United States Patent

[11] 3,609,659

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[45] Patented **Sept. 28, 1971**

[54] **THERMAL DISPLAY UNIT**
7 Claims, 9 Drawing Figs.

[52] **U.S. Cl.** **340/166,** 219/216, 340/324
[51] **Int. Cl.** **H05b 3/20**
[50] **Field of Search** ..... 340/166, 176, 166 X, 324; 219/216; 178/6.6, 18, 23

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ABSTRACT: This invention relates to improvements in display units, and it relates particularly to units in which the display utilizes temperature differences and principally where the temperature difference are made to provide a visual display. The specification discloses a rectangular coordinate printer and plotter incorporating a matrix of semiconductor rectifier junctions connected in rows and columns whereby selected ones of the rectifiers may be rendered conductive. Heat generated in the rectifier is conducted to the surface of a platen where it acts upon a thermally sensitive paper which changes color at the point of heat application. Two forms of platens are illustrated and described. In one the several rectifiers of the matrix comprise discrete units interconnected by conductor deposits and wires. In the other, the several rectifiers are formed as a monolithic structure of semiconductor material.

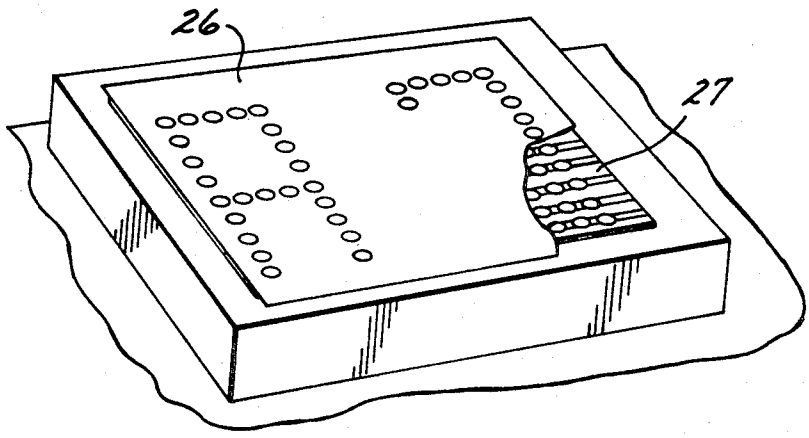


FIG. 1

