed in U.S. Pat. No. 3,631,512, entitled "Slave Printing Apparatus" by J. L. Janning, which patent is assigned to The National Cash Register Company, the assignee of the present application. In one embodiment disclosed in that patent, a first matrix of light sources may be selectively energized to produce a desired character pattern. A second matrix of semiconductor areas is positioned with respect to the first matrix such that each semiconductor area receives the light from a corresponding light source. Pairs of conductors, positioned on opposite edges of each semiconductor area, sense the decrease in resistivity in a light actuated semiconductor area, causing an increased current to flow through the semiconductor area which increased current is used to heat a resistance element that is positioned in proximity to a thermal sensitive medium.

From the foregoing description of the prior art it can be seen that the need exists for a business machine which uses low power and a minimum number of mechanical parts to provide both a visual display and a printout.

SUMMARY OF THE INVENTION

The present invention is directed to a system having a printer and visual display utilizing a common optical character generator for providing a temporary and a permanent record of the generated characters. The system is particularly adaptable for use with low power integrated circuits.

In one preferred embodiment of the invention, finding particular utility in a business machine, the optical character generator is comprised of a light source and an electro-optical cell wherein character images are formed by changing the polarization characteristics of a liquid crystal which is interposed between character electrodes. A polarizer interposed between the light source and the electro-optical cell polarizes the light from the source before it impinges on the liquid crystal cell. An analyzer positioned to receive the polarized light passing through the cell provides an output (passes light) which has the correct polarization angle and stops all other light. The polarization angle of the light passing through the liquid crystal is controlled by applying a potential across selected conductors in the cell. The light beam from the analyzer is then directed to a beam splitter element, which element provides as an output two separate beams having identical characteristics. One of the beams is fed to a photothermographic element, which element is used in conjunction with a thermal sensitive material to provide a permanent copy. The other beam is directed to a viewing screen for direct viewing. Means are also provided for activating selected electrodes in the electro-optical cell to form desired characters which means are under the control of an operator.

In a second embodiment of the present invention, a matrix of light emitting diodes are connected in circuit to an operator selector element which element activates selected diodes in response to the operators request so as to form character light images. The light from the activated diodes is directed to the beam splitter to provide the two separate output beams.

From the foregoing it can be seen that it is a principal object of the present invention to provide an improved business machine.

It is another object of the present invention to provide a printer and visual display utilizing an optical character generator. It is a further object of the present invention to provide a means for activating a visual display and printer. These and other objects of the present invention will become more apparent when taken in conjunction with the following description and drawings, throughout
which like reference characters indicate like parts and which drawings form a part of this application

**BRIEF DESCRIPTION OF THE DRAWINGS**

FIG. 1 is a block schematic diagram of one preferred embodiment of the present invention.

FIGS. 2A, 2B, and 2C are front, back and a sectioned side view of an electro-optical cell which may be used in the embodiment of FIG. 1.

FIGS. 3A and 3B are a top view and a sectioned view of a photothermographic element which may be used in the embodiment of FIG. 1.

FIGS. 4A and 4B are a bottom view and a sectioned view of a second photothermographic element which may be used with the preferred embodiment of FIG. 1.

FIG. 5 is a top view of a photothermographic element which may be used in the preferred embodiment of FIG. 1.

FIG. 6 is a block diagram of a second embodiment of the invention.

FIG. 7 is the front view of an optical element which may be used with the embodiment of FIG. 6; and

FIG. 8 is a perspective view of a business machine wherein the embodiments of FIG. 1 and FIG. 6 find particular utility.

**DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Referring to FIG. 1, a light source 10, such as a tungsten bulb, powered by the power supply 26, provides a beam of light to a lens 12. The lens 12 focuses the provided beam of light onto a polarizer 14. The polarizer polarizes the received beam in a preferred plane. The polarized beam is then directed to an electro-optical cell 20 which may be of the field effect twisted nematic type.

A character selector 25, connected to the power supply 26, in response to operator-activated keys 39, provides a voltage to selected areas of the electro-optical cell 20 so as to select a desired character. The voltage remains applied to the selected areas until the operator presses a "clear" key. Means for accomplishing this function are well within the state of the art and are not shown for purposes of clarity.