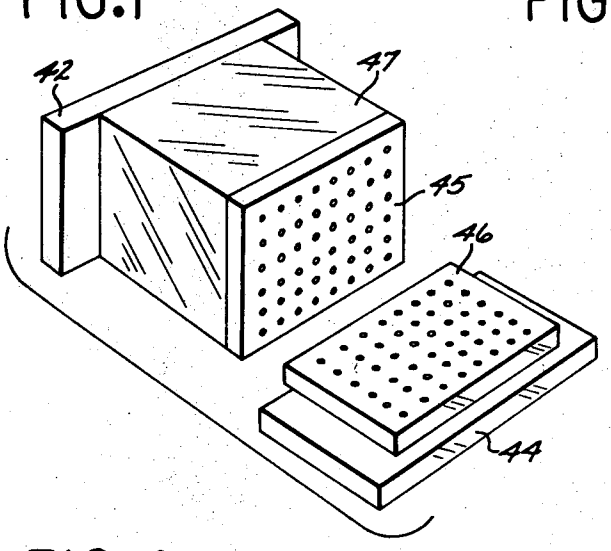


FIG. 2

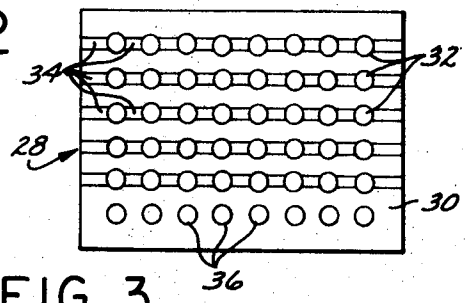


FIG. 3

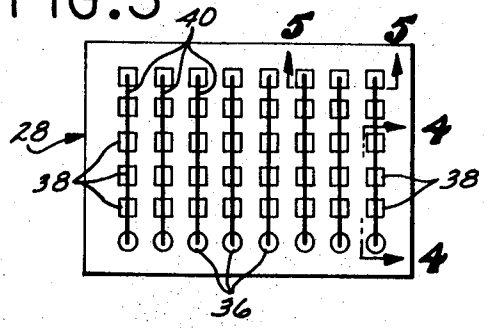


FIG. 4

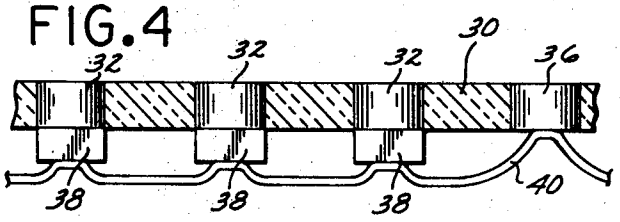


FIG. 5

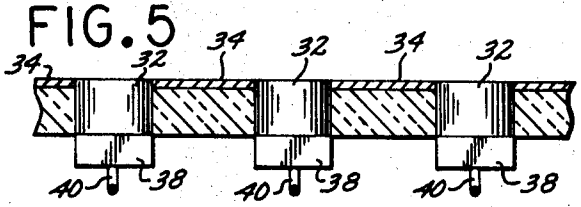


FIG. 6

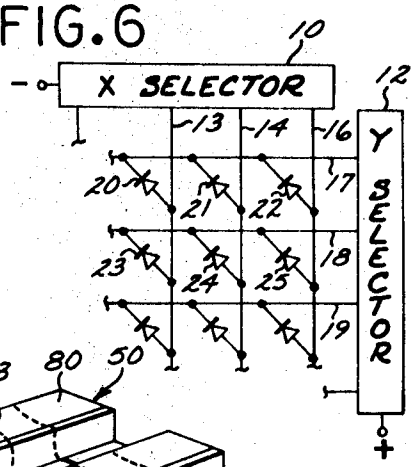


FIG. 7

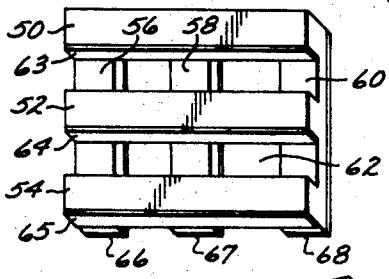
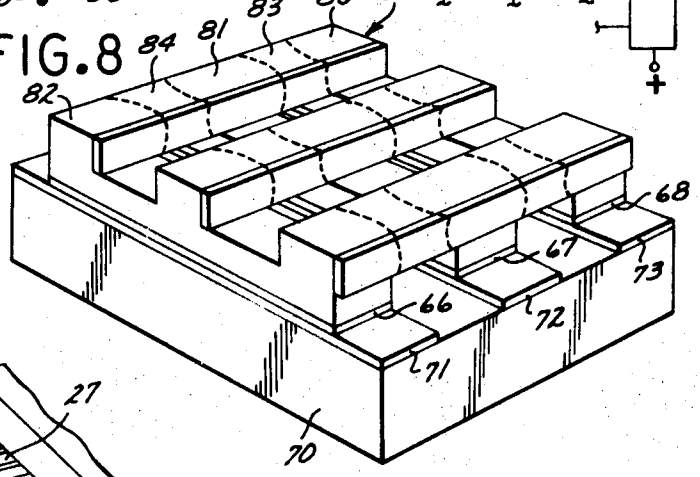


FIG. 8



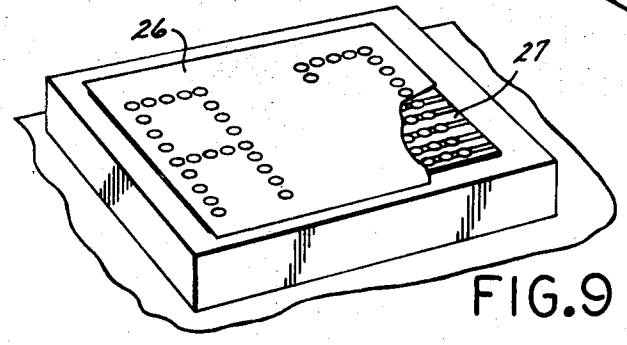


FIG. 9

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THERMAL DISPLAY UNIT

This invention relates to improvements in thermal display units and in methods of making them. It relates particularly to units in which information represented by electrical signals is presented in the form of thermal signals whose spacial relation is indicative of the information represented electrically.

A number of devices exist which present information contained in electrical signals in the form of spacially arranged indicia. Familiar examples are the matrix printer and various devices which display symbols, numeral and letters appearing as the composite of a number of elemental indicia. An object of the invention is to provide an improved device of this kind. Another object is to provide an apparatus which will produce a thermal signal at any of a number of predefined spacial positions in response to electrical signals in accordance with a prearranged code.