Cell 20 rotates the incident polarized light by a predetermined angle, generally 90°, when there is no power applied to the cell. Under the control of element selector 25 portions of the cell have an electric field applied across the liquid crystal and no longer rotate the polarized light. An analyzer 27 is positioned to absorb the rotated polarized portions of the polarized beam from the electro-optical cell 20 and to transmit the nonrotated portions of the polarized beam.

The beam from analyzer 27 is directed to a beam splitting element 29, which may be a partially silvered mirror. A portion of the transmitted beam is reflected from the beam splitter 29 on to mirror 30, with the remaining portion of the beam passing through the beam splitter to a lens 32. Lens 32 focuses the beam onto a photothermographic element 33.

The character selector 25 has an output connected to a photothermographic element power supply 37. The photothermographic element power supply 37 is connected to the thermographic element 33 to provide an activating voltage to the element 33 in response to a print command from the character selector 25. In operation, power is applied to element 33 for a fixed period of time, approximately 500 milliseconds, by the photothermographic element power supply 37 in response to the depression of a printout key on the character selector 25. The photothermographic element 33 provides a heated pattern corresponding to the image received from lens 32.

A thermal sensitive material 40 is positioned adjacent the heated areas of element 33 for recording the generated heat image. The period of time that a voltage is applied to element 33 is dependent somewhat on the response time of the thermal sensitive material, but in the preferred embodiment a 500 millisecond period provided satisfactory results.

The beam imaged onto mirror 30 is reflected to a lens 42, which lens focuses the beam to a viewing screen 45. The viewing screen may be made from any of a number of light scattering surfaces such as etched glass.

Referring to FIGS. 2A, 2B and 2C for a detailed description of the electro-optical cell 20, a glass front plate 21 has deposited thereon sector electrodes 22 in a common numeric configuration which electrodes are transparent to light. Conductors 23 connect each of the electrodes 22 to conductive tabs 15a. A glass rear plate 24 has deposited thereon a common electrode 26 formed from a light-transparent conductive material such as tin oxide, connected by a conductor 28 to a tab 15b. The tabs 15a and 15b are connected in circuit to the character selector 25. The two plates 21 and 24 are positioned parallel to each other and are spaced apart by a spacer 34. The plates and spacer are sealed together by a sealer 31 so as to form a cavity. A nematic liquid crystal material 36 fills the cavity and is in electrical contact with the electrodes 22 and 26.

The type of liquid crystal cell used in the preferred embodiment of this invention is of the Twisted Nematic Field Effect Type (sometimes called Bilevel). A basic description of the liquid crystal cell is set forth by M. Schadt and W. Helfrich, in Applied Physics Letters 18 127 (1971).

The liquid mixture used in these cells has a positive dielectric anisotropy — that is when an electric field is applied across the liquid crystal the molecules tend to line up with their long axes parallel to the field direction.

The composition of the nematic liquid crystal mixture for the filed effect cell used was 40% p-methoxybenzilidine-p'-butylaniline (MBBA) 40% p-ethoxybenzilidine-p'-butylaniline (EBBA) 20% p-butoxybenzilidine-p'-aminobenzonitrile.

This mixture acts as a liquid crystal in a temperature range from 10°C to 70°C.

A field effect cell with this mixture will undergo an electro-optic switching at about 4–12 volts of alternating field. The distance between electrodes is about 0.5 mil. The current is in the range of microamps per character, and the display is readily operated directly from MOS integrated circuits with no amplification.

The size of the liquid crystal cell is not critical. For the direct reading of a number ~1/4 inch height is desirable, in the display. Actual cell dimensions would be typically 1 inch height and a width of 0.8 inch times the number of characters +1. (0.8 inch X (1/n+1)). In operation, selected ones of the electrodes 22 and the common electrode 26 have a potential applied therebetween. The potential is selected so as to either eliminate or change the amount of angular rotation which occurs to the polarized light. Because the field
is localized between the selected electrodes 22 and the common electrode 26, only those portions of the liquid crystal material located between the aforementioned electrodes will be affected. Therefore, by adjusting the angular position of the polarizer 14 and the analyzer 27, the light transmitted through the liquid crystal material between the electrically activated electrodes will be of a different intensity from the light transmitted through the electrodes where no electrical field is applied. Depending on this adjustment, either a light digit on a dark background or a dark digit on a light background can be transmitted.