The invention is applicable where it is desired to represent information by location or relative position of display signals on either flat or nonflat surfaces. It is applicable to the presentation of information in positions identified by polar coordinates or rectangular coordinates or by any other system of coordinates into which a plane or surface may be divided. Thus information can be presented in rows or columns which may or may not be straight and it is an object of the invention to provide an apparatus which can present information thermally in any of the wide variety of spacial arrangements so defined. Nonetheless, the invention is particularly well suited to the presentation of indicia in straight rows and columns as in conventional X-Y plotting and an object of the invention is to provide a superior X-Y plotting apparatus.

Another object of the invention is to provide a unique and efficient structure for the conversion of information represented by electrical signals to spacially arranged indicia by transforming the electrical signals to thermal signals.

Certain of these, and other objects and advantages of the invention, are realized by the provision of a thermal display unit utilizing heat generated at selected spaced points by an electrically conductive device which experiences greater heat rise as an incident to current flow in one direction than in the other.

In the drawings:

FIG. 1 is an isometric view of a glass block in which heat conductors are imbedded and from which platens are cut;

FIG. 2 is a top plan view of a platen according to the invention;

FIG. 3 is a bottom plan view of the platen of FIG. 2;

FIG. 4 is a cross-sectional view of a portion of the platen taken on line 4—4 of FIG. 3;

FIG. 5 is a cross-sectional view of a portion of the platen taken on line 5—5 of FIG. 3;

FIG. 6 is a schematic diagram of a portion of the platen shown in FIGS. 2, 3, 4 and 5 illustrating connection to x and Y-selector switching units;

FIG. 7 is an isometric view of a monolithic block of semiconductor material as it appears in a preliminary stage of construction of an alternative form of platen embodying the invention;

FIG. 8 is a completed platen of alternative design which embodies the invention and incorporates the monolithic structure of FIG. 7; and

FIG. 9 is an isometric view of a fragment of an X-Y plotter showing a platen holder, a platen embodying the invention, and a thermosensitive printing paper overlying the platen.

It enough rectifiers are employed, it is possible to energize selected ones of a number of two terminal electrical elements with a minimum number of switches by dividing the terminals into groups. Corresponding terminals of the elements are divided into groups and each group is connected to a switch. The other terminal of each element is assigned to one of the second series of groups such that no two elements which are in the same group of the first series are classified in the same group of the second series. Each of the second groups also is connected to a switch. Thus arranged, the elements can be energized selectively without energization of any other element if a unidirectionally conducting device is connected series with it. The invention makes use of this phenomenon except that it omits the two terminal elements.

Such a circuit, a circuit of the kind employed in the invention, is illustrated schematically in FIG. 6. The X-selector 10 and the Y-selector 12 are switch units selectively energizing one or more of the output lines emanating from them from a course of electrical power, not shown. Thus the X-selector 10 is effective to energize line 13, 14 or 15 or any combination of them. The X-selector may comprise a stepping switch or a solid state switch bank or any of a number of known devices. The Y-selector 12 similarly may comprise any of such well-known devices which will energize one or more of the output lines 17, 18 and 19. The unidirectionally conductive device interconnects the several lines at each intersection. Thus rectifier 20 interconnects lines 13 and 17. The rectifier 21 interconnects lines 14 and 17 and rectifier 22 interconnects lines 16 and 17. Rectifiers 23, 24 and 25 interconnect line 18 with lines 13, 14 and 16 respectively. Similarly, three other rectifiers interconnect line 19 with each of the lines 13, 14 and 16. If line 16 is energized by the X-selector 10 and line 17 is energized by the Y-selector 12, then a current will flow through rectifier 22; provided, of course, that the polarity of the currents applied to the X and Y-selector inputs is proper as shown. Every other rectifier in the network is effective to prevent connection of the line 16 with any other of the lines emanating from the Y-selector. Similarly, all of the rectifiers acting together prevent interconnection between the lines 17 and any line of the X-selector other than line 16. If lines 14 and 16 are energized by the X-selector and line 17 is energized by the Y-selector then current will flow through two of the rectifiers numbered 21 and 22. But current may flow through no other rectifier unless it be connected to one line energized by the Y-selector and one line energized by the X-selector. The several rectifiers may be of any well-known type. Thus the may comprise metal oxide rectifiers or crystal rectifiers or any other type of rectifier in which losses within the rectifier result in its becoming heated. Advantageously the rectifiers employed in the invention comprise semiconductor materials. In the preferred form they comprise a junction and while that junction may comprise one element of a transistor or other, more sophisticated multiple terminal device, in preferred form the rectifier comprises a single, P N, semiconductor junction.