In the present embodiment, printing at the photothermographic element is light activated so a light digit is the preferred configuration.

Referring to FIGS. 3A and 3B simultaneously, the photothermographic element 33 is shown comprised of a glass substrate 50 on which is formed two conductors 52 and 53. The conductors 52 and 53 are configured to be substantially parallel to each other throughout the plane of the element. A photoconductive material 51 is deposited over and between the conductors. In operation, a potential is applied to conductors 53 and 52 so as to create a field between the conductors. Light impinging on the photoconductive material located between the conductors causes a decrease in resistivity which in turn causes a localized current to flow between conductor 52 and 53, which localized current causes a localized heating. By adjusting the spacing and the number of parallel paths per cross-sectional area of the element the resolution of the localized heat patterns can be increased or decreased as desired.

Referring to FIGS. 4A and 4B, a second photothermographic element is disclosed wherein a glass substrate 55 has deposited thereon a mesh configured electrode 56 having a plurality of openings 59 defined thereby. A photoconductive material 57 is deposited onto the electrode 56 and into the defined openings 59. An electrode 58 is deposited onto the photoconductive material 57. In operation, a potential is formed between electrodes 56 and 58. Light traversing electrode 56 and impinging on photoconductive material 57 changes the resistivity of the photoconductive material causing current to flow between conductors 56 and 58 in a localized pattern, which current causes a localized heating of electrode 58. Electrode 58 is positioned in close proximity to the thermal sensitive material 40 so as to effect a transfer of the localized heat pattern.

Referring to FIG. 5, another photothermographic element which may be used with the preferred embodiments of the invention is shown formed from a glass substrate 60 onto which are deposited an electrode 62 and an electrode 63. A photoconductive material 61 is deposited over and between the electrodes. Potentials are applied to the electrodes 62 and 63 by means of conductors 64 and 65, respectively. Conductors 64 and 65 are connected in circuit to the photothermographic element power supply 37. When activated by a printout signal from the character selector 25, a potential field is created in the areas 66 between the electrodes 62 and 63. Potential fields will occur in other areas, but no light should impinge in those areas. The area 66 (between the electrodes) is a substantial duplicate of the area formed by the seven bar elements 22 used in the electro-optical cell 20.

In operation, light transmitted through the electro-optical cell 20 impinges on the corresponding areas between the electrode 62 and the electrode 63, causing a change in the resistivity of the photoconductive material, which change increases the current flowing through the photoconductive material within the areas onto which the light impinges, thereby causing localized heating of these areas. The thermal sensitive material 40 is positioned adjacent the heated areas to allow the heat formed image to be transferred to the material 40.

Referring to FIGS. 6 and 7, an array 70 of light emitting diodes 73 is used to generate a light pattern corresponding to an operator-selected character. Conductors 74 and 75 connect each of the diodes 73 to the character selector 25 in the well-known matrix configuration. The operator-selected keys 39 apply the proper potentials to the column and row conductors of the matrix so as to cause the diodes 73 connected at the cross-over points of the selected row and column electrodes to emit light. The light image formed by the array 70 is transmitted to the beam splitter 29. The beam splitter 29 reflects a portion of the beam onto a mirror 30 with the remaining portion of the beam being passed through to lens 32. Lens 32 then directs and focuses the image onto the photothermographic element 33 similar to the first embodiment. Element 33 is activated by the photothermographic element controller 37 for printing out the image onto the thermal sensitive material 40. Mirror 30 reflects the other beam to lens 42. Lens 42 in turn focuses the image onto the viewing screen 45.

FIG. 8 illustrates a business machine (transaction terminal) wherein the viewing screen 45 is mounted for easy customer viewing and the thermal sensitive material 40, which may be a sales receipt, is shown ready for dispensing to the customer. The operator-selected key-board 39 is shown mounted in an easily accessible position on the business machine.