The representation in FIG. 6 is schematic. The rectifier devices need not be arranged in rows and columns as they are there shown to be although the row and column arrangement is quite advantageous and has been selected for illustration in the several embodiments of the invention depicted in the drawings. As the X and Y-selectors are actuated to complete the circuits to any one of the rectifiers that rectifier becomes heated. The invention envisions the incorporation of means for detecting which ones, if any, of the rectifiers are heated. The rectifiers are given a placement (or a heat conductor connected to conduct heat from the rectifier to another place is given a placement), relative to all the other rectifiers, which has a predefined meaning. That is, the spacial arrangement of the heated rectifiers is given some meaning in accordance with a predefined convention or code. For example, if a number of rectifiers are arranged in a matrix of parallel rows and columns then selected rectifiers may be heated by connection to an electrical power source so that the heated rectifiers form a curve in rectangular coordinates or so that they form various symbols such, for example, as letters and numerals as illustrated in FIG. 9. The invention contemplates the employment of means for converting to visible form the thermal signals and displays thus established. This can be done in a variety of ways. Advantageously it is done by utilizing the heat from the rectifiers to change the color of a thermosensitive paper at the point of heat application. In FIG. 9 the layer of paper 26 which overlies the platen 27 is thermosensitive in that it changes color when subjected to heat. In FIG. 9 a number of points in platen 27 have been heated as an incident to current flow through rectifiers arranged in a rectangular coordinate pattern

as in FIG. 6. These rectifiers have burned or "printed" the letter "A" and the figure "7" on the thermally sensitive printout paper as shown in FIG. 9.

The platen 27 is similar in construction to the platen illustrated in FIGS. 2, 3, 4 and 5, but the latter is designated by the reference numeral 28. The top of this platen is illustrated in FIG. 2. Here a matrix of circular heat-conducting elements are exposed at the upper surface of a sheet of glass. All of the heat conductors of a horizontal row are interconnected by a layer of electrically conductive material deposited in a groove which extends the width of the glass sheet. The glass sheet is designated by the reference numeral 30. Representative ones of the heat conducting elements are designated by the reference numeral 32. Representative sections of the conductive material deposited between the heat conductive elements are designated by the reference numeral 34. The circular elements 36 which comprise the lower row of circular elements in FIG. 2 are electrical connector terminals.

Each of the heat-conducting elements 32 seen in FIG. 2 is in electrical communication with a rectifier at its opposite face as illustrated in FIG. 3. Each of the rectifiers 38 comprises a die of germanium doped to form a P N junction. The heat conductors 32 are also electrical conductors and one material of each junction, advantageously the P material, is bonded to a respectively associated one of the heat conductors 32. FIG. 3 is a view looking down on the N material side of the rectifiers. The rectifiers of each column are bonded together at their N surfaces and they are connected to a respectively associated one of the terminals 36. For identification, several of the wires which bond the columns together are designated by the reference numeral 40.

Referring to FIG. 4 where the platen is shown in cross section, the heat conducting elements 32 comprise short lengths of round wire embedded in the flat sheet of glass 30 so that their respective axes are parallel and so that the spacing between the several heat-conducting elements is uniform. The connector terminal 36 also is formed of a short length of the same wire and differs from the heat conducting elements, in this embodiment, in its purpose rather than its construction. The material of these wires is advantageously a good conductor of heat. Advantageously, it is also a good conductor in electricity for the invention does not rely upon the resistance of the heat conductors for successful practice. The P material has greater resistivity than does the N material of the semiconductor die. Most of the heat generated in the semiconductor material is generated at the P side. Advantageously, it is this side which is bonded to the heat conductor. The material may be formed by inclusion of aluminum atoms as impurities in the germanium of the die. It follows that aluminum, being also a good conductor of heat, makes an excellent heat conducting element although other materials will be found to be suitable. The N side of the several semiconductor dice 38 are interconnected by a wire 40 which is also bonded to the terminal member 36.

A cross-sectional view of the platen taken at right angles to the view depicted in FIG. 4 is shown in FIG. 5. A channel is etched in the upper surface of the glass platen at each row of heat-conducting elements as shown in FIG. 2. A layer 34 is conducting material is deposited in that channel so that it makes electrical contact with all of the heat conducting elements 32.