An amount of heat used to make the print will vary depending on the voltage across the photothermographic element and the time allowed for the print cycle assuming the light is a constant. For an interdigital photothermographic element with 3 mil electrodes and 6 mil spacing (FIG. 3), typical figures would be:

Voltage across element approximately 25 volts (AC) Illumination approximately 200 foot candles Printing cycle time approximately 500 milliseconds

The above figures can be varied considerably but are interdependent. Print resolutions of about 6 line pairs per millimeter have been obtained with this type of cell.

The print size would most likely be the same as that of a typewriter or an adding machine (approximately % inch height, 1/10 inch width, per character). Good resolution has been obtained in prints of this size. Characters of larger sizes could be printed. The resolution is dependent on both printing cycle time and electrode configuration. Special purpose electrodes (FIG. 5) should give excellent resolution and print sharpness because:

a. They are “matched” to the liquid crystal and the electrodes act as light masks.

b. The large electrodes act as heat sinks.

While there have been shown what are considered to be the preferred embodiments of the invention, it will be manifest that many changes and modifications may be made therein without departing from the essential spirit of the invention. It is intended, therefore, in the annexed claims, to cover all such changes and modifi-
What is claimed is:

1. Apparatus comprising, in combination:
   means for forming light images;
   means for directing said light images along at least two optical paths;
   transducer means intercepting the image in one of said optical paths for transforming said image into a corresponding heat image capable of being transferred to a heat sensitive record material;
   said transducer means comprised of:
   an optically transparent substrate;
   a plurality of electrodes adapted to receive an electrical potential therebetween positioned on said optically transparent substrate, in a pattern which outlines a desired composite character;
   a layer of photoconductive material covering said electrodes such that a light image of a selected character impinging on the photoconductive material in the electrode outlined pattern causes a change in resistance of the photoconductive material on which the light impinges thereby causing an increased temperature of said photoconductive material in the areas on which light impinges; and
   viewing means positioned to intercept the image in another of said optical paths.

2. The apparatus according to claim 1 wherein said means for directing is comprised of:
   a beam splitter positioned to intercept the light images from said means for forming light images and for directing said light images along said two optical paths.

3. The apparatus according to claim 1 and further comprising:
   means for activating said transducer means only when a heat image is to be transferred to a heat sensitive material.

4. Apparatus comprising, in combination:
   means for forming light images;
   means for directing said light images along at least two optical paths;
   transducer means intercepting the image in one of said optical paths for transforming said image into a corresponding heat image capable of being transferred to a heat sensitive record material;
   said transducer means comprised of:
   an optically transparent substrate;
   an electrode having a plurality of openings positioned on said substrate;
   a layer of photoconductive material positioned over said electrode and in said openings;
   a second electrode positioned on said layer of photoconductive material, said optically transparent electrode and said second electrode adapted to receive an electrical potential therebetween such that light impinging on said photoconductive material changes the resistance between said optically transparent electrode and said second electrode which in turn changes the current flow through said photoconductive material and the temperature of said photoconductive material; and
   viewing means positioned to intercept the image in another of said optical paths.

5. An optical display and printer system comprising in combination:
   a plurality of light sources arranged in a matrix;
   means for causing selected ones of said light sources to emit light;
   means for directing the image formed by said light sources along two optical paths;
   an optical-to-thermal transducer positioned to intercept the image in one of said optical paths, for transforming said optical image into a corresponding heat image which is adapted to be transferred to a heat sensitive material, said optical-to-thermal transducer comprised of:
   an optically transparent substrate;
   a plurality of electrodes adapted to receive an electrical potential therebetween positioned on said optically transparent substrate, in a pattern which outlines a desired composite character;
   a layer of photoconductive material over and between said electrodes such that a light image of a selected character impinging on the photoconductive material in the electrode outlined pattern causes a change in resistance of the photoconductive material on which the light impinges thereby causing an increased temperature of said photoconductive material in the areas on which light impinges; and
   a viewing screen positioned to intercept the image in the second of said optical paths.