It will be apparent that the heat conductors need not be arranged so that their N faces all lie in a flat plane. It is entirely possible to produce platens that are cylindrical or have various other curved shapes. It will also be apparent that the heat-conducting elements need not be arranged in rows and columns that are parallel. For example, it will be apparent that the rows could be formed as concentric circles, that the columns could be arranged to radiate from the center of those concentric circles whereby to form a platen whose elements are arranged in polar coordinate form. It will be apparent that more than one rectifier can be connected in series or in parallel across a junction of energizing conductors and that the rectifiers may be placed at spaced points to form various patterns ultimately to provide individual visible displays different from others. It will be apparent that a wide variety of coordinate arrangements and alphabetical and numerical and other symbols may be provided by appropriate arrangement of the rectifiers in their heat-conducting elements.

To produce a platen, a sheet of electrically and thermally insulating material is formed. That sheet if provided with a plurality of heat-conducting elements which extend to the opposite faces of the sheet and are arranged in some predefined pattern by being appropriately spaced in the body of the sheet. FIG. 1 illustrates that such a sheet may be formed by extending a series of wires of suitable material, here Kovar, arranged taut and parallel and spaced in rows and columns between two end holders 42 and 44. The space between the holders 44 is filled with molten glass which is permitted to harden into a solid block. The block is then sliced in the direction perpendicular to the axis of the wires. Two such slices, identified by the reference numerals 45 and 46 respectively, have been sliced from the block of glass 47 in FIG. 1. After slicing the faces of the flat sheet are ground parallel. One face of the sheet is covered with a "resist" material except along lines marking rows of the Kovar heat conductor wires. The wire ends and the remaining surface of the glass sheet are protected by the resist from an acid which is then used to etch a channel in the surface of the sheet between the aluminum wires of each row. Conducting material, advantageously a very thin coating of highly electrically conductive material, here copper, is deposited in the channel thus formed. The deposited layer of copper is made to contact each of the Kovar wire heat conductor elements of the row.

At the opposite face of the sheet semiconductor dice are connected to the flat ends of the conducting wires. Each dies is bonded to a respectively associated heat conducting element using heat and pressure to accomplish a mechanical and electrical bond. All of the dice are oriented in the same direction, advantageously so that their P material is toward the heat-conducting element. Thereafter, the other side of all the semiconductor rectifiers of each column are bonded together in a wire bonding process, or other interconnection process, whereby all of the semiconductor rectifiers are connected in the matrix in a fashion that is described electrically by the schematic diagram of FIG. 6.

The platen thus formed is made of readily available, reliable and long lasting material. If added protection is desired, the upper surface of the platen is easily passivated and the lower surface is readily protected by coatings that are impervious to air and moisture. The semiconductor dice need not be of high quality. In fact, rectifiers of poor quality in that they have high resistive loss, are preferred.

Procedures for embedding the conductor wires in glass, for slicing glass, for bonding semiconductors to wires imbedded in glass, for etching glass, and metallizing etched surfaces, for wire bonding, and all of the other steps involved in the process are known and available thereby permitting the production of relatively large sized, glass filled platens.

Moreover, techniques are well known by which monolithic semiconductor platen structures may be produced. It is possible to produce P-type semiconductor material in very thin sheets of relatively large area. If one face of such a sheet is coated with an etch resistant material, except in parallel strips corresponding to evenly spaced rows and the other face of the sheet is covered with an etch resistant material except along lines evenly spaced in the direction of columns and if the whole sheet is then subjected to an etching material, it is possible to etch the P-material to a sufficient depth so that the sheet is perforated entirely through at those areas at which etching proceeds from both sides thereby forming a lattice structure in the form of bars and columns of P material. A structure of this kind is shown in FIG. 7. It is monolithic consisting of three rows 50,52 and 54 and three columns, 56, 58 and 60. The numeral 62 designates one of the openings extending entirely through the semiconductor sheet where etching proceeding