6. The optical display and printer system according to claim 5 wherein said optical-to-thermal transducer is comprised of:
   an optically transparent substrate;
   an optically transparent electrode positioned on said substrate;
   a layer of photoconductive material positioned over said transparent electrode; and
   a second electrode positioned on said layer of photoconductive material, said optically transparent electrode and said second electrode adapted to receive an electrical potential therebetween such that light impinging on said photoconductive material changes the resistance between said optically transparent electrode and said second electrode which in turn changes the current flow through said photoconductive material and the temperature of said photoconductive material.

7. The optical display and printer system according to claim 5 and further comprising:
   means for activating said optical-to-thermal transducer only when a heat image is to be transferred to said heat sensitive material.

8. An optical display and printer system comprising in combination:
   a light source;
   character image forming means positioned to intercept the light from said light source, said character image forming means comprised of:
   a light polarizer for receiving the light from said light source and for polarizing the light;
   a liquid crystal cell positioned to intercept the polarized light;
   means for changing the polarization characteristics of said liquid crystal cell in selected areas so as to change the angle of the polarized light in the selected areas;
   an analyzer for passing light having a selected polarization angle;
   an optical-to-thermal transducer positioned to intercept the image in one of said optical paths, for
transferring said optical image into a corresponding heat image which image is adapted to be transferred to a heat sensitive material; and a viewing screen positioned to intercept the image in the second of said optical paths.

9. The system according to claim 8 wherein said liquid crystal cell is further comprised of:

at least one pair of electrodes, one of which electrodes of the pair is configured to represent a character, positioned on opposite sides of said liquid crystal cell, said electrodes connected in circuit to said means for changing the polarization characteristics of said liquid crystal cell.

10. The system according to claim 9 wherein said means for changing the polarization characteristics of said liquid crystal cell is comprised of:

a voltage source the level of which is sufficient to change the polarization angle of said liquid crystal cell by a desired amount; and select means for applying the voltage from said voltage source to said at least one pair of electrodes.

11. The system according to claim 9 and further comprising:

a lens interposed between said analyzer and said viewing screen for focusing the light passed by said analyzer onto said viewing screen.

12. The system according to claim 9 wherein said means for directing the image from said character image forming means along two optical paths is a beam splitter positioned to intercept the image from said character generator.

13. An optical display and printer system comprising in combination:

a light source;
character image forming means positioned to intercept the light from said light source;
means for directing the image from said character image forming means along two optical paths;
an optical-to-thermal transducer positioned to intercept the image in one of said optical paths, for transforming said optical image into a corresponding heat image which is adapted to be transferred to a heat sensitive material, said optical-to-thermal transducer comprised of:
an optically transparent substrate;
a plurality of electrodes adapted to receive an electrical potential therebetween positioned on said optically transparent substrate, in a pattern which outlines a desired composite character; and
a layer of photoconductive material covering said electrodes such that a light image of a selected character impinging on the photoconductive material in the electrode outlined pattern causes a change in resistance of the photoconductive material on which the light impinges thereby causing an increased temperature of said photoconductive material in the areas on which light impinges; and
a viewing screen positioned to intercept the image in the second of said optical paths.

14. The optical display and printer system according to claim 13 and further comprising:

means for activating said optical-to-thermal transducer only when a heat image is to be transferred to said heat sensitive material.

15. An optical display and printer system comprising in combination:

a light source;
character image forming means positioned to intercept the light from said light source;
means for directing the image from said character image forming means along two optical paths;
an optical-to-thermal transducer positioned to intercept the image in one of said optical paths, for transforming said optical image into a corresponding heat image which is adapted to be transferred to a heat sensitive material, said optical-to-thermal transducer comprised of:
an optically transparent substrate;
an electrode having a plurality of openings positioned on said substrate;
a layer of photoconductive material positioned over said electrode and in said openings;
a second electrode positioned on said layer of photoconductive material, said optically transparent electrode and said second electrode adapted to receive an electrical potential therebetween such that light impinging on said photoconductive material changes the resistance between said optically transparent electrode and said second electrode which in turn changes the current flow through said photoconductive material and the temperature of said photoconductive material; and
a viewing screen positioned to intercept the image in the second of said optical paths.

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