from the opposite side of the plate has removed all of the material and formed the through opening. A metal electrode is deposited on one face of each of the rows and the lower face of each of the columns. The conductor layer on row **50** is designated by the reference numeral **63** and the layers on rows **52** and **54** are designated **64** and **65** respectively. These layers are deposited on the side of the row rather than on the upper face. A layer of metallic conductor material **66** underlies the column **56**. Layers **67** and **68** underlie the columns **58** and **60** respectively. This monolithic structure is only a few thousandths of an inch thick and requires support. In FIG. **8** the monolithic structure of P-material is shown resting upon a base **70** whose dimensions, at least in one direction, are greater than those of the monolithic row and column structure. The upper surface of the base **70** is provided with a deposited layer of electrically conductive metal in a position to underlie the conductive layer on the other side of the columns of semiconductor material. Thus the layer **71** underlies the conductive layer **66**. Similarly, the layers **72** and **73** underlie and extend beyond the conductive layers **67** and **68**. These several pairs of layers are bonded together so that contact may be made with the conductor underlying the columns by making electrical connection to the layers **71**, **72** and **73**. Spaced areas of each of the three semiconductor rows of the monolithic row and column structure are converted to N-material by a diffusion process. The area of each row which overlies a column has doner atoms diffused into it so that the N-layer extends downwardly to the column of P-material and entirely across the width of the column. The N-material boundaries are identified in FIG. **8** by the dashed lines. All three rows are treated alike. This being a three by three matrix, there are nine sections of N-material. In the rear bar **50** there is a section of N- material **80** at the right, a section of N-material **81** at the center, and a section of N-material **82** at the left. The two sections **80** and **81** are separated by a segment of P-material **83** and the N-sections **81** and **82** are separated by a segment of P-material **84**. These intervening sections of P-material cooperate with the N-material sections **81**, **82** and **83** in a way that isolates each N-material section from the other through a pair of back-to-back diodes in the equivalent circuit. Since these diodes serve to isolate adjacent diode sections of the monolithic structure, the electrical nature of the whole is adequately described by simplified equivalent circuit which is shown in FIG. **6**. The construction of FIG. **8** has the advantage that heat generated by all of the diodes is available in a single plane whereby it is unnecessary to employ heat conducting elements to create a platen surface from which the heat is transformed to a display. In FIG. **8** the spaces between the several rows would be filled with silicon oxide or other convenient insulating material to provide a flat platen surface. The silicon oxide has been omitted from FIG. **8** for the sake of clarity.

In operation of platens of the kind described above, heat is generated in the several diodes very rapidly upon being energized and is very rapidly dissipated in the thermal sensitive paper whereby high speed printing can be achieved. It will be apparent that current is made to flow through the heat conducting wires **32** in the embodiment of FIGS. **2**, **3**, **4** and **5**. To the extent that these wires have resistance this current flow results in heating. However, the heating is negligible. The material selected for use as heat conductors materials will have very low resistivity whereby heating results entirely, in practical effect, from heating in the rectifying device. Accordingly, it is entirely practical to form the conductor which connects to the side of the rectifier adjacent to the heat conductors at the rectifier side of those conductors. In the embodiment shown, this may be done by depositing the conductor segments **34** on the lower face of the glass plate rather than to the upper face. In certain applications of the invention this modification is the preferred form.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

We claim:

1. A printing heat comprising a heat conductor imbedded in an electrically and thermally insulating plate with portions thereof exposed in heat conducting relation at opposite sides of said plate, and a two terminal electrical rectifier having impedance resulting in greater heating when subjected to current flow in one direction than in the other, said rectifier having thermally conductive connection to said heat conductor and further comprising means for connecting said rectifier to a source of electrical power.

2. In a thermal printer:

at least two pairs of conductors ant at least four unidirectional, semiconductor junction devices of a kind whose temperature increases when conducting electrical currents;

a respectively associated one of said devices being connected from each of said first pair of conductors to each of said second pair of conductors, said conductors and said devices forming part of a platen having a printing surface;

heat-conducting means for selectively conducting heat from each of said devices to a respectively associated surface area of said platen.

3. The invention defined in claim **2** in which said heat-conducting means comprises a portion of the material of said semiconductor devices.

4. The invention defined in claim **2** in which said semiconductor junction devices are formed integrally from a monolithic block of semiconductor material.

5. The invention defined in claim **2** in which said platen is formed by an integral grid of parallel bars of P-type material overlying parallel bars of N-type material.

6. The invention defined in claim **2** in which said heat-conducting means comprises a layer of thermal and electrical insulating material and a plurality of spaced heat conductors extending through the layer, each heat conductor being in thermal communication with a respectively associated one of said devices.

7. A monolithic printing platen comprising an integral grid consisting of a first set of parallel members of P-type material overlying a second set of parallel members of material extending crosswise of said first set and including N-type material at the points of intersection of the members